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PERFORMANCE OF SELECTED CULTIVATION MACHINES IN RELATION TO FUEL CONSUMPTION

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ABSTRACT

Correct juxtaposition of a tractor with a machine affects time and being on time with a treatment as well as fuel consumption. The article presents analysis of the selection of various cultivation machines to a 14 kN class tractor in the aspect of obtaining maximum performance and minimum fuel consumption. The following cultivation machines were investigated: cultivation aggregates and chisel plows, disc harrows, field ploughs. During exploitation, research measurements of fuel consumption and actual speed of the units operation were taken. It was showed that incorrect selection of the working width of a machine for a tractor results in a decrease of the cultivation unit performance and in many cases in the increase of fuel consumption.

Introduction and objective of the paper

The range of offered farm machines and devices, both domestic as well as foreign is still increasing at the Polish market. Poland becomes one of the biggest users of farm equipment in the EU. Due to the newest technologies, machines are even better and as a result, more enduring, less energy consuming and more efficient. A considerable increase of sale of the said machines has taken place in the recent years. 2011 was record-breaking in the amount of sold tractors and agricultural machines. There were 17, 035 new farm tractors on our fields. Statistically, it is a digit by 34% higher than in comparison to 2010 (GUS, 2011). The increase of the number of purchased machines is the most frequently justified with the increased interest of farmers in the European Union subsidies. Tractors are equipped in even better engines, which meet even higher standards of combustion (Landis and Schiess, 2006). Machines aggregated to them, are characterized with even higher performance at low consumption of working elements. Farmers who have such tractors and machines look for savings in their exploitation (Lorencowicz, 2008; Muzalewski, 2008). Purchase of diesel oil is currently expensive, therefore, there is a tendency to obtain possibly the highest performance of machines, at the possibly the lowest fuel consumption (Talarczyk, 2012). The increasing range of machines, constant technology development and existing trends in agriculture, prove that analysis of the sets of a tractor-machine units is indispensable. High performance and optimization of costs of exploitation of machine aggregates may be obtained only by means of a correct selection of machines (Kuczewski and Majewski, 1999; Marks and Krzysztofik, 2000). Many factors affect the selection, inter alia: farm size, scale and type of plant production, form of mechanization of a farm, individual conditions of farming and economic power of a farm (Banasiak, 1999).

The objective of the paper was analysis of the selection of various cultivation machines for a farm tractor in order to obtain maximum performance at the minimum fuel consumption. The following measurements were requisite for performance of the objective: fuel consumption by a farm tractor, actual speed of work of tractor units and determination of operation of the researched tractor units.

Subject and methodology of research

During the field research, machine aggregates composed of a tractor Zetor Proxima 75 of class 14 kN and the following cultivation machines were subjected to assessment:

- cultivation aggregates of a working width 3.2. and 3.6.m;
- chisel plows of a working width 1.8 and 2.2. m;
- disc harrows of a working width 2.4 and 2.7. m;
- 3 and 4 -furrow field ploughs.

Cultivation units and chisel plows as well as disc harrows were produced by BOMET company from Węgrów and ploughs by Akpil company from Pilzno and equipped with Vogel&Noot elements. A tractor was equipped with an engine of 53kW/72KM power at 2,200 rot·min^{-1} and the volume 4,156 cm^{3}. It was characterised with a modern structure which meets the standards of fuels emission TIER IIIA. It is a 4-cylinder engine equipped with a in-line pump and a turbo compressor along with an intercooler.

A module consisting in a measurement unit ZP2- 4-I by Rotameter company (fig. 1a), composed of a volumetric flow-meter, fuel filter and a clarifier as well as a digital recorder NOSAL-TECH (fig. 1b) were used for measurement of fuel consumption. A mentioned device measured actual fuel consumption determining the difference between the amount of diesel oil collected from a tank and excess of diesel oil, which was returned to the tank.

Actual speeds of tractor sets were determined for calculation of the performance of the investigated units. It was carried out by measurement of time of passing the measured 100 metres length from the first to the second control post (Banasiak, 2004).

Investigation were carried out in a farm in Waleńczów near Częstochowa on two fields of soil class 4a and 4 b, these were light soils. Measurements for particular groups of cultivation machines were carried out on the same fields, therefore, the soil compaction and moisture did not have to be determined. Weather conditions during investigations were varied depending on the performed cultivation treatments. Investigations with the use of cultivation units were carried out in Spring at the air temperature of 11ºC, then high moisture of soil occurred, which translated into the increased skid of tractor wheels. Subsequent investigations were carried out at the beginning of August when machines for stubble cultivation were investigated. During testing disc harrows temperature was 24ºC, and in case of testing chisel plows it was 26ºC. The mentioned tests were carried out on the third day after mowing grains by a combine harvester. Whereas, research of field ploughs was performed at the end of August when it was very dry, temperature was 24^{o}C and soils was overdried. Analysis of the selection of machines consisted in comparison of the quality of work of two similar sets which differed with a working width, working at the same field.

a) b)

Figure 1. Measurement unit a – flow meter ZP@-4-I by Rotameter company, b – NOSAL-TECH mounted on a tractor

Results of the research

During research, assumptions presented in figure 2 were followed. Four rotational speeds of an engine from the minimum 1,500 rot.·min^{-1} each 250 rot.·min^{-1} to the signifying 2,200 rot.·min^{-1}were accepted for determination of fuel consumption. 100 m measurement lenghts were determined. Constant depth of operation between units was established in order to better compare their operation parameters. This depth for units and harrows was 0.1 m and for ploughs 0.15 m. Unit crossings with simultaneous soil cultivation were performed at the researched lengths. Time of operation of units and fuel consumption was determined during crossing.

Following measurements, hour fuel consumption and per 1 hectare of cultivated surface during a crossing of the investigated length, speed of the unit, cultivation time of 1 ha and efficiency of the investigated units in ha·h^{-1} were calculated. The above parameters of the cultivation units operation were set in table 1. Depending on the theoretical working width of units, cultivated surfaces for one crossing were ranging from 180 m^2 for a chisel plow of a working width of 1.8 m to 360 m^2 for a cultivation unit of a working width 3.6 m. Whereas for a 3 – furrow plough the surface area of the cultivated measurement length was 120^2 and for a 4-furrow plough it was^2.

When comparing the speed of the investigated machines, one may state that the lowest working speed was for the cultivation unit and was within 1.63 to 2.31 m·s^{-1}; a similar speed was for a chisel plow within 1.67m·s^{-1} to 2.78 m·s^{-1}. The highest working speed was at the cultivation of a disc harrow of 2.4 m and a rotational speed of an engine 2200 rot.·min^{-1} and was 3.33 m·s^{-1}.

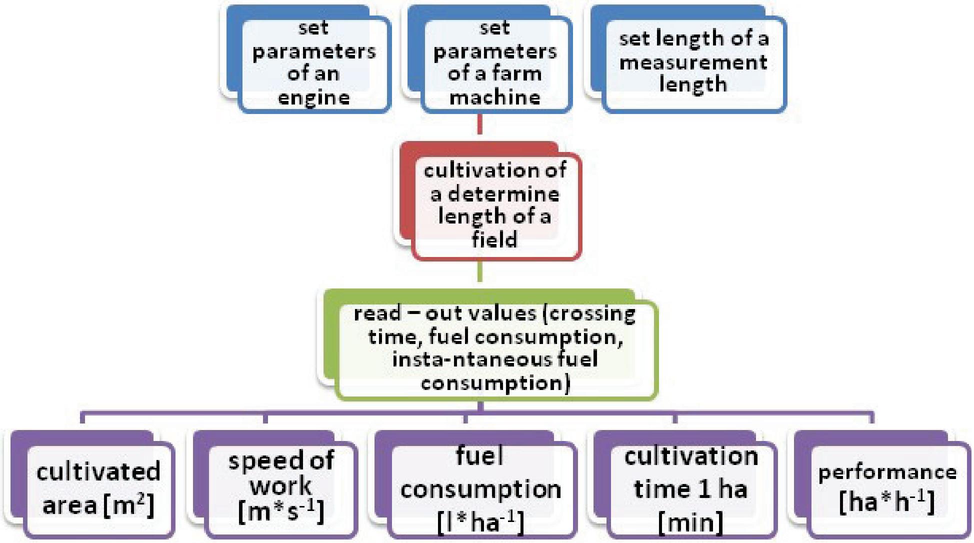

Figure 2. Schematic representation of procedure during exploitation tests

Comparing performance of the investigated cultivation machines, which performed cultivations at the same depth, one may observe that the lowest performance was for a chisel plow and was within 1.56 to 2.2 $ha \cdot h^{-1}$ and the highest for a disc harrow from 2.11 do 3.14 $ha \cdot h^{-1}$. Completely different performances were for plough work from 1.31 $ha \cdot h^{-1}$ for a 3-furrow plough at the engine rotations 1,750 $rot \cdot min^{-1}$ to 1.86 $ha \cdot h^{-1}$ for a 4-furrow plough for rotations 2200 $rot \cdot min^{-1}$. However, it was related to higher resistance, which occur at ploughing with a higher depth of operation i.e. 0.15 m.

Lower consumption of fuel in liters per a hectare was for a cultivation unit and a disc harrow and was within 4.2 to 6.3 $l \cdot ha^{-1}$. Higher consumption occurred at the operation of chisel plows and plough and was within 7.5 to 10.0 $l \cdot ha^{-1}$.

When comparing performance of the researched machines and fuel consumption in liters per hectare, one may state that a chisel plow with a lower width of 1.8 m characterizes with higher performance i.e. within 1.72 to 2.20 $ha \cdot h^{-1}$ at a lower fuel consumption from 7.7 to 9.5 $l \cdot ha^{-1}$ in comparison to an aggregate with a higher width (2.2 m), for which performance was within 1.56-1.84 $ha \cdot h^{-1}$ and fuel consumption was within 7.7-10.0 $l \cdot ha^{-1}$. It resulted from the fact that at the lower width of a chisel plow, a working speed of a unit was higher. Additionally, cultivation time of one hectare was shorter from 3 to 7 minutes. For the remaining cultivation machines - a cultivation unit and a disc harrow, a lower performance occurred in case of a machine with a lower width and a higher performance for higher width. Performance of field ploughs depended on the working width and was within 1.31 to 1.39 $ha \cdot h^{-1}$ for a 3-furrow plough and within 1.65 to 1.86 $ha \cdot h^{-1}$ for a 4-furrow. However, it was reported here that at the higher performance of a 4-furrow plough, lower consumption of fuel occurred 7.5-8.8 $l \cdot ha^{-1}$ in comparison to a smaller plough where fuel consumption was within 9.2 do 10.0 l·ha^{-1}. Ploughing time for a bigger plough was shorter and it was within 32 to 36 min·ha^{-1} and for a smaller within 43 do 46 min·ha^{-1}.

Table 1
Operation parameters of cultivation aggregates, disc harrows and field ploughs

		Cultivation aggregate – depth 0.1 m							
Working width	(m)	3.2.				3.6.			
Area of cultivation	(m^2)	320				360			
Rotations of an engine	(rot·min^{-1})	1,500	1,750	2,000	2,200	1,500	1,750	2,000	2,200
Speed of the unit	(m·s^{-1})	1.63	1.81	2.21	2.31	1.63	1.91	2.14	2.25
Cultivation time 1 ha	(min)	32	29	23	22	28	24	22	20
Performance	(ha·h^{-1})	1.87	2.08	2.55	2.67	2.11	2.47	2.77	2.92
Fuel consumption	(l·ha^{-1})	4.4	5.0	5.9	6.3	4.2	4.7	5.3	5.8

		Disc harrow – depth 0.1 m							
Working width	(m)	2.4				2.7			
Area of cultivation	(m^2)	240				270			
Engine rotations	(rot·min^{-1})	1,500	1,750	2,000	2,200	1,500	1,750	2,000	2,200
Speed of the unit	(m·s^{-1})	2.44	2.78	3.13	3.33	2.50	2.78	3.13	3.23
Cultivation time 1 ha	(min)	28	25	22	21	25	22	20	19
Performance	(ha·h^{-1})	2.11	2.40	2.70	2.88	2.43	2.70	3.04	3.14
Fuel consumption	(l·ha^{-1})	4.6	5.0	5.4	6.3	4.4	4.8	4.8	5.6

		Chisel plow – depth 0.1 m					
Working width	(m)	1.8			2.2		
Area of cultivation	(m^2)	180			220		
Engine rotations	(rot·min^{-1})	1,750	2,000	2,200	1,750	2,000	2,200
Speed of the unit	(m·s^{-1})	2.17	2.50	2.78	1.67	1.82	1.96
Cultivation time 1 ha	(min)	35	30	27	38	35	33
Performance	(ha·h^{-1})	1.72	1.98	2.20	1.56	1.70	1.84
Fuel consumption	(l·ha^{-1})	7.7	8.6	9.5	7.7	8.8	10.0

		Field plough – depth 0.15 m					
Number of machine frames	items	3-furrow			4-furrow		
Area of cultivation	(m^2)	120			160		
Engine rotations	(rot·min^{-1})	1,750	2,000	2,200	1,750	2,000	2,200
Speed of the unit	(m·s^{-1})	3.03	3.13	3.23	2.86	3.13	3.23
Cultivation time 1 ha	(min)	46	44	43	36	33	32
Performance	(ha·h^{-1})	1.31	1.35	1.39	1.65	1.80	1.86
Fuel consumption	(l·ha^{-1})	9.2	10.0	10.0	7.5	7.5	8.8

The graph of fuel consumption presented in figure 1 confirms that the change of the working width of the cultivation unit from 3.2 to 3.6 m slightly affected hourly fuel consumption. For the same depth of the unit operation, fuel consumption was independently close to the working width. For example, only at the engine rotations amounting to 2000 rot·min^{-1} and the depth of work amounting to 0.1 m a smaller unit (3.2. m) consumed by

0.3 l·h^{-1} more fuel than the bigger one (3.6 m). The scope of the hourly fuel consumption was for an cultivation unit 3.2 m from 8.23 to 16.87 l·h^{-1} and for a unit 3.6 m from 8.86 to 16.94 l·h^{-1}. Moreover, based on fuel consumption, it was found that in case of the use of a bigger cultivation unit, the power of the researched unit was optimally used.

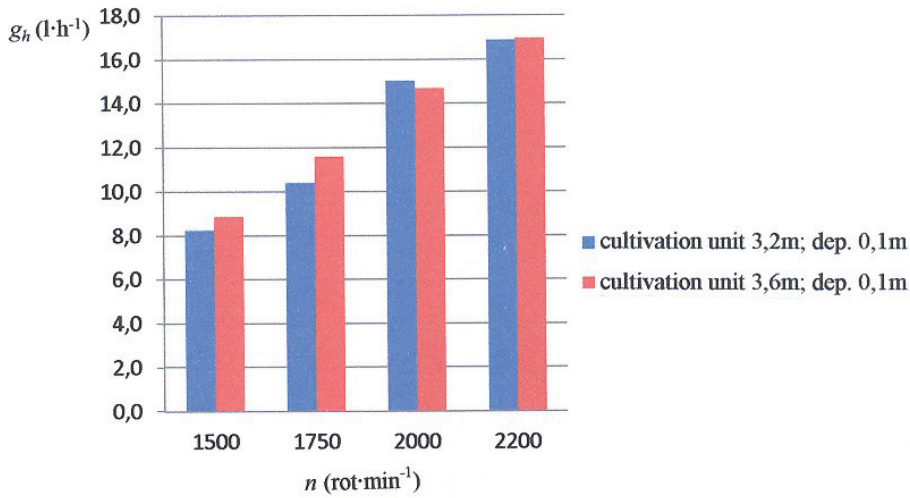

Figure 3. Relation of an hour fuel consumption for the tested tractor to rotational speed of its engine for cultivation units. g_h – hour fuel consumption, n – engine rotations

Figure 4 presents the fuel consumption for disc harrows. It was reported that for the investigated four rotational speeds of an engine, the working width of a disc harrows (2.4 and 2.7 m) did not affect considerably the fuel consumption. The investigated units had similar values of fuel consumption for a set measurement length. For example for engine rotations 2000 rot·min^{-1} both harrows with width of 2.4 and 2.7 m has the same hourly fuel consumption 14.6 l·h^{-1}.

Hourly fuel consumption for the selected chisel plows with the width of 1.8 and 2.2 m were presented in figure 5. The data presented on the graph show that the cultivation with a chisel plow 1.8 m had higher fuel consumption for all rotational speeds of an engine. For the highest gear (2,200 rot·min^{-1}) a unit of 1.8 m had fuel consumption even by 2.5 l·h^{-1} higher.

Relation of fuel consumption for engine rotations for the selected field ploughs was presented in figure 6. Analysis of data allowed observation of a slight effect of the number of plough frames and thus a working width on fuel consumption. A tractor with a 3-furrow plough consumed the same amount of fuel within one hour as a tractor with a 4-furrow plough for a working speed 0.15 m. Only at higher rotations of an engine 2,200 rot·min^{-1} a 4-furrow plough working at the depth of 0.15 m consumed almost by 2.5 l·h^{-1} more fuel than a 3-furrow plough.

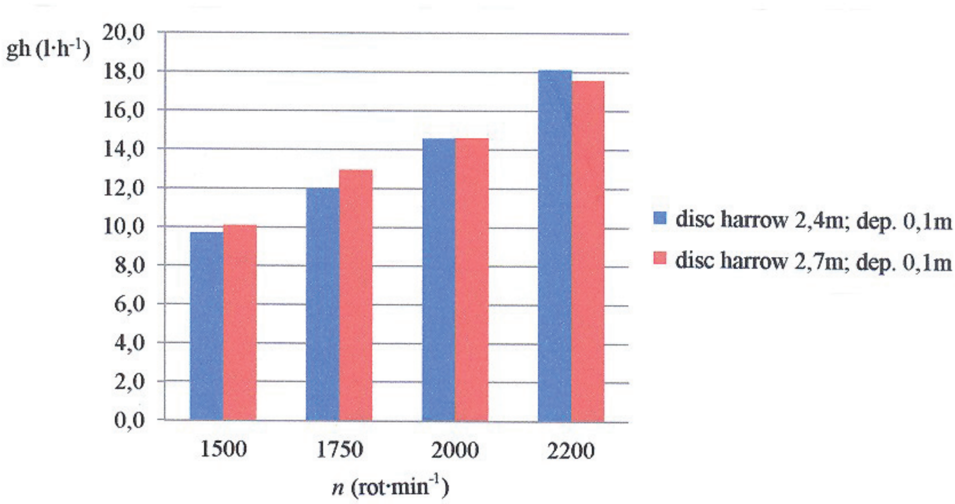

Figure 4. Relation of an hour fuel consumption for a tractor to rotational speed of its engine for disc harrows. g_h – hour fuel consumption, n – engine rotations

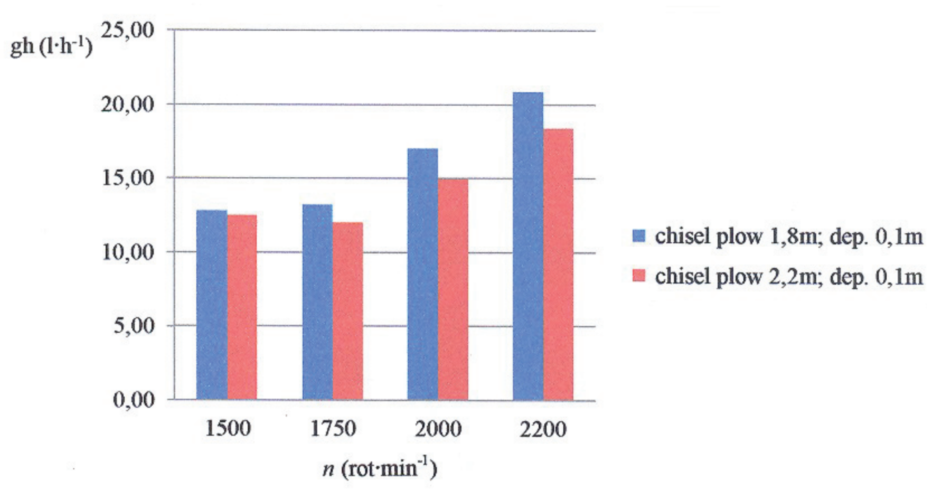

Figure 5. Relation of an hour fuel consumption for a tractor to rotational speed of its engine for stubble aggregates. g_h – hour fuel consumption, n – engine rotations

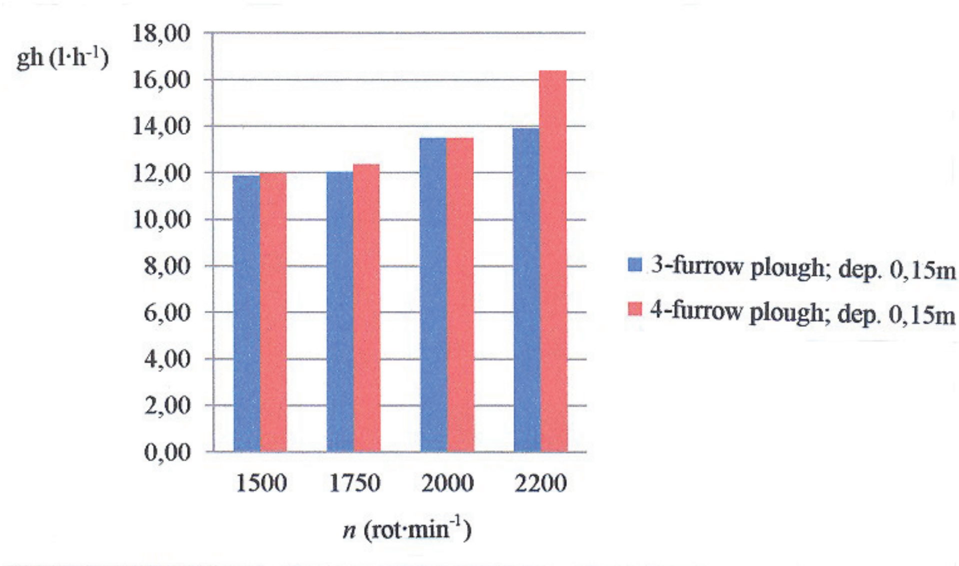

Figure 6. Relation of hour fuel consumption for a tractor to rotational speed of its engine for field ploughs. g_h *– hour fuel consumption, n – engine rotations*

Conclusions

Based on the research which was carried out, the following conclusions were expressed:

1. A unit, whose working width was 3.6 m was an optimum cultivation unit. This set obtained the highest performance; ca. 3 ha·h^{-1} at the working speed 2.25 m s^{-1} and engine rotations 2,200 rot·min^{-1} at the simultaneous saving 0.5 litres of fuel per hectare in comparison to the speed 2.14 m s^{-1} and engine rotations 2,000 rot·min^{-1}.
2. At the selection of disc harrows for the investigated tractor, it was reported that aggregating it with a wider disc harrow (2.7 m) affected obtaining the maximum performance 3.14 ha·h^{-1} and by 11% of the lower fuel consumption in comparison to the plough with a lower working width.
3. A chisel plow with a working width 1.8 m should be selected for 14 kN class tractor, since it will affect obtaining the maximum performance amounting to 2.2 ha·h^{-1} and simultaneously fuel consumption will lower by 5% in comparison to a bigger unit.
4. Combining a tractor with a 4-furrow field plough caused that the maximum performance of work was obtained and it amounted to1.86 ha·h^{-1} and allowed obtaining fuel savings 1.2 l·ha^{-1} for engine rotations 2,200 rot·min^{-1} and at rotations 2000 rot·min^{-1} savings were even 2.5 l·ha^{-1} in comparison to a 3-furrow plough.
5. Disc harrows had the highest working speeds from among the investigated machines and the maximum working speed amounting to 3.33 m·s^{-1} (12.0 km·h^{-1}) was obtained during cultivation with a harrow of 2.4 m width.

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WYDAJNOŚĆ WYBRANYCH MASZYN UPRAWOWYCH A ZUŻYCIE PALIWA

Streszczenie. Prawidłowe zestawienie ciągnika z maszyną ma wpływ na czas i terminowość zabiegu oraz na zużycie paliwa. W artykule dokonano analizy doboru różnych maszyn uprawowych do ciągnika klasy 14 kN, w aspekcie uzyskania maksymalnej wydajności i minimalnego zużycia paliwa. Badaniom poddano następujące maszyny uprawowe: agregaty uprawowe i ścierniskowe, brony talerzowe, pługi zagonowe. W trakcie badań eksploatacyjnych dokonano pomiarów zużycia paliwa i rzeczywistej prędkości pracy agregatów. Wykazano, że nieodpowiedni dobór szerokości roboczej maszyny do ciągnika powoduje spadek wydajności agregatu uprawowego oraz w wielu przypadkach wzrost zużycia paliwa.

Słowa kluczowe: maszyna uprawowa, wydajność, zużycie paliwa

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ANALYSIS OF MUNICIPAL WASTE COLLECTED BY THE SELECTED WASTE MANAGEMENT ESTABLISHMENTS

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ABSTRACT

From the moment of Poland's accession to the EU, we have been obliged to adjust the waste management system to directives issued by the European Community Council. Our waste management has been adjusted to the requirements of the European Union directives. The objective of the paper was to determine: firstly, the amount of the produced mixed municipal waste; secondly the amount of municipal waste collected in a selective manner with the use of collection methods through segregation in the place of their production using two containers located next to each other – one for collective collection of paper, cardboard and plastic and the second for collection of glass; thirdly, the size of recovered secondary raw material such as glass, plastic and paper from mixed municipal waste; fourthly, the amount of containers or plastic bags designated for selective waste collection. For execution of this objective, two establishments using various waste management systems were selected. Research was carried out in Firma Usług Komunalnych [Municiapl Services Company] "Wodnik" in Trzebnica and in Zakład Gospodarki Komunalnej [Municipal Management Establishment] in Gać, which have dealt with municipal waste sorting for many years. The research proved that the plastic bag method is more effective than segregation with the use of containers located in the neighbourhood.

Introduction and the objective of the paper

The increasing amount of municipal waste produced in households, production establishments and other economic establishments inflicts natural environment pollution and its degradation. The increasing costs of municipal waste disposal and their management influenced formation of illegal rubbish dumps. From the moment of Poland's accession to the EU, we have been obliged to adjust the waste management system to directives issued by the European Community Council. Directives should be transformed to suit the state law by statutory laws and other normative acts (Kozłowska, 2006; Jurasz, 1998; Żurek, Zarokiewicz, 1992). Council Resolution of 24th February 1997 set forth the Community strategy in waste management. The frame directive which determines basic requirements concerning dealing with waste is of basic significance in the normative acts systems (Górski, 2006).

The most important European legal acts on waste are Directive 2008/98/EC and 99/31/EC of the Parliament and the European Council which determine the main requirements concerning waste management in the Community and waste disposal. The EU strategy in waste management accepts principles, which assume protection against waste production due to the use of the so-called clean production technologies, recycling and re-use of waste, optimal management, waste disposal and their appropriate transport (Directive 2008/98/EC).

The most important document in Poland, which introduces guidelines of the EU is a National Cohesion Strategy adopted for 2007-2013 (Kulczycka and Pietrzyk-Sokulska, 2009). Basic legal regulations on waste management comprise the Polish law in statutory laws, as follows: Act of 13th September 1996 on maintaining cleanness and order in municipalities (Dz. U. [Journal of Laws] 2005 no 236 as amended in 2011), the National Plan of Waste Management of 2010 (KPGO 2014, www.sejm.gov.pl, Ustawa o odpadach).

The following constitute objectives of the ecological politics of the country: maintaining the increase of selective collection, recycling along with the economic growth, increase of ecologically safe waste combustion, liquidation of dumping grounds which fail to meet the requirements of environmental protection and their reclamation, appropriate management of hazardous waste and particularly selective management of at least 50% of waste which are produced in households (Kulczycka and Pietrzyk-Sokulska, 2009).

Main advantages following from selective collection of municipal waste are following (KPGO 2014):

- decrease of the mass and volume of waste transferred to be deposited on a landfill,
- selection of hazardous substances from waste and transferring them to a suitable establishment, which deals with their neutralization,
- decrease of original raw material and energy consumption for production of new products as a result of the use of segregated waste,
- financial profits from selling selected raw material as well as lower charges for waste disposal on a landfill (Kozłowska, 2006).

Selective selection of secondary raw material assumes the following waste collection systems: containers located in the neighbourhood, collective points of selective collection, selective collection "at the source of formation", district waste collection centres (Hryb, 2010, 2011; Żygadło, 2001).

The objective of the paper was determination of the following changes for the period from 2007 to 2010:

- the amount of produced mixed municipal waste,
- the amount of municipal waste collected selectively at the place of their production (two containers located next to each other, one for a joint paper, cardboard and plastic collection and the other for collection of glass),
- the amount of secondary raw material, such as: glass, plastic, paper and cardboard from mixed municipal waste,
- the number of containers or plastic bags designated for selective waste collection.

A facility and methodology of research

The research was carried out on the territory of Dolnośląskie voivodeship in Zakład Usług Komunalnych "Wodnik" [Municipal Services Establishment] which is located in Trzebnica and in Zakład Gospodarki Komunalnej [Municipal Management Establishment] in Gać. These establishments have been dealing with collection and segregation of municipal waste for many years.

The company ***Usługi Komunalne „Wodnik" in Trzebnica*** collected mixed municipal waste in the investigated period from the territory of the following communes: Trzebnica, Zawonia, Krośnice, Wisznia Mała, Długołęka, Prusice. On the territory of communes: Trzebnica, Krośnice, Zawonia and Prusice it carried out a selective collection of the used packages with a container method and with the use of plastic bags. It also carried out waste paper collection by collecting three times a week from collection points and waste paper establishments. Moreover, it collected waste paper from schools, which joined in collecting waste paper on the territory of a commune.

The establishment owns two sorting lines, one designated for processing of mixed municipal waste and the other for waste collected selectively. Sorting lines are constructed of the following devices: trough conveyor ascendant, a sorting sieve, horizontal conveyor, a sorting tribune, a waste packing press. The collected raw material was collected on the territory of an establishment in Trzebnica, where on a sorting line they were divided into appropriate fractions, which are compressed by baling and in this form they are prepared for further transport (Grabowski and Spalińska, 2008).

Zakład Gospodarki Odpadami in Gać is Ekologiczny Związek Gospodarki Odpadami Komunalnymi „EKOGOK" [Ecological Association of Municipal Waste Collection] with its registered office in Oława. The following communes have been served by the establishment since 2002: Skarbimierz, Lubaszka, Oława as well as cities of Oława and Brzeg. The establishment carries out selective collection system which consists in joint collection of plastic, metal as well as paper and cardboard to one container. Glass is collected in a separate container. This system of waste segregation was accepted in the establishment since it obtains higher and higher social acceptance on account of their simplified collection and decrease of their transport costs because majority of waste is collected during a single crossing of a transport mean. Mechanical sorting of non-segregated municipal waste as well as waste from selective collection is carried out in the Establishment. Waste recovery is carried out at the sorting hall equipped with mechanical waste segregation line, composed of a drum sieve, an electromagnetic separator of ferrous metals, a non-ferrous metals separator, two optical-pneumatic separators and a baling press for sorted secondary raw material. A sorting plant operates in a two-shift system and the maximum performance of a sorting line is 100 600 $Mg \cdot year^{-1}$ (Pozwolenie zintegrowane ZGO Gać, 2007, Prezentacja ZGO Gać).

Results of research and their analysis

Mixed municipal waste and selectively collected waste were collected by ***Firma Usługi Komunalne „Wodnik"*** from households, from municipal services establishments, trading, small business establishments and offices. Waste was collected from 100 000 citizens.

When analysing the size of the mass of the obtained waste (fig. 1), the highest share in the total mass comprised of household waste which amounted to approximately 300, 000 Mg and from establishments which run business activity, which was approximately 200, 000 Mg. Considerably lower number of waste was from municipal services and was within 35 000 Mg to 55, 000 Mg. In case of total municipal waste, this number increased by over 260 000 Mg from 2007 to 2010.

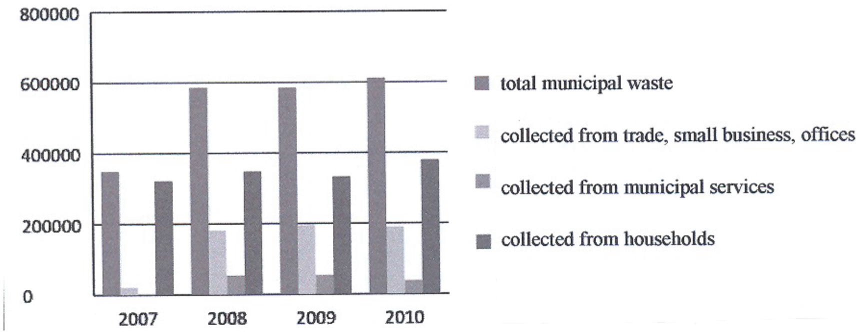

Figure 1. Collected municipal waste M_k in Mg by company Usługi Komunalne "Wodnik" in Trzebnica (author's own study based on data obtained from FUK „Wodnik” in Trzebnica)

Total recovery of paper, cardboard, glass and plastic from total mass of mixed waste was within 3.5% in 2007 to 2.5% in 2010 and in the remaining years was 2% of waste mass. It should be emphasised that in the analysed period the amount of secondary raw material separated on the waste segregation line decreased. Within 2007-2010 the mass of waste processed on a sorting line was lower by 28, 455 Mg. Considerable differences in the amount of collected waste obtained at their segregation occurred. Mass of selectively collected paper and cardboard increased almost by 500 Mg (fig. 2). In case of glass containers the biggest recovery of them took place in 2008 and it was over 7,000 Mg. Between 2008 and 2009 a decrease of the obtained mass took place and it was approx. 1,500 Mg. In 2007 the highest number of plastic containers was selectively collected – it was over 3,600 Mg and in 2010 almost 3,200 Mg.

A sorting facility owned by the Establishment served 22.2 thousand citizens in 2010. The mass of waste accepted to a sorting facility in 2010 was 5, 567 Mg and was higher in comparison to 2006 by approx. 2,000 Mg. 23% of raw material were recovered for recycling in 2010. In 2010 selective waste such as cullet was collected from 17 thousand citizens, plastic from 22.1 thousand citizens, whereas paper scrap from 12.1 thousand of citizens. Plastic and glass was collected to containers of "Iglo" type of 2.5 m^3, PCV 240 l, and to plastic bags of 240 l and 110 l volume. At the average approximately 60, 000 thousand plastic bags are used to collect secondary raw material every year. In 2010, 444 containers for glass, the same number for plastics and 424 for paper scrap were used for selective waste collection.

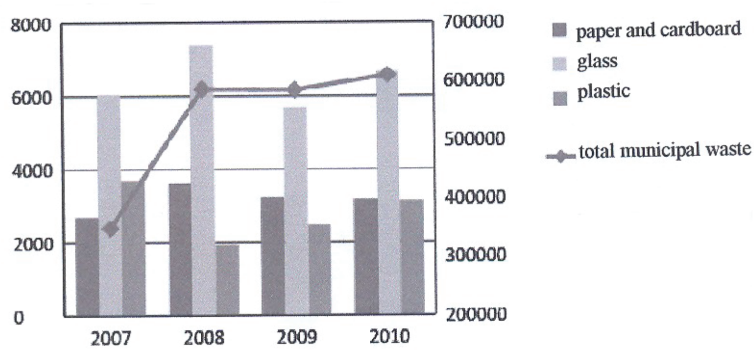

Figure 2. Waste collected selectively M_s in Mg and municipal waste M_k in Mg by Firma Usługi Komunalne "Wodnik" in Trzebnica (author's own study based on data obtained from FUK "Wodnik" in Trzebnica)

Due to cooperation with a local society, ecological education of citizens and constant investment inputs increase Firma Usługi Komunalne "Wodnik" in Trzebnica obtained a high level of recovered secondary raw material.

The other analysed establishment is ***Zakład Gospodarki Odpadami in Gać***, which from 2007 to 2010 increased the amount of the accepted non-segregated municipal waste by 16, 000 Mg (fig. 3) which constitutes the increase by 30%.

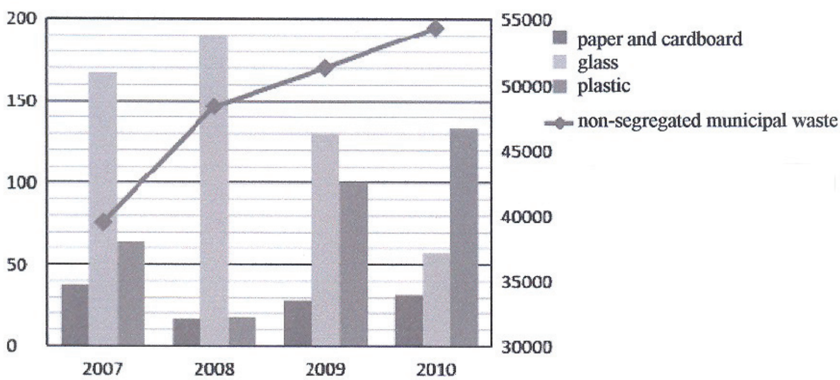

Figure 3. Municipal waste segregated in M_s in Mg and municipal waste M_k in Mg collected by ZGO Gać in Trzebnica (*author's own study based on data obtained from Zakład Gospodarki Komunalnej Gać)*

Taking into consideration municipal waste collected selectively in ZGO "Gać", in 2007 they amounted to 7.08% and in 2010 to 7.75%. The difference resulted from the increase of the mass of mixed waste accepted and segregated, which increased by approximately 18, 000 Mg. In 2007, a mass of sorted raw material was 2, 983 Mg and in 2010 4, 694 Mg. In case of a selective collection of all types of secondary raw material, we may notice an upward tendency of the recovered mass not earlier than since 2006.

When analysing data on segregation of mixed packages waste, which was carried out on the territory served by ZGO "Gać", one may state that the system of such integration is effective and allowed separation of 2, 708 Mg raw material in 2010. Separate segregation of glass was 1, 029 Mg and decreased in comparison to 2009 by 300 Mg (fig. 4).

In 2004, 92 Mg of this waste was separated and in 2010 only 31 Mg. Glass is segregated in a lower amount, at the level of 57 Mg, when in 2006 it reached the level of 235 Mg. 133 Mg of plastics were obtained in 2010. The lowest number of this material was separated in 2008 and was at the level of 18 Mg. ZGO "Gać" earned PLN 1, 815, 279 from sale of secondary raw material in 2010, which means a unit profit at the level of 512.50 PLN·Mg^{-1} of waste.

Mass of waste transferred to repeated use from the beginning of operation of the Establishment was 33, 236 Mg. In 2004, 1,899 Mg was recovered and in 2010 4, 693 Mg. The increase of the obtained mass of selective waste follows from the increase of the number of containers for segregation, from ecological education of citizens and from modernization of the waste segregation line.

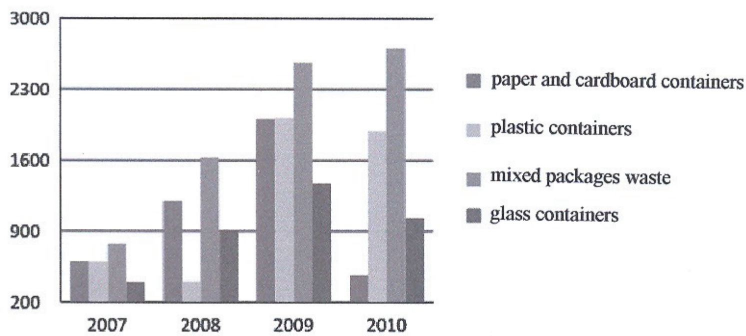

Figure 4. Packages waste M_s in Mg accepted by ZGO Gać [author's own study based on the data obtained from Zakład Gospodarki Komunalnej Gać]

Conclusions

Based on the research, one may make the following conclusions:

1. Within 2007 to 2010 Firma Usług Komunalnych "Wodnik" in Trzebnica recovered in total on the entire served area approximately 560 Mg more waste collected selectively which constitutes an increase by 4.3%.
2. An increase of the amount of waste collected selectively was reported in Zakład Gospodarki Odpadami in Gać. It followed from modernization of an establishment and the increase of the scope of segregation system with the use of two containers. In 2004, 1, 899

Mg of waste was collected and in 2010 4, 693 Mg which constituted an increase by 60%.
3. Research of two different methods of selective collection of municipal waste proved that the use of segregation at the source with a plastic bags method is more effective than segragaton with the use of containers located in the neighbourhood.

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ANALIZA ODPADÓW KOMUNALNYCH ZBIERANYCH PRZEZ WYBRANE ZAKŁADY ZAGOSPODAROWANIA ODPADÓW

Streszczenie. Od momentu wejścia Polski do UE zobowiązani jesteśmy do dostosowania systemu gospodarki odpadami do dyrektyw wydawanych przez Radę Wspólnoty Europejskiej. Nasza gospodarka odpadami została dostosowana do wymogów dyrektyw Unii Europejskiej. Celem pracy było określenie: po pierwsze ilości wytwarzanych odpadów komunalnych zmieszanych, po drugie ilości odpadów komunalnych gromadzonych selektywnie przy wykorzystaniu metod zbiórki poprzez segregację w miejscu ich powstawania stosując dwa kontenery ustawione obok siebie – jeden do łącznego gromadzenia papieru, tektury oraz tworzywa sztucznego a drugi do gromadzenia szkła, po trzecie wielkości odzyskanych surowców wtórnych takich jak szkło, tworzywo sztuczne oraz papier z odpadów komunalnych zmieszanych, po czwarte ilości pojemników lub worków przeznaczonych do selektywnej zbiórki odpadów. Do zrealizowania tego celu wybrano dwa zakłady stosujące różne systemy zagospodarowania odpadów. Badania zostały przeprowadzone w Firmie Usług Komunalnych „Wodnik" w Trzebnicy oraz w Zakładzie Gospodarki Komunalnej w Gaci, które od wielu lat zajmują się sortowaniem odpadów komunalnych. Badania dowiodły, że metoda workowa jest efektywniejsza od segregacji za pomocą kontenerów ustawionych w „sąsiedztwie".

Słowa kluczowe: odpady, segregacja, zakład gospodarki odpadami

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APPLICATION OF PLANO RS SOFTWARE IN A FARM

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ABSTRACT

The paper presents evaluation of Plano RS software used in a farm that is covered with agri-environmental scheme. The objective of the research was to check to what extent Plano RS software influences the process of defining quantity of fertilizers necessary in a farm. Wide spectrum of the program, its common availability, and the fact it is user-friendly, allows even people with basic knowledge of computers to use Plano RS software as an effective tool supporting their decisions. Using Plano RS software, a farmer is able to define quantities of fertilizers that should be applied in a farm, crosscheck manual calculations.

Introduction

Profitability of production in a farm requires a farmer nowadays to have not only agricultural knowledge, but also the one concerning agricultural engineering, law, finances, and management. Collecting all data related to a farm and production, and then analyzing and obtaining information, may turn out a difficult and time consuming process. Computer or internet decision support systems for agriculture may undoubtedly bring necessary assistance.

First Decision Support Systems (*DSS)* were developed at the turn of 60s and 70s, and they were used for business management (Bojar, 2010). Since the beginning of 80s and the development of information technology, which was accompanied by appearing of computers that were available almost for all people, decision support systems have been used in agriculture as well. A decision support system is in different words a set of rules recorded in a form of a mathematical formula or logical questions, the answer for which should be found in computer software (Grudziński, 2006). Apart from obvious economic advantages observable for a farmer who uses decision support systems, there are also advantages for environment. Taking the advantage of agri-environmental schemes means the reduction in production process of e.g. fertilization, or using plant protection products, which should be followed by a farmer in return for some financial instruments such as subsidies that compensate them (Kuszewska and Fenyk, 2010, Brodzińska, 2009). Quantity of used pesticides gets reduced and processes are performed in the so called optimum conditions, which means, that these products are in full consumed by plants, and they do not pose a threat to functioning of ecosystems. Reduction of a number of performed processes and farm works limits the usage of machines in a farm, which means the decrease in carbon dioxide emission from fuels used in farm machines. Consultancy concerning fertilizers requires exact analysis of soil and filling in data form about a farm, but it assures rational, sustainable fertilization of plants, and safe application of natural and mineral fertilizers (Fotyma (Ed.), 2009). In principle, all these requirements and factors that are sometimes too difficult to be analyzed by an individual, are taken into account by an appropriate software of decision support in the scope of making a fertilization plan (Jadczyszyn, 2009).

Objective, scope and methodology of research

The objective of the research was to evaluate application of Plano RS software used in particular for making fertilization plans in farms covered with agri-environmental schemes within the framework of Rural Areas Development Plan 2007-2013.

The research has been conducted based on an experimental method – there has been simulation run of Plano RS software application in relation to data and indicators of a particular farm. In the experiment there have been used: data put in the agri-environmental scheme adopted for a farm, as well as statistical data of a farm, current soil analysis and field work. The research was run in the business year 2011/2012. It was run in a farm located in Jaświły commune (in north-eastern part of Mońki County, Podlaskie Voivodeship). The northern part of the commune is Biebrza National Park, and the eastern border is marked by Brzozówka River, which is one of the biggest tributaries of Biebrza River.

Research results

Application of Plano RS software allowed to make fertilization plan not only for one business year, but also for some next years (e.g. a period of fulfilling an agri-environmental scheme), although it turned out that it was necessary to introduce unexpected modifications that depended e.g. on weather conditions or applied agro-technical procedures, e.g. soil drying, fertilization, introducing a new form of crop and livestock production.

The software allowed not only planning quantities of necessary fertilizers, but it also verified certain routine mistakes made by farmers in the process of defining quantities. Comparison of fertilizers demand calculated by a farmer for permanent pastures: 102 kg $N \cdot ha^{-1}$, 34 kg $P_2O_5 \cdot ha^{-1}$, 70 kg $K_2O \cdot ha^{-1}$, 21 kg $MgO \cdot ha^{-1}$and 10 kg $CaO \cdot ha^{-1.}$ In the process of calculation, Plano RS software changed quantities of fertilizers 41 kg $N \cdot ha^{-1}$, 11 kg $P_2O_5 \cdot ha^{-1}$, 35 kg $K_2O \cdot ha^{-1}$, 6 kg $MgO \cdot ha^{-1}$and 3800 kg $CaO \cdot ha^{-1}$.

The discussed software allowed in a very precise manner to calculate a necessary fertilizers dose, which influenced economically the farm. It was defined that the farmer should spread agricultural lime more often on pastures because acidity of the soils is within the range 5.1-5.5 pH. The advantage of the software is calculating nitrogen doses that should be delivered for a particular plant together with giving the dates of application. No matter if it is a pasture (e.g. A field: dose I – before sowing, dose II – after the first windrow, dose III –

after the windrow), or triticale (e.g. dose I – before the beginning of spring vegetation, dose II – stem extension stage), the software will conduct a necessary calculation.

Table 1
Nutrition demands of a field with permanent pastures (printout)

	Field No.(name): O					Field area (ha): 5.74				
Crops	Recommended portions kg per 1 ha					Recommended portions for field				
	N	P_2O_5	K_3O	MgO	CaO(t)	N	P_2O_5	K_3O	MgO	CaO(t)
Crop: grass	41	11	35	6	3,8	235	63	201	34	22
Nitrogen fertilization (kg N/ha/ year): 54	incl. Natural and organic fertilizers:13								N balance:14	

Organic fertilizer for a plant: liquid manure-fermented and unfermented 48 tons/field
Distribustion of nitrogen doses:(kg·ha^{-1})
Dose I:16 before sewing
Dose II:12 after the first windrwow
Dose III:12 after the second windrow
Half of calculated CaO dose is recommended to apply in a form of magnesium lime

It was observed on the basis of fertilization analysis that the reason for incorrect growth of plants was shortage of phosphorus and potassium macroelements in the soil. The research pointed out that the farmer calculating manually doses of applied fertilizers, even when applying very high amount of nitrogen (143 kg N·ha^{-1}, 34 kg P_2O_5·ha^{-1}, 40 kg K_2O·ha^{-1}) was not able to achieve satisfactory crops of triticale, because in order to obtain on average 5 tons of triticale, we need 67 kg N·ha^{-1}, 50 kg P_2O_5·ha^{-1}, and 71 kg K_3O·ha^{-1} (Jadczyszyn, Kowalczyk, Lipiński, 2008).

Table 2
A farm balance (printout)

Balance indicators of a farm			
Area	ha	Consumption of natural fertilizers	
Agricultural area	44.12	NIG (statistical farm number):024136041	Year:2012
Arable area	37.91	Farm:	Farm tested
Fallows incl.	0		
Pastures	6.21		
Grain crops	4.04	11% share in crops structure	
Permanent	0		
Green fields	13.78	36% share in arable area	
Fields with ploughed straw	0	0% share in arable area	
Main feed area	40.08		
Crop in grain units	dt		
For 1ha of agricultural area	37.5		

Balance indicators of a farm			
Area	ha	Consumption of natural fertilizers	
For 1 ha of crop area	43.6		
LSU/1ha of agricultural area	0.96		
LSU/ 1 ha of main feed area	1.06		
indicators	N	P	K
NPK quantity in applied natural fertilizers (kg)	356	179	564
NPK consumption in natural fertilizers in $kg \cdot ha^{-1}$ of agricultural area	8	4	13
NPK consumption in mineral fertilizers in $kg \cdot ha^{-1}$ of agricultural area	91	34	89
Intake of components from all sources in $kg \cdot ha^{-1}$ of agricultural area	133	22	99
Intake of components from all sources in $kg \cdot ha^{-1}$ of arable area	144	25	108
Intake of components from all sources in $kg \cdot ha^{-1}$ of pastures	62	6	45
NPK balance for 1ha of agricultural area	12	3	-9
Fertilization of arable area with nitrogen (N kg/ha/year)	113		
Fertilization of agricultural area with nitrogen (N $kg \cdot ha^{-1}$/year)	45		
Recommended value of balance indicator		1.08	1.92
Current value of balance indicator		1.15	0.92
Straw management:			
Demand for straw for litter (tons)	15.7		
Amount of straw for litter to be used by farm (tons)	33.3		Print
Ratio of using straw for litter	2.13		Close

Another advantage of the software is the fact that it contains a lot of important information necessary for a farmer, e.g. such as: crop rotation on a particular field, NPK ratio$\cdot ha^{-1}$ of agricultural land, quantity of straw in a farm and demand for litter, shortage of nutrition components $kg \cdot ha^{-1}$ of agricultural land, livestock of adult animals $LSU \cdot ha^{-1}$. It is required that a farmer puts in a very exact and correct manner all data from his farm, and then it will be possible to use such an analysis in the farming production process.

An element of the software that requires further improvement is calculating the natural fertilizers quantity, which can be used by a farm. It depends on the number of livestock in a farm, type of breeding, age and number of days spent on pasture. From the practical point of view, in a farm there are quite frequent changes to a number of livestock and their age, as well as number of days spend on pasture. One may notice when trying to compare calculations of the software and realistic usage of liquid and stable manure from the barn on deep litter, that they are quite different, which results from averaging the number of animals by the software. It does not include either the possibility of combining production of a particular farm with others, whereas in farm production, there are frequent cases of e.g exchanging products by neighbours, which may not be included in the data input (no such function).

Table 3
SWOT analysis of Plano RS program application

Advantages:	Disadvantages:
- Common and free access to the software. - User-friendly, even for people with basic knowledge of computers. - High number of variables, which allows matching to a particular farm. - A possibility to plan for many years. - Low hardware requirements. - Commonly used by agri-environmental experts in the process of preparing fertilization plan. - Recommended by Farming assistance center and farming chambers.	- Incomplete data. - Takes into account only standard situations, no possibility to modify in extraordinary situations. - High number of commands to be done in order to make calculations. - Reading is possible only at the computers where Plano RS is installed, no possibility of exporting data. - A necessity of putting fertilization data twice in different periods of a business year. - Limited possibility of manual changes in order to match with the specificity of a particular farm.
Chances:	**Threats:**
- A modern software for making fertilization plans. - Well-tried in scientific research and in practice, which proves its usefulness. - Allows a better planning and usage of natural and mineral fertilizers.	- It requires monitoring of its correctness with a realistic farm production process since too high level of trust into the software calculations may result in negative effects. -

Summary and discussion

In Polish conditions computer decision support programs in farming undoubtedly still remain a certain novelty, and they are too seldom used. As field works prove, only ca. 17% of farm producers who have a computer with the Internet access, use a program for defining the quantity of necessary fertilizer (Borusiewicz, 2009). A significantly higher percentage of farmers use computers to select the goods, make a purchase, fill in subsidiary applications correctly, or for plain entertainment. It is worth mentioning that numerous "traditional" farmers do not have necessary knowledge to use computers and the Internet, and main users of their computers are their children or grandchildren (Lorencowicz and Figurski, 2008), which gets confirmed by the research carried out by Kapela and Borusiewicz (2012).

However, taking into account western practices and experience, this thinking is incorrect, since a computer is extremely useful, and more importantly it is an effective tool for fertilization planning. Grudziński (2006) quotes most important reasons of certain objections of farmers against modern programs of decision support, i.e.:

- worries of farmers concerning high purchase costs of hardware and software that might not get compensated by savings obtained thanks to their application,
- too much complicated hardware and software service,
- low reliability of solutions suggested by a software, which results from accepted simplified models,
- difficulties to modify software according to individual farm properties,
- being up to the date with information stored in the data base memory,
- knowledge level of a user may be a factor that discourages from using a software.

Despite all indicated reasons, when getting better acquainted with the practical aspect of using a farming computer software such as Plano RS, they are not obstacles that may not be overcome, the more that majority of farms is assisted by different forms of farming assistance experts, farming assistance centers, farming chambers or other entities.

The research of Kapela and Borusiewicz (2013) point out that the average age of farmers got lower, but education level, scope of competences and awareness of modern solutions increased, and these factors mean greater interest into modern technologies, including the programs of decision support in farming.

Plano RS program includes all these factors: soil properties, e.g. acidity, content of basic elements; forecrop and fertilization that was performed specially for a plant, issue of an aftercrop and the aim of crop, managing the side crop, application of natural fertilizers. Using Plano RS software allowed reduction of quantity of applied mineral fertilizers, which meant the cost reduction of farm costs.

Each farm producer, even the one having specialist education and practical knowledge, when using the computer software may obtain a lot of valuable information that may bring about visible economic results. Wide spectrum of the program, its common availability and the fact it is user-friendly, allows even people with basic knowledge of computers to use Plano Rs software as an effective tool supporting their decisions. One may expect in the future that – as in western countries – a computer equipped with decision support systems – will be one of the most basic tools used in a modern farm.

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ZASTOSOWANIE PROGRAMU PLANO RS W GOSPODARSTWIE ROLNYM

Streszczenie. W pracy przedstawiono ocenę działania programu Plano RS wykorzystywanego w gospodarstwie rolnym objętym programem rolnośrodowiskowym. Badanie miało na celu sprawdzenie, w jakim stopniu program Plano RS wypływa na określenie ilości stosowania niezbędnych nawozów w gospodarstwie. Wszechstronność programu, jego powszechna dostępność oraz łatwość obsługi, pozwala nawet dla osób z podstawową znajomością obsługi komputera wykorzystać program Plano RS, jako skuteczne narzędzie wspomagania decyzji. Stosując program Plano RS, rolnik może ustalić ilości nawozów jakie powinny być zastosowane w gospodarstwie, zweryfikować wyliczenia ręczne.

Słowa kluczowe: Plano RS, nawożenie, komputerowa aplikacja rolnicza, programy rolnośrodowiskowe

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IMPLEMENTATION OF PRECISE FARMING TECHNIQUE ON THE EXAMPLE OF A MULTI-SURFACE AGRICULTURAL FARM

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ABSTRACT

An attempt to assess the use of modern technique in multi-surface agricultural farm and an attempt to compare the system of precise farming management with conventional was made. Based on the research, which was carried out, it was determined that the purchase cost of the precise farming devices will bring measurable advantages as soon as in the second year of use. Introduction of the precise fertilization treatment and application of pesticides brought the highest savings in a farm. The use of the parallel move system in the investigated farm brings approx. 10% of savings in consumption of production means, that is, sowing material, fertilizers, pesticides and fuel. Advantages arising from the use of precise farming application are estimated to account to approx. 37 PLN·ha^{-1} per year.

Introduction

Modern agriculture becomes a field of agriculture which is to a higher extent based on professional knowledge, ability to manage and apply information in the production process. Ability to process bigger amount of information related to implementation of new technologies becomes a key for maintaining profitability of production and meeting requirements of protection of natural environment. The basic assumption of the precise farming system is adjusting production technology to specific conditions of environment including spatial variability of single fields. Precise farming is determined as a farming system which uses highly developed navigation and informatics technologies – satellite positioning systems (GPS – *Global Positioning System*) and methods of obtaining and processing spatial data (GIS – *Geographic Information System*), (Gozdowski et al., 2007). The basis for operation in the precise farming is collection of information on the natural variability of a given area, e.g. a field with precision to as much as 1 cm and using them to prepare precise agrotechnical treatments e.g. fertilization or using pesticides. Preparing a digital map of resourcefulness and variability of soil is a precondition for implementation of precise farming. In the recent years, precise farming is implemented more extensively for agricultural production in many countries, especially in the United States, Australia and other countries of Western Europe. Significance of precise farming in Poland has been low so far. However, one may forecast that within several years, this farming system will be gradually popularized (Gozdowski et al., 2007; Dreszer, 2005). Implementation of these technologies to farming opened completely new possibilities in agricultural technology, providing basis for use in the field production of the so-called precise farming system (Doruchowski, 2005; 2008). Completely new generation of machines and work technologies with great participation of electronics, computerization and satellite connection systems has been created. It gives high time and energy savings (Narkiewicz, 2007; Turowski and Kapela, 2001). The Polish conditions indicate that there are many factors, which hinder more extensive popularization of the precise farming systems, including: high fragmentation of agrarian structure, farmers' reluctance to associate in producer's associations, high prices of satellite navigation systems and machines (Minta, 2008).

Objective and methodology of research

The objective of this research was analysis of profitability of implementation of precise agriculture techniques on the example of large farms. Research was carried out in 2011 based on the direct survey and documents obtained from agricultural farm. The list of purchased devices was made and SWOT analysis was carried out. Calculations were made with the use of data analysis method. A farm takes a total area of ca. 4,000 ha (with leased land). A 4-year cycle of crop rotation is applied. The structure of crops: potatoes 1000 ha, grains 1850 ha (wheat 1000 ha, barley 700 ha, rye 150 ha), rape 850 ha, grass mixture 200 ha, maize 100 ha. The last two crops are intended for demands of own fodder production used in milk production (a herd of 300 dairy cows). Results obtained from implementation of the precise farming systems were compared with the results of conventional farming.

Research results and discussion

In the investigated farm, various techniques of precise farming are implemented. The first solution introduced in 2003 was collection of soil samples every 4 years in the system of points mesh with resolution of ca. 2 hectares. Simultaneous equipment of the device for collecting soil samples in GPS allows drawing maps of soil pH and phosphorus, potassium and magnesium content. Maps of content created with the use of AgroWin software, are mainly used for "manual" determination of fields with different pH and on this basis for differentiating calcium doses. Savings on this account are estimated to be ca. 15% of lower costs of fertilization consumption. The main reason for implementation of the fertilization system is searching for methods of levelling of potato tubers quality. The system for supporting parallel move GPS OUTBACK'S, mounted on tractors aggregated with fertilizer spreaders of Amazone company with a working width 24 and 36 cm has been used for improvement of precision of pre-sow use of fertilizers since 2006. Mineral fertilization is carried out with Amazone spreaders - suspended ZA-M Profis and connected ZG-B Drive. The latter spreads also calcium. All spreaders are equipped with Amatron drivers+, which may cooperate with Trimble devices. This system allows limitation of "underlaps" and spots where fertilizer was double applied and allows precise fertilization at night and at bad weather conditions. Since 2005 a farm has crop meters mounted on Class Lexion 560 equipped with GPS. Maps of yielding of grains and rape are drawn with the use of AGRO-MAP programme. Presently AutoControl system is being tested in a farm, which enables constant analysis and optimization of the use of tractors in a farm. Possible implementation of the AutoControl system depends on possible financial savings, which will follow from its application. The costs of one transmitter/receiver amounts to PLN 3 thousand, a fixed charge for monitoring of one vehicle amounts to PLN 85 monthly. A farm owns 50 tractors, thus their control on the area of 4 thousand is impeded. Since 2001 a farm maintains a record of all cultivation treatments with the use of PlantPlus application. Such solution allows to quickly find both current and historic cultivation data.

The whole area of potato cultivation is watered with sprinkling machines of Pivot type and reel sprinkling machines Irydelta. Time limit and dose of water is determined based on precise measurements of soil moisture with the use of sonde Diviner 2000 by Sentek Sensor Technologies. At the average, in the vegetation season potatoes are irrigated with a dose of 100-120 litres of water per m^2.

Planning works on fields, where potatoes are cultivated shall be started with placing reel and rotational sprinklers on them. In case of the first group, following their placing on a given plot, a direction for planting potatoes shall be determined.

Then, referential lines A-B for each field shall be determined. Thanks to these lines, 3 sets with tractors equipped with the system of automatic parallel move, whose operation is supported by RTK aerial of base station, which measure errors and send by radio the so-called correction to tractors which are in its scope (at the maximum 12-15 km), will be able to plant potatoes.

Due to the use of precise devices, a farm decreased annually its treatment costs. Purchase of RTK station and equipment for two tractors, which use a precise signal cost ca. PLN 170 thousand. However, according to calculations made by the farm manager, during work with cultivation machines of 6 m width, actual width of cultivation is approx. 5.40 m. With RTK station an effective width of the same equipment is 5.90 m. Calculating this difference by a farm area, average number of cultivation crossings, during operation without GPS, area of the so-called covers was approx. 1,000 ha. Due to RTK and elimination of covers during cultivation, a farm decreased annual costs from PLN 102 thousand to PLN 83 thousand. Besides the use of satellite navigation for planting and sowing it is also used for parallel crossing during reaping off the stubble field and sprinkling calcium. Then the tractor operator, as during sowing, may concentrate on observing a tool and leaves tractor driving to devices of automatic parallel move.

Trimble Autopilot systems are mounted on three tractors New Holland T7030 and they interfere through solenoid valves in their hydraulic steering systems. Moreover, sensors of turning AutoSense and centrals NavController II with compensation of vehicle tilts in three axes T3, which is formed by three couples of acceleration meters and gyroscopes measuring all machine movements 50 times per a second. It is indispensable for precise tractor driving, since an aerial on its roof does not reflect the axis location, which always has to be on the navigation line. Application of the described automatic parallel move for driving three tractors which pull the sets composed of active plough Baselier 4FKC380, a 4-row structural planter Miedema PM40 Structural and a ridge former Miedema AAK 4R allows planting 950 ha of potatoes within three weeks of work 24 hours a day (including approx. 250 ha of seeds plantations).

Table 1
GPS devices used in a farm (3,800 ha of annual plants)

Use of a device	Name of a device	Purchase price (PLN)	Estimated savings (PLN·year^{-1})
Precise farming, precise cropping	Trimble Autopilot	100, 000	133, 000 (35 PLN·ha^{-1})
Precise fertilization, Precise use of pesticides	Panele CFH, FmX plus VRA firmy Trimble	12, 000 23, 000	190, 000 (50 PLN·ha^{-1})
Precise sowing Precise farming,	EZ –Steer, EZ- Guide 500 plus aerial	45, 000	95, 000 (25 PLN·ha^{-1})
The increase of the quality of signal	RTK station	170, 000	Included above in agro-technical treatments
Total		350, 000	418, 000

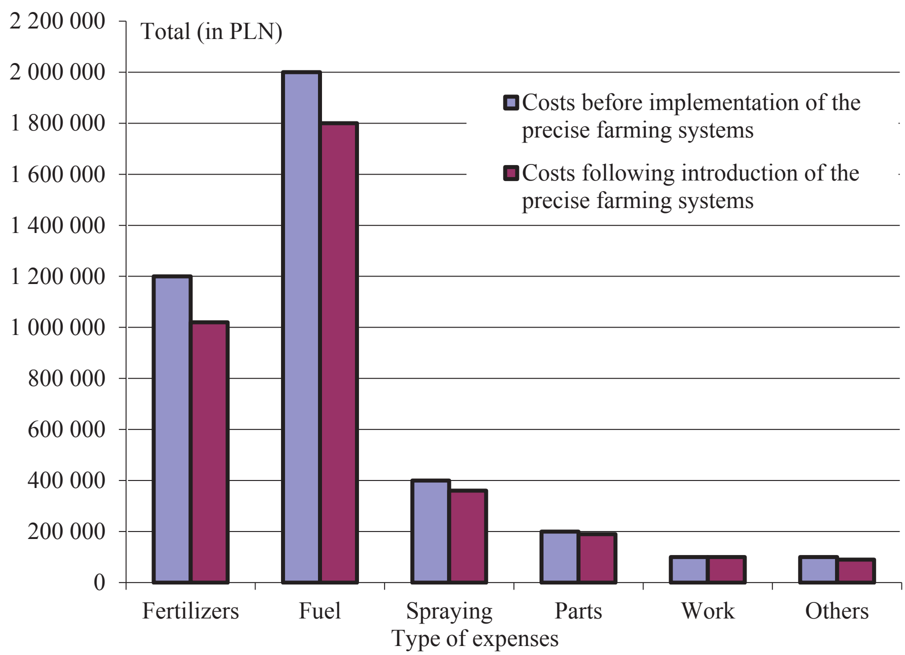

Figure 1. Calculation of costs incurred by a farm before and after introduction of navigation systems

Table 2
SWOT analysis

Strengths	Weaknesses
Savings in consumption of fertilizers and pesticides	High cost of purchase of equipment
Increase of effectiveness of fuel consumption, Increase of crops	Necessity of possessing modern machines
Time savings, Optimal field and plant cultivation	Burdensome moving of GPS devices from one machine to another
Decrease of machines consumption, Decrease of labour input	No universal GPS device for all machines
Improvement of the quality of farm products	No compatibility of various producer's devices
Decrease of a negative effect of agricultural activity on natural environment	Necessity of paying a subscription for GPS signal of the increase precision
Automatic control of technical devices	Need for training for employees
Automatic formation of documentation concerning fertilization, protection and cropping, constant collection of data, processing, analysis	GPS signal cannot be accessed everywhere

Table 3
Chances and threats related to implementation of precise farming

Chances	Threats
Increase of the demand for services related to collection, management and interpretation of data	Without a good understanding of data interpretation and equipment compatibility, there is a threat that full advantages from GPS use will not be executed
Development of local training institutions	No GPS signal within a specific period may lead to delays in a correct execution of agricultural treatments
There is a need to create a friendly-user application for interpretation of various layers of spatial data in agronomic solutions	Relation to GPS signals, loss of some traditional skills at the operation of machines, such as ability to drive mechanical vehicles in a straight line without the use of technology
Increase of income from agricultural production	Spatial technology may help in development of machines, robots, potentially reducing demand for work and costs of human errors, but it also may lead to the loss of human operators of machines in rural societies

Size of acreage, in conditions, in which introduction of precise farming is economically justified depends on many factors, such as: applied technologies, cultivated plant species and produce and production mean prices (Gozdowski et al., 2007). In the researched farm, amortization of equipment is assumed for 10 years, whereas, savings from the use of precise farming techniques is estimated at the average of approx. PLN 37 ha^{-1} per a year (table 1). Godwin et al. (2003), analysed the area from which the use of precise farming technology will bring income and they provide 250 ha for a complex equipment in indispensable devices, additionally assuming the increase of crop by 0.25-1.6 $t{\cdot}ha^{-1}$. However, these are conditions which differ many times from existing conditions of farming in Poland. The use of the parallel move system brings ca. 8% of savings in consumption of production means, that is seeds, fertilizers, pesticides and fuel, whereas in the researched farm, these savings are at the level of ca. 10%. This difference probably follows from the highest level of precision of the system, applied in this farm and from the possession of big-area fields, where effective operation of the set of machines is longer.

Conclusion

Based on the research which was carried out, it was determined that the purchase cost of the precise farming devices, in the investigated farm will bring measurable advantages as soon as in the second year of use. Introduction of the precise fertilization treatment and application of plant protection substances brought the highest savings in a farm.

In Poland there are more and more businesses which render services of precise farming. A farmer before taking up a decision on the selection of the equipment or a service company, should carry out a precise analysis of the selection of equipment, since savings from implementation of the precise farming systems may be ostensible, which is confirmed by the research of Šařeca et al. (2009).

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WDROŻENIE TECHNIK ROLNICTWA PRECYZYJNEGO NA PRZYKŁADZIE WIELKOPOWIERZCHNIOWEGO GOSPODARSTWA ROLNEGO

Streszczenie. W pracy podjęto próbę oceny zastosowania nowoczesnych technik w wielkopowierzchniowym gospodarstwie rolnym oraz porównania systemu gospodarowania rolnictwa precyzyjnego do konwencjonalnego. Na podstawie przeprowadzonych badań stwierdzono, że koszt zakupu urządzeń zwrócił się w drugim roku jego użytkowania. Największe oszczędności w gospodarstwie przyniosło wdrożenie zabiegu precyzyjnego nawożenia oraz stosowanie środków ochrony roślin. Miało to również swoje odbicie w mniejszej ilości zużytego oleju napędowego. Stwierdzono, że minimalna powierzchnia gospodarstwa, od jakiej stosowanie technologii rolnictwa precyzyjnego przyniesie dochody wynosi 310 ha. Korzyści płynące z precyzyjnego gospodarowania szacuje się na ok. 75 $PLN \cdot ha^{-1}$.

Słowa kluczowe: rolnictwo precyzyjne, GPS, GIS, nowoczesne technologie

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EFFECTS OF SEASONAL BEDDING MATERIALS CHANGE ON DAIRY PRODUCTION

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ABSTRACT

The aim of this research was to answer the question if the seasonal cow's bedding changes are indifferent to dairy production. The research was held in two different Wielkopolska farms which had very high milk productivity. In one of the farms, the cow's beddings, were located indoor, and in the second one outdoor under the roof. The autumn's change from sand into straw and spring's from straw into sand are either indifferent to milk productivity or they have positive influence.

Introduction

Most frequently straw functions as bedding in a free-stall daily cowshed. Sand or other materials such as sawdust and shavings, scrap paper or paper mass, including granulated, straw with hydratyzed lime, compost, rubber mats etc. and even very expensive water mattresses are used as a substitution (Bedding options for dairy cows). Recently, information on harmful use of sawdust, which causes mastitis disease in relation to presence of a considerable number of intestinal bacteria *Klebsielli*, have been reported (Neja, 2013). Sand may come from a mine or be obtained from crushed rocks. In such form it is sharper. Diameter of its grains should be up to 3 mm. According to American recommendations a layer of sand in stalls should be 6-8 inches thick (approx. 15-20 cm) (Gooch and Inglis). Non-organic bedding, containing lower number of pathogens is less responsible for mastitis. According to Zdanowicz's research (2002) the number of bacteria cells occurring in the end of tits is related to their number in the bedding. Coefficients of correlation for the straw bedding are within +0.47 to 0.60 and for sand are slightly lower and are within +0.35 and + 0.40. A stall, which ensures welfare, influences long rest of a cow. Due to this, blood flow through an udder increases by 20-30%, which raises milk secretion (Osborne, 2012). According to Adamski and Zabłocka (2003) when a cow remains in a standing position for a long time, pressure in its cloven hooves increases, which reduces blood flow and leads to lameness. Sand beddings are slippery, therefore it results in a lower number of injuries and swelling of ankle joints and wrists in case of cattle occur very rarely (Rodenburg, 2000).

Moreover, sand helps to heal cloves faster (Norring et al., 2008). Dutch farmers pay attention to advantages of the mixture of cut straw and sand, which they use to cover stalls in cowsheds equipped with milking machines, which ensures a good condition of cows' limbs (Jonckers, 2011). Kaczor et al. (2011) stated that based on the research, the number of somatic cells in milk of cows, which rest on straw-lime beddings is lower in spring and summer, however, on sand it is lower in autumn and winter. Rodenburg (2000) also pays attention to a lower number of somatic cells in milk of cows maintained on sand. The advantage of sand beddings is that in summer their temperature is almost by 2ºC lower than the temperature of air, which advantageously influences thermal comfort of animals. It is confirmed by Gooch and Inglis. Cook claims that a cow should stay in a stall 12 hours a day. This time is shortened by a prolonged milking, which lasts over 3 hours. Cows prefer to rest in straw stalls than in the sand stalls. Moreover, sand has its disadvantages, because it damages machines by rubbing their working elements and when it is not used carefully it clogs up drain system (Gooch and Inglis). The joint paper written by Buli et al. (2010) is a valuable piece of literature on the knowledge of bedding and laying cowsheds. These authors carried out detailed literature studies and they included 113 mainly English publications from around the world.

The objective and the scope of the study

A temporary shortage of bedding straw is a milk producers' problem. It may be easily replaced with sand, but production outcomes of seasonal replacement have not been well recognized in Poland. Thus, the objective of the research was verification of the hypothesis that in high-performance cowsheds with stalls for cows, located indoor as well as outdoor, a seasonal replacement of sand bedding with straw and reversely is neutral for animals and does not cause any changes in their milk productivity. A cow farm with outdoor stalls was in the centre of special interest, the sense of which was to protect cattle against the effects of heat stress (Chaberski et al., 2012).

Methods

The research was carried out in two farms of dairy cows: in the end of April 2012 and in the end of autumn and beginning of winter 2012 and in two first days of 2013. Both farms are located in Wielkopolska, they belong to one, big farm and are managed by the same person. In farm B with inside stalls, usually ca. 360 dairy cows were maintained. In farm S, with outdoor stalls, there were ca. 240 cows. Including dry cows, heifers and calves, the number of cattle in the entire farm was in total 1400. Annual productivity of cows was high and reached 11, 000 kilo of milk, which places the farm at a high position on the list of the best milk producers in the country (Ocena wartości użytkowej ...., 2013).

Farm B and S differ considerably since in farm B stalls for cows are located inside cowsheds, and in farm S outside under the roofs. Thus, microclimate conditions are not identical. Lairs in farm B are of the following dimensions 112x245 cm at the threshold height of 17 cm and in farm S it is respectively 120x230 and 12 cm. In both farms stalls are laid alternatively with straw or sand, relatively to the season. At the beginning of April, straw is removed and laid with fossil sand. In December, sand is removed and replaced with straw. Photo 1. presents stalls for cows in farm S during spring replacement of straw with sand.

Figure 1. Spring bedding change in farm S (end of April, 2012)

For analyses of the impact of bedding change on the milk production a collected documentation was used. Figure data referring to a daily milk production in farm was calculated into average daily milk production from 1 milked head. Thus, disturbances which were frequently caused by a changing number of milked cows, resulting from their physiological preconditions were eliminated (birth, drying, culling etc.). For statistical calculations everyday data were applied (10 days before and 10 days after the bedding change) and weekly data including milk production 4 weeks before and 4 weeks after the change. The process of change of bedding lasted relatively to a farm – 9 or 10 days. Milk productivity of cows in transitory periods was not the subject of interest.

Daily productivity of cows in time before and after the replacement of straw with sand in stalls and reversely was statistically compared by means of analysis of variance. The authors' software was applied basing on the method described by Ruszczyc (1981). Test F was used for assessment of the significance of statistical differences between the investigated groups.

Moreover, climatic conditions in the time of analyses were checked. For this purpose meteorological data available in the Internet from a near station of permanent control in Krzyżowka, located approximately 20 km from both farms were used (Air control for Wielkopolska region).

Based on farm documentation average consumption of bedding - straw and sand were determined. Results were referred to a single stall.

As a part of the research, a single, random assessment of correctness of cow feeding was carried out on account of a proper balancing of components of TMR fodder performed by mixing fodder machines. Feeding in a farm is mono-diet and stable as to the mixture. Results of analysis of collective milk, including the content of fat, protein and urea were compared with normative data quoted in Fleszar's (2012) and Lipiński's and Winnicki's (2013) works. Chemical analyses were carried out by the Polish Federation of Cattled Breeders and Milk Producers.

Results

During decades subsequent to and following the periods of bedding change, the cows' milkability was partially varied. Table 1 contains results of statistical calculations. Weather was typical with no extremities. Average daily speed of winds was in spring within 0.2 to 2.9 $m \cdot s^{-1}$ and in late autumn and in winter within 0.4 to 2.7 $m \cdot s^{-1}$.

Table 1

The impact of seasonal bedding change on dairy production in 10 days before and after

Stall bedding change	Parameters	Farms	
		B (inside stalls)	S (outside stalls)
Straw replaced with sand (spring)	Before the bedding change		
	- average daily cows' milkability (l)	30.4	33.1
	- standard deviation (l)	0.7	0.5
	After the bedding change		
	- average daily cows' milkability (l)	32.2	33.1
	- standard deviation (l)	0.7	0.6
	Value of coefficient F	34.5 **	0.03
Sand replaced with straw (autumn/winter)	Before the bedding change		
	- average daily cows' milkability (l)	30.2	33.9
	- standard deviation (l)	0.6	0.4
	After the bedding change		
	- average daily cows' milkability (l)	30.3	34.8
	- standard deviation (l)	0.6	0.8
	Value of coefficient F	0.03	10.5 **

In the spring time, it was reported that in farm B with inside stalls, transfer from straw to sand is advantageous and the increase of cows' milkability is noticeable. Before the change during 10 days, at the average 30.4 l of milk daily was obtained from a cow and after – 32.2 l. This difference is statistically highly significant. This phenomena may be justified by more advantageous thermal conditions (inter alia with slightly cooler stalls), since dairy cows prefer lower temperatures (Chaberski et al., 2012; Rodenburg, 2000). In farm B autumn-winter change of sand does not result in the change of cows' milkability. In case of farm S the situation is different. There, after the change of sand into straw, a daily milk production increased from 33.9 to 34.8 l from a statistical cow. Differences are also statistically considerably significant. However, there are no differences in spring, where sand replaces straw in stalls. Laying of outside stalls with straw in autumn may improve general conditions of the animals' rest and as a result cause increase in milk production.

Consideration of production effects of bedding change in longer, monthly time horizons brings similar results. In farm B before a spring bedding change of straw into sand, an average daily milk production in a month was 30.3 l and after the change – 31.3 l. However, these differences are not statistically significant ($F_{calc.}$=3.29, is lower than the table one, which is $F_{tab.}$=5.12). The source of insignificance of differences is obviously a small number of freedom degree. Almost the same is at the replacement of sand with straw, when average milk production before the change is 30.0 and after – 30.7 l of milk at the average from a cow. Bedding change in farm S with outisde stalls from sand into straw (autumn/winter) is obviously advantageous. Milkability increases from 34.1 to 35.0 l of milk from cow daily, differences are statistically highly significant (F=18.15).

In the light of the above, a hypothesis placed in the objective of this paper, partially was not confirmed. Changes in cows' milkability occur after seasonal bedding change: sand - straw, straw- sand and what is the most important they may be advantageous for milk producers. Milk secretion in cattle herds increases or does not change. Possibility of almost neutral for cattle, alternative use of both bedding materials allows more rational management of straw. Many years ago Gawarecki (1862) recommended: “maintaining cattle even in summer on richer green fodder and laying soil underneath in order to save straw for the whole year will considerably improve the national breed of cattle”.

In farms 600 kg of sand and 9 kg of straw is used for first bedding of a stall. Sand is later added in lairs every two weeks in portions 60-70 kilo. Straw is spread every day, consuming 1.5-2.0 kilo for one stall. Price of a tonne of sand is PLN 20 and straw PLN 250. Research carried out by Gaworski (2008) indicate possibility of using slightly bigger amount of sand: 6.6-28.2 kg·day^{-1} and 3-5 kg of straw per day. The American add sand in stalls every second day and they rinse the hall with water (Mirek and Pustuła, 2010). In the USA, according to Rodenburg (2000), costs of laying stalls with sand are 8-10 USD·tonne^{-1}, and with straw 40-50 USD·tonne^{-1}. When comparing costs incurred for beddings in our investigated farms and in American farms one may say that they are quite similar.

In case of feeding, one should pay attention that in both investigated farms (with TMR system), it was correctly balanced and had a mono-diet nature. Fodders were subject to laboratory assessment of quality. Chemical tests of cumulative milk were carried out in a farm systematically each month. Their exemplary results are included in table 2. A slight exception to requirements may be reported only once, in farm S, in the half of December 2012, where the content of urea in cumulative milk slightly exceeded the limit of 300 mg·l^{-1} (by approx. 5%). It is a signal that a feeding dose might have had a slight excess of protein and energy, although it is not completely sure. In literature among reasons for such phenomena a high dairy productivity of cows or insufficient consumption of water by animals is given (Nowak, 2009).

Table 2
The assessment of cows feed correctness in examined farms

Farm	Date of analyses	Content in milk			Relation of fat to protein	Assessment of feed
		fat (%)	Protein (%)	Urea ($mg \cdot l^{-1}$)		
B	14th Jan 2013	4.21	3.28	273	1.28	Correct
	11th Feb 2013	4.04	3.31	271	1.22	Correct
S	14th Dec 2012	3.91	3.46	315	1.13	Alert on the excess of protein And energy in fodder
	18th Jan 2013	3.81	3.37	234	1.13	Correct

Source: Authors' own assessment based on numerical data Obtained from the Polish Federation of Cattle Breeders and Milk Producers

Conclusions

1. In climatic conditions of Wielkopolska region, straw and sand may be alternatively used as stall bedding for dairy cows without the production risk. It concerns both inside as well as outside stalls.
2. Seasonal replacement of bedding in cow stalls with very high dairy productivity does not disturb milk secretion and is even advantageous.
3. In open cowsheds, with outisde stalls for cows, autumn-winter change of sand to straw ensures that animals have appropriate welfare ensured during the winter cold.

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WPŁYW SEZONOWYCH WYMIAN ŚCIÓŁEK LEGOWISKOWYCH NA MLECZNOŚĆ KRÓW

Streszczenie. Celem badań było sprawdzenie, czy sezonowe wymiany ściółek na legowiskach dla krów pozostają obojętne dla ich mleczności. Badania przeprowadzono w 2 różniących się miejscem umieszczenia legowisk wielkopolskich fermach o bardzo wysokiej produkcji mleka. Legowiska dla krów w jednej z ferm zlokalizowane są wewnątrz, a w drugiej na zewnątrz budynków, pod zadaszeniami. Badania wykazały, że jesienne wymiany ściółki piaskowej na słomę i wiosenne ze słomy na piasek są w zależności od umieszczenia legowisk albo obojętne dla produkcyjności krów lub działają korzystnie.

Słowa kluczowe: sezonowa wymiana ściółek, produkcja mleka w oborze

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ANALYSIS OF DATA OF ORGANIC FARMS WITH THE USE OF NON-STANDARD REPORTS IN GEKKO SOFTWARE[1]

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ABSTRACT

Gekko software is designed to keep reporting in organic farms, which is required by supervising institutions. The program enables collection in its base, data, which are required from a farmer and additional information as well. Based on these data, reports and lists are generated in the program. However, beside standard lists, the software enables programming by a user his calculations. These calculations enable generating unpredicted lists in a standard version of the software. Gekko software was developed within the National Centre for Research and Development (NCBiR) project No NR 12-0165-10/2010 titled "Innovative influence of technology and information management supporting system on production efficiency in organic farms"

Introduction

Organic farming means a system of farming, which activates natural environment production mechanisms through application of natural means, technologically non-processed, ensures at the same durable soil fertility and animal health as well as high biological quality of agricultural products (Sołtysiak, 1995). Rational use of environmental resources is a basis of organic farming, and one of the purposes of organic production is creating a sustained system of agricultural management, which includes environmental systems and cycles and influences the increase of biodiversity (Kuś and Jończyk, 2009). On the other hand, competitiveness of this activity towards other agricultural systems preconditions its development in future (Komorowska, 2006). Reporting, which is required at organic agricultural production, is a basic condition for obtaining subventions. Thus, farming is an area where implementation of IT systems may activate farmers to use modern tools, which support management (Szeląg-Sikora, 2011; MINROL, on-line, 2014).

[1] *The paper was carried out as a part of the project of the National Centre for Research and Development NCBiR NR 12-0165-10, titled „Innovative influence of technology and information management supporting system on production efficiency in organic farms".*

Although, there are considerably not many programs designed for farmers, one may find also such that are used to support agricultural producers' activity (Cupiał, 2006; Lorencowicz and Figurski, 2008). Gekko software is designed to keep reporting in organic farms, which is required by supervising institutions. The software enables collection in its base, data, which are required from a farmer and additional information as well. Based on these data, reports and lists are generated in the programme. However, beside standard lists, the software enables programming by a user his calculations. These calculations enable generating analyses and unpredicted lists in a standard version of the software. Gekko software was developed within the National Centre for Research and Development (NCBiR) project No NR12-0165-10 titled "Innovative influence of technology and information management supporting system on production efficiency in organic farms". Assumptions of the research project and an application program, which was developed within its frames, were described in literature (Cupiał, 2011; Cupiał et al., 2012; Kowalski et al., 2012).

Types of reports in Gekko software

Gekko software, in the module of lists has two bookmarks: "Zestawienia 1" and "Zestawienia 2". In both bookmarks, in a standard version of the software, one may find tables with lists generated based on the collected data.

In "zestawienia 1" (fig. 1) the following tables may be selected: Rejestr działań agrotechnicznych, Bilans produktów oraz Obsada zwierząt. This type of lists includes procedures written in the code of the software, which may not be modified by a user. However, it gives a possibility of obtaining additional functions, such as filtrating data in a table. In the present version it is possible to determine the scope of dates, but ultimately increase of the number of filters is planned. It is also possible to obtain additional information by clicking a selected position in a table. Presently, such information is available in the balance of products, where upon selection of a given product one may obtain information, what components are included in this product.

"Zestawienia 2" in a standard version consists in 10 tables: Rejestr działań agrotechnicznych, Wykaz działek, Bilans produktów, Zużycie nawozów i środków ochrony roślin, Zakup środków produkcji (produktów roślinnych), Zbiór produktów roślinnych, Ewidencja zwierząt, Żywienie zwierząt, Ewidencja zbywanych produktów and Rejestr zakupów. Despite a higher number of tables placed in this bookmark, these data do not have filtration of data, there is also no possibility of obtaining contextual information (which were available in "zestawienia 1"). However, because "zestawienia 2" are formed based on batch files, which are not placed in the code of the software, but they are downloaded from the catalogue of the software, there is a possibility of modification of the calculation manner. As a consequence, this software may be easily upgraded by subsequent tables and lists without the necessity of creating next versions. Appropriate batch files which include a code which controls calculations, may be formed by a software user or supplied from other sources. A user may also modify the existing files provided along with the software, which enable calculations made in the second bookmark. Thus, one may create inter alia tables which include additional filtres or create any analyses of data, which are in the software base.

Combining defined reports by an author of the software with a possibility of defining own schemes, gives a possibility of using the software by users, who apply only standard functions and gives a chance for obtaining an increased functionality for those who need additional tables. It also gives a chance to third parties, who create non-standard reports, to join the process of the software development.

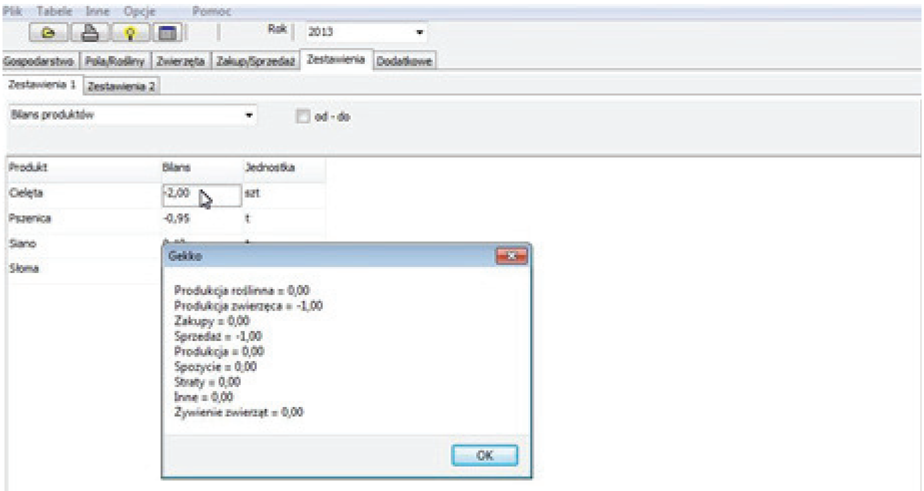

Figure 1. Exemplary standard report in Gekko programme (screen capture)

Structure of a file with a definition of a non-standard report

Information on the manner of creating a non-standard table is located in two files in the catalogue with application program libraries. File "raporty.dat" includes a list of defined tables. Each line includes a name of one table, the name may be given by description - which is user-friendly. However, it is recommended to provide short names - too long names decrease clarity and legibility of interface. These names appear in the developed field "combi" which serves for selection of a suitable list.

Next tables are defined in particular files numbered respectively "raport-1.sql", "raport-2.sql", "raport-3.sql", etc. A following number of a file corresponds to the number of a line from a file "raporty.dat", thus the number of files should be equal to the number of lines (names of tables). In case of a bigger number of files than the names of tables, the last tables will not be displayed, thus in case of adding a new report, one must remember to add the name of a table to the list.

Table 1
Exemplary definitions of non-standard tables

Item	*Title of a table*	*Code included in a file*
1	Rejestr działań agrotechnicznych	SELECT DziennikPola.data AS "Data wykonania czynności", Pole.nazwa AS "Oznaczenie działki rolnej",

Item	*Title of a table*	*Code included in a file*

	(plik raport-1.sql)	DzialkaEw.nr_dzialki AS "Numer działki ewidencyjnej",
		PoleSkladowe.pow AS "Powierzchnia działki rolnej",
		Roslina.nazwa AS "Rodzaj użytkowania",
		Czynnosc.nazwa AS "Rodzaj wykonywanej czynności",
		Produkt.nazwa AS "Nazwa środka ochrony roślin/nawozu",
		DziennikPola.ile AS "Zastosowana ilość środka",
		Warianty.kod AS "Numer pakietu lub wariantu",
		DziennikPola.uwagi AS "Uwagi/powierzchnia wykonanej czynności"
		FROMPole,Roslina,DziennikPola,Czynnosc,Produkt,
		PoleSkladowe,DzialkaEw,Warianty
		WHERE Pole.id=DziennikPola.pole
		AND Pole.roslina=Roslina.id
		AND Czynnosc.id=DziennikPola.czynnosc
		AND Produkt.id=DziennikPola.produkt
		AND Pole.id= PoleSkladowe.pole
		AND DzialkaEw.id= PoleSkladowe.dzialka
		AND Warianty.id= Roslina.wariant
		ORDER BY Pole.nazwa,DziennikPola.data;
		# koniec zapytania
		t=80,50,50,50,150,150,100,50,80,100
		Zastosowana ilość środka=#0.##
		Powierzchnia działki rolnej=#0.00
		# koniec formatowania liczb

2	Ewidencja zwierząt
	(plik raport-7.sql)
		SELECT
		DziennikStada.data AS "Data",
		Zwierze.nazwa AS "Zwierzę",
		Zwierze.szt AS "Szt",
		TypZdarzenia.nazwa AS "Zdarzenie",
		Przyczyny.nazwa AS "Przyczyna",
		DziennikStada.uwagi AS "Uwagi"
		FROM DziennikStada,Zwierze,GrupyZwierzat,TypZdarzenia, Przyczyny
		WHERE DziennikStada.zwierze=Zwierze.id
		AND Zwierze.grupa=GrupyZwierzat.id
		AND DziennikStada.zdarzenie=TypZdarzenia.id
		AND DziennikStada.przyczyna=Przyczyny.id
		AND DziennikStada.zdarzenie>0
		AND DziennikStada.zdarzenie<5
		ORDER BY Zwierze.id,DziennikStada.data;
		# koniec zapytania
		t=70,100,50,100,100,150
		# koniec formatowania liczb

3	Rejestr zakupów (plik raport-10.sql)	SELECT Zakupy.data AS "Data zakupu", Produkt.nazwa AS "Produkt", Zakupy.ile AS "Ilość", Jednostka.nazwa AS "produktu", Zakupy.cena AS "cena", Typeko.nazwa

Item	*Title of a table*	*Code included in a file*

		AS "Status eko",
		Firma.nazwa AS "Firma", Zakupy.uwagi AS "Uwagi"
		FROM Zakupy,Produkt,Jednostka,Firma,Typeko
		WHERE Produkt.id=Zakupy.produkt
		AND Produkt.jed=Jednostka.id AND Zakupy.firma=Firma.id
		AND Zakupy.typeko=Typeko.id AND Zakupy.typ=1
		UNION
		SELECT DziennikStada.data AS "Data zakupu",
		Produkt.nazwa AS "Produkt", DziennikStada.ile AS "Ilość",
		Jednostka.nazwa AS "produktu",
		DziennikStada.cena AS "cena", Typeko.nazwa AS "Status eko",
		Firma.nazwa AS "Firma",
		DziennikStada.uwagi AS "Uwagi"
		FROM DziennikStada,Produkt,Jednostka,Firma,Typeko
		WHERE Produkt.id=DziennikStada.produkt
		AND Produkt.jed=Jednostka.id AND DziennikStada.firma=Firma.id
		AND DziennikStada.typeko=Typeko.id AND
		DziennikStada.zdarzenie=4
		ORDER BY 1;
		# koniec zapytania
		t=80,100,50,50,80,150,150
		Ilość=#0.##
		# koniec formatowania liczb

For Gekko application program, a format of files was designed, where non-standard analyses will be defined. Table 1 presents the content of exemplary batch files added to Gekko software. Information included in the file, which defines a non-standard table includes a SQL question, columns size in a table and a manner of formatting of numbers. According to the above information, in order to create own table, knowledge of SQL language and the structure of data bases is required, in particular, names of tables, relations and names of particular fields. This last information may be read out from a present scheme of a data base of Gekko software. Following information in a line starting with "t=" determine the size of subsequent columns in the table. If these numbers are not provided, columns will have a standard size (in such case, a table may be not be clear enough). Since, some real numbers determining selected columns require proper formulation, it may be done in the following lines of a file. SQL question defined in the batch file is processed to the moment a line beginning with # sign occurs.

Manner of processing a non-standard report

In the moment of starting Gekko software, from the file "raporty.dat" names of non-standard tables are collected. Then, each table has an ordinal number ascribed and simultaneously the file name with a definition of the report. Non-standard reports are started after a proper bookmark is selected in the programme. Upon indication of an appropriate report (selection from the drop-down list box) the software loads a proper batch file with a report definition (such file must be available in the catalogue with the program libraries). After loading the content of the file to the program, its subsequent lines are analysed and processed. The first part means the SQL question, which determines the table content and its headings. Still, the width of columns and a proper numbers format in the selected columns are determined. Upon a correct processing of data, the content of a table is shown in the program window.

It must be emphasised here, that the program has many security protections which improve its stability. However, implementation of the possibility of "programming" the reports by the user may destabilize the application in case an incorrect batch file is designed. Although, it is a significant danger, it was accepted that advantages obtained from the possibility of defining new program expansions, which may occur in relation thereto. As a consequence, the user may increase the possibility of application but it should do it consciously with the use of his own knowledge or using the verified sources.

Conclusions

Frequent change of provisions and requirements concerning reporting by farmers who own organic farms, enforces constant adjustment of computer software which supports management of a farm. It also concerns Gekko software, which supports reporting in organic farms. Authors, try to predict directions of incoming changes in legislature, however, they can not determine in full, which requirements will exist in future. In order to prevent software from being outdated in future years, a scope of data, which may be collected there, was determined. This scope is wider than present needs, although entering all data is not required from the user. Since, it was assumed that respectively a big number of data will be in the base of the programme, the use of them was enabled by formation of own analyses and reports. Those lists may be defined in such a manner that they enable placing results of calculations in tables, not predicted in the basic version of the application program. It will also create a possibility of grouping data in a different manner than the previous one. Therefore, one may say that it gives a possibility of considerable increase of functionality of Gekko software and also will enable in future adjusting the software to new requirements without necessity of developing its new versions.

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ANALIZA DANYCH GOSPODARSTW EKOLOGICZNYCH Z WYKORZYSTANIEM RAPORTÓW NIESTANDARDOWYCH W PROGRAMIE GEKKO

Streszczenie. Program Gekko przeznaczony jest do prowadzenia w gospodarstwach ekologicznych sprawozdawczości wymaganej przez instytucje nadzorujące. Program umożliwia gromadzenie w swojej bazie, danych wymaganych od rolnika, a także informacji dodatkowych. Na podstawie tych danych generowane są w programie raporty i zestawienia. Jednak poza standardowymi zestawieniami, program umożliwia programowanie przez użytkownika własnych obliczeń. Te obliczenia umożliwiają wygenerowanie zestawień nieprzewidzianych w standardowej wersji oprogramowania. Program Gekko opracowany został w ramach projektu NCBiR Nr NR12-0165-10 pt.: „Innowacyjne oddziaływanie techniki i technologii oraz informatycznego wspomagania zarządzania na efektywność produkcji w gospodarstwach ekologicznych".

Słowa kluczowe: program komputerowy, gospodarstwo ekologiczne, sprawozdawczość, język SQL

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ANALYSIS OF THE SIZE OF DUST PARTICLES WHICH WERE FORMED DURING PELLET PRODUCTION

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ABSTRACT

The objective of the paper was to analyse by means a laser diffraction method, the granulometric composition of dust which settled on various surfaces of factory floors, where pellet was produced. A laser analyser of the size of particles MASTERSIZER 2000 was used in the research. Based on the research, it was found out that the sample of dust contained a limited amount of fractions particularly dangerous for health, i.e. PM_4 and PM_{10} respectively 1.4% and 5.1%. The content of particles of dimension up to 100 μm did not exceed 60% of total volume of the analysed dust. Moreover, a shape of particles was analysed with the use of optic and scanning microscope and NIS – Elements BR software. Values of shape coefficients and histograms of their distribution were determined. Furthermore, relations between the size of particles and its shape were described.

Introduction

Dust is one of the main hazardous factors occurring in the work environment and causes many illnesses including pneumoconiosis and cancer (Koradecka, 1999; GUS, 2013). Pursuant to the Labour Code (Labour Code, Chapter 10) professional risk resulting from hazardous effect of dust should be limited. Inter alia, it should be carried out by encapsulation of production processes, which are the main sources of dust emission and the use of group or individual personal protection equipment (Koradecka, 1999). According to PN-N-18002:2000 a low professional risk is admissible, when the value of the exposition index is $W \leq 0.5$ NDS – values of the highest admissible concentration of dust.

Influence of dust on human body is a resultant of the hardness of the performed physical work, concentration of dust, dimensions and the shape of fraction, their chemical composition and crystal structure as well as solubility in body fluids. Particularly hazardous is a fraction of a respirable dust determined as Particulate Matter, $PM_{2,5}$ – (Konieczyński, 2010) or PM_4 (Ordinance of the minister of labour and social politics of 29th November 2002) – which constitutes a collection of fractions which settle in air sacs. In case of PM_4 average value of an aerodynamic diameter of particles is 3.5 ± 0.3 μm. Also thoracic fraction of PM_{10} of an aerodynamic diameter of inhaled grains smaller than 10 μm, which may reach upper respiratory track and lungs (Konieczyński, 2010; PN-EN 482:1998). Acc. to a nomogram presented in the report (NEPSI) for a particle of an aerodynamic diameter of 4 μm there is 50% of chances that it will penetrate the region of air sacks and only 1.3% that a particle of 10 μm will penetrate through. According to this nomogram, among all particles which are in the air of dimensions ≤100 μm only 50% of them may get to a respiratory track.

Some of technological processes related to agricultural production are characterized with very intense emission of dust. Especially during harvesting and threshing, the concentration of dust may exceed 40 $mg \cdot m^{-3}$. It many times exceeds admissible concentration (Ordinance of the minister of labour and social politics of 29th November 2002). Constant exposure on organic dust activity results in toxic syndrome which is specific for this professional group (Dutkiewicz, 2006).

Production of pellets and briquettes especially from straw brings the same risks as dustiness which occurs in some works in agriculture (Maciejewska, et al., 1997). It particularly refers to small establishments which produce biofuels from solid biomass, in which encapsulation of production processes is less effective and fan systems functioning is weakened. No systematic removal of dust deposited on the surface of production halls favours concentration of dust in the air. Then, a professional risk and the risk of explosion or ignition of dust increases (Sawicki, 2003).

Concentration of dust in the work environment is determined with weight by reference to the mass of dust deposited on measurement filters to measurement fractions of dust particles which deposit in various fragments of a human respiratory track. In Poland, for determination of the content of a total dust PN-91/Z-04030/05 applies, whereas for respiratory dust PN-91/Z-04030/06. Dust measuring equipment and devices based on cascade impactor operation are used for measurement (Konieczyński, 2010).

As alternative for direct measurement of dust concentration, a method based on the analysis of the amount and the size of dust particles on surfaces of production halls was suggested. It was assumed that in the condition of saturation of air with volatile fractions which are in the air and dust which deposited on surfaces are similar.

The objective of this article is determination of the content of fractions, particularly dangerous for health, the so called fractions PM_4 and PM_{10} in dust deposited on the surfaces of production halls and determination of properties which characterize the shape of given particles.

Methodology

Determination of the PM_4 fraction content and PM_{10} was carried out through an analysis of results of the distribution of the size of particles of the tested sample at the laser analyser of the size of particles. The applied analyser by MALVERN Company, model MASTERIZER 2000 with an attachment SIROCCO 2000 enables the measurement within 20 nanometers up to 2 milimeters. Mastersizer device records distribution of the volume of particles and then calculating into the volumes of equivalent balls determines their diameters. The method for description of the sizes of a particle was described in the British Standard BS 2955.

The object of the research were samples of dust collected from three selected producers of pellet manufactured from the mixture of sawdust of hardwood and softwood as well as straw. In the shop floor of each company, samples of approx. 10 g of dust settled on various surfaces was collected from three spots located approximately 2 m from the source of dusting. Samples have been initially purified and sieved through a sieve of 0.25 mm meshes. For each sample, triple measurement of the size of particles was carried out at the assumed value of the residual error at the level of 1% and then the results of analysis were averaged and presented in the form of a histogram.

Moreover, properties which characterise their shape were analysed by means of measurement of specific particles. For this purpose the following microscopes were used: optic stereoscopic Nikon SMZ 1500 and a scanning microscope EVO LS 15 f. Zeiss. The obtained images were subjected to analysis with the use of software NIS-Elements BR. For each particle the following were measured: *A* – Area; *P* – Perimeter. Then, values of the following shape indices were calculated:

d_z – hydraulic diameter (Eqdia), diameter of a circle of the surface area equal to the object area

$$d_z = \left(\frac{4 \cdot A}{\Pi} \right)^{0,5} \tag{1}$$

w_K – circularity index (Circularity)

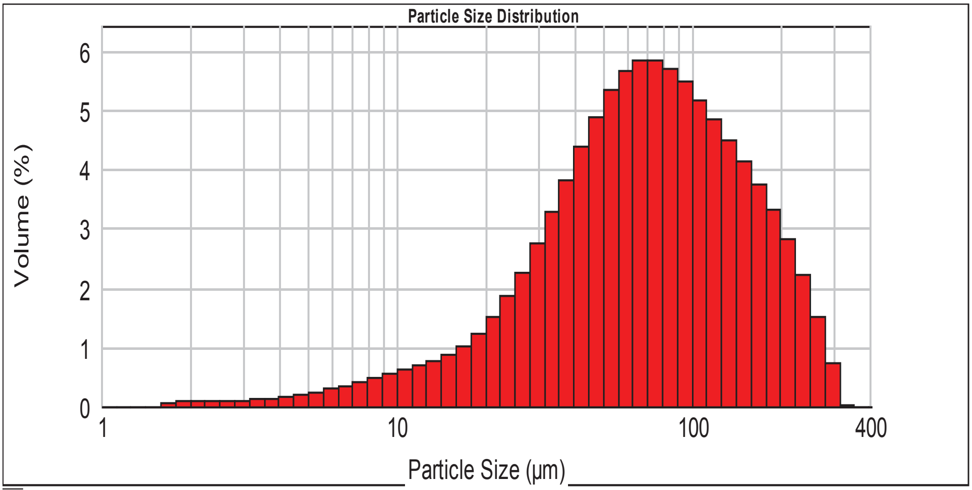
$$w_K = \frac{4 \cdot A \cdot \Pi}{P^2} \tag{2}$$

Values of the circularity index w_K were grouped according to ranges and then densities of number corresponding to them were determined. Moreover, values of the hydraulic diameters d_z corresponding to the particles assigned to a specific group of values w_K. were grouped Results were statistically analysed.

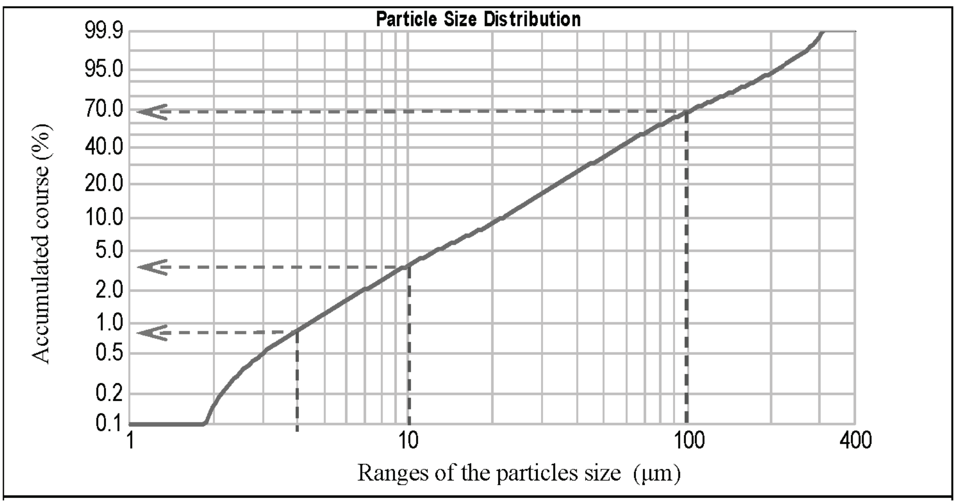
Results

Figure 1 presents exemplary results of the analysis of the distribution of sizes of dust particles, where at the cumulative curve, border interests of the volume of PM_4, PM_{10}, PM_{100} fractions were determined. Results of this determination carried out for 9 samples were listed in table 1.

Figure 2 presents a microscope image of the dust particles and the manner of their dimensioning. Results of measurements of the surface area *A* and the perimeter *P* was carried out for at least 300 particles and was listed in figure 3. Results of grouping the number of particles acc. to a range of values of the circularity index w_K were presented in figure 4. According to the value of this coefficient also values of hydraulic diameter d_z were grouped and the results were presented in figure 5.



a)



b)

Figure 1. Exemplary results of analysis of the particles size distribution, a) histogram of the distribution of classes of particles size; b) accumulated course, where axis y according to Rosin-Rammler scale

Table 1
Volumetric participations designated for border values of fractionsPM$_4$, PM$_{10}$, PM$_{100}$

No of a sample	Volumetric participation for fraction, (%)		
	PM$_4$	PM$_{10}$	PM$_{100}$
1	1.2	4.4	57.2
2	1.6	5.2	63
3	1.4	5	61.2
4	1.2	5.3	55
5	2.2	5.9	69.8
6	2.2	6.1	70
7	1.2	5.7	61.8
8	0.8	4.8	52.6
9	0.6	3.8	50
Average	1.4	5.1	60.1
Standard deviation, SD	±0,55	±0,73	±7,0
Coefficient V, (%)	40	14.3	11.7

Average value of respirable fraction PM$_4$ is 1.4%; of thoracic fraction PM$_{10}$ – 5.1% and a fraction to 100 μm – 60%. High value of index V for a fraction PM$_4$ proving considerable diversification of the content of this fraction in particular samples of dust is significant.

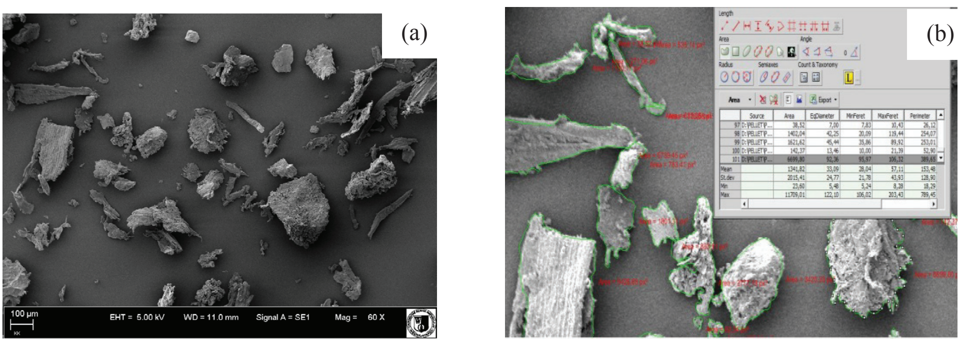


Figure 2. Image of dust particles: a – photo from a scanning microscope, 60x; b – manner of particles determination and their dimensioning

Analysis of the image of dust particles proves that their size and shapes are varied. Very small particles, of a hydraulic diameter d_z of 10 μm have regular shapes, considerably bigger particles d_z of 100 μm are very irregular.

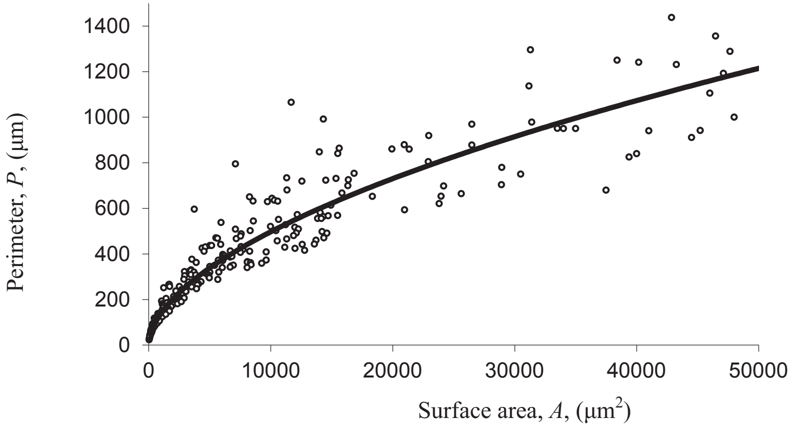


Figure 3. The list of results of measurements, A – Area, P – Perimeter

Relation between the values of particles perimeter *P* and its area *A* may be described with the following equation:

$$P = 3 \cdot A^{0,555}, R^2 = 0.966 \tag{3}$$

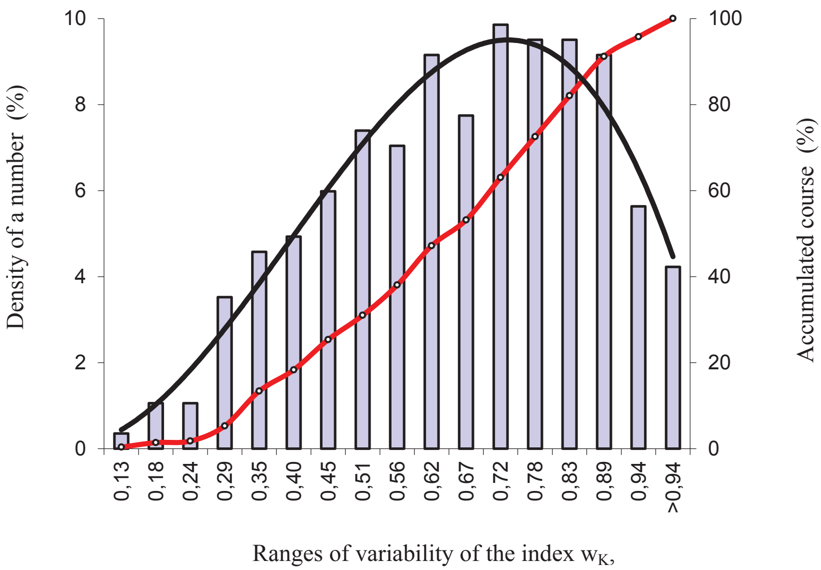


Figure 4. The list of statistical analysis results: histogram of the distribution of ranges of variability of the circularity coefficient w_K *and the accumulated course*

From the analysis of figure 4 follows that a modal value of the circularity index is value 0.72 and that 62% of all particles are within the value of this index 0.56–0.89. Values $w_K = 0.89$ and 0.56 are equivalent for an ellipse of the proportion of the length of the long semi-axis to a short one respectively 1.5:1 and 4:1. For ca. 5% of particles a very elongated shape of ellipse is characteristic.

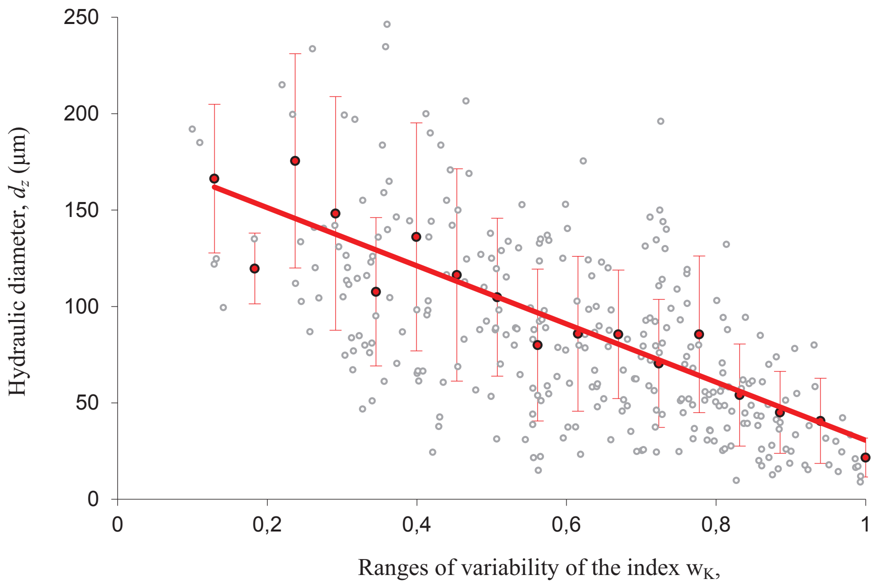


Figure 5. Relation between values of the hydraulic diameter d_z and the circularity coefficient w_K

Analysis of figure 5 shows that there is a correlation between the shape of a particle and its size. The smaller particles have more rounded shape. Relation between values of the hydraulic diameter d_z and the circularity index w_K may be described with an empirical coefficient:

$$d_z = -150.8 \cdot w_K + 181.1 \quad R^2 = 0.878 \tag{4}$$

Conclusions

1. Analysis of samples of dust collected from the surface of shop floors, where pellet was produced shows that the average content of respiratory fraction PM_4 is 1.4% and thoracic fraction PM_{10} – 5.1%. It was determined that 60% of total volume of the analysed dust comprises of a fraction of diameters up to 100 μm. Possibly a half of this amount may be inhaled so 30% of the dust settled on various surfaces of shop floors creates risk.

2. High value of the coefficient of variability V referred to PM_4 proves significant variability of the content of this fraction in particular samples. In case of the remaining fractions, for which $V < 15\%$, the content of particles of dimensions > 4 µm in particular samples was similar.
3. The shape of particles is correlated with their size. The smaller particles are the more regular and rounded they are. For big particles their considerably extended shape of an expanded area is characteristic.

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ANALIZA WIELKOŚCI CZĄSTEK PYŁU POWSTAŁEGO W PRODUKCJI PELETU

Streszczenie. Celem pracy była analiza metodą dyfrakcji laserowej składu granulometrycznego pyłów osiadłych na różnych powierzchniach hal, w których produkowano pelet. W badaniach wykorzystano laserowy analizator wielkości cząstek model MASTERSIZER 2000. Na podstawie badań stwierdzono, że próbki pyłu zawierały ograniczone ilości frakcji szczególnie niebezpiecznych dla zdrowia, tj. PM4 oraz PM10 odpowiednio 1,4% oraz 5,1%. Zawartość cząstek o wymiarach do 100 μm nie przekraczała 60% ogólnej objętości analizowanego pyłu. Analizowano również kształt cząstek z wykorzystaniem mikroskopu optycznego i skaningowego oraz oprogramowania NIS-Elements BR. Wyznaczono wartości współczynników kształtu oraz określono histogramy ich rozkładu. Określono również zależności zachodzące pomiędzy rozmiarem cząstek a jej kształtem.

Słowa kluczowe: pyły, frakcje, rozkład wielkości

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VARIABILITY AND CORRELATION OF THE SELECTED PHYSICAL PROPERTIES OF PUMPKIN SEED (*CUCURBITA PEPO L.*)

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ABSTRACT

Basic dimensions (length, width and thickness), critical velocity of transporting seeds, sliding friction angle and the mass of pumpkin seeds, obtained from four fruit of various mass were determined. Based on the measurements, volume and thickness of each seed and its spherical index were calculated. Interdependence between the tested properties and indexes was evaluated based on the test for independent samples, analyses of variance, correlation and regression. It was found that the seeds mass is the most variable property and their length is the least variable. Empty and full pumpkin seeds should be separated with a pneumatic separator, where a vertical air stream of velocity approx. 5 $m \cdot s^{-1}$ is a separating element. Length and mass of seeds may be used at separation of seed material into quality fractions. As a result of separating the smallest seed fraction, a seed material may be obtained in which after the process of removing the fruit-seed coat, 95% of ripe seeds will be available.

The list of symbols:

k	– seeds volume index,
K_m, K_w	– spherical indexes of a seed,
m_n, m_p	– seed mass without fruit-seed coat and seed mass (g),
S	– standard deviation of a property,
T, W, L	– thickness, width and length of a seed (mm),
v	– critical velocity of transporting seeds ($m \cdot s^{-1}$),
V	– volume of a seed (cm^3),
V_p	– total volume of seeds in a sample (cm^3),
V_s	– coefficient of the feature variability (%),
x, x_{max}, x_{min}	– average, maximum and minimum value of the feature,
γ	– sliding friction angle of a seed on steel (°),
ρ	– density of a seed ($g \cdot cm^{-3}$).

Introduction and the objective of the paper

Cucurbita pepo is an annual plant, which belongs to the cucurbitales family. It was brought to Europe in the 16th century by Spanish along with the conquest of the Middle America. On account of the dimensions it achieves and edible pulp and seeds, is has been cultivated for many years as a vegetable and a fodder plant. A pumpkin is a stenthermal plant, which needs big amount of water during the entire vegetation period. Fertile soils, which are heated is a short time, with a neutral reaction, permeable to air with a limited tendency for fast crusting are the most recommended for cultivation (*Polowa*... 2000; *Rośliny*... 2010).

The pumpkin fruit is a big, round, pear-shaped, cylindrical or disc-shaped berry, hard outside, filled with a pulp, with seeds inside. A fruit may also be a decoration after hollowing out and is frequently used for Halloween. The pulp of pumpkin is a dietary product, which is the most frequently used as an addition to salads or meat and sometimes processed into jam. Pumpkin flowers are used for preparing tasty salads (Dedilo, 1992; Sojak, 1999; Sacilik, 2007; Balkaya et al., 2010; *Rośliny*... 2010; Jacobo-Valenzuela et al., 2011; Nawirska-Olszańska, 2011).

Pumpkin fruit grown for seeds have to reach full maturity, which is necessary for seeds to have appropriate aroma and taste (*Rośliny*... 2010; Sosińska and Panasiewicz, 2012).

Currently, seeds for industrial scale are obtained with specialist combine harvesters, equipped with a characteristic pick-up assembly with studs. Seeds taken out of fruit after harvesting must be dried out (Can, 2007; Sacilik, 2007).

During the processes of obtaining seeds, their cleaning, sorting, transport, processing and sowing, knowledge on the the scope of variability of physical properties of the processed seed material and interdependencies occurring between those properties is necessary. It allows planning and controlling the above processes and gives a possibility of selecting parameters to functioning of devices and machines.

The objective of the paper is determination of the scope of variability of the selected physical properties of seeds of cucurbita pepo and interdependencies occurring between them on account of using those data during division of the material into quality classes.

Material and methods

Seeds of cucurbita pepo of Danka Polka cultivar constituted a research material. Seeds were obtained manually from 4 randomly selected ripe pumpkin seeds, which come from crops of 2011 from a plantation located in Bystrzyce (lubelski province) – 51.31°N and 22.70ºE. Mass of pumpkin fruit was: 4.0; 4.3; 6.3 and 7.6 kg. All seeds were taken out of fruit and then placed in a dry, air permissible place on paper towels in a manner which did not allow their touching each other. After 7 days of drying, 300 seeds were selected from each sample, basing on an alternative method (Greń, 1984).

Critical velocity of transporting seeds was determined with the use of a pneumatic classifier of Petkus company type K-293 with precision to 0.11 $m \cdot s^{-1}$. Measurements were taken according to the method described in the paper written by Kaliniewicz and Trojanowski (2011).

Measurements of 3 basic dimensions of seeds with the use of electronic calliper with precision to 0.01 mm were carried out. Sliding friction angle was determined on the inclined plane of a regulated inclination angle with a friction plane made of steel sheet (GPS – *Ra*=0.46 µm). Each seed was placed along a longitudinal axis in parallel to the inclination of a plane, and the value of sliding friction angle was read out from a protractor with precision up to 1º.

Mass of pumpkin seeds and seeds following a manual removal of a fruit-seed coat was read out from the laboratory scale WAA 100/C/2 with precision up to 0.1 mg.

At determination of the shape of seeds, spherical indexes were calculated from patterns (Grochowicz, 1994):

$$K_m = \frac{W}{L} \tag{1}$$

$$K_w = \frac{T}{L} \tag{2}$$

Volume *V* of each seed was determined according to the following relation:

$$V = k \cdot T \cdot W \cdot L \tag{3}$$

where coefficient of the seeds volume *k* was determined by means of experiment based on the measurement of length, width and thickness of 100 randomly selected seeds from material, which remained after preparing research samples. Seeds were located in a graduated cylinder of 250 cm^3 volume (half-filled with water) and they were immersed with a piece of a sieve mounted on the rod. Based on the determined volume and dimensions an average value of the volumetric coefficient was calculated from the formula:

$$k = \frac{V_p}{\sum T \cdot W \cdot L} \tag{4}$$

Finally, volume of each pumpkin seed was calculated from the relation:

$$V = 0.539 \cdot T \cdot W \cdot L \tag{5}$$

Density ρ of seeds was determined from the pattern:

$$\rho = \frac{m}{V} \tag{6}$$

Results of measurements and calculations were prepared statistically with the use of Statistica programme (version 10) using generally known statistical procedures, such as test t for independent samples, analysis of one-factor variance, correlation analysis and analysis of linear regression (Rabiej, 2012). Calculations were carried out at the level of significance of 0.05.

Separation indexes of mixture of empty and full pumpkin seeds were determined from the formula (Rawa and Semczyszyn, 1988):

$$\delta = \left| \frac{x_1 - x_2}{3(S_1 + S_2)} \right| \tag{7}$$

where indexes 1 and 2 at symbols mean average value and standard deviation of a given physical property respectively of full an empty seeds.

Results and Discussion

Characteristic of physical properties of pumpkin seeds from particular batches was presented in Table 1. The highest values of coefficient of variability were reported for the mass of seeds and the lowest for their length. Generally, one may state that the analysed physical properties of seeds change in the following scopes:
- critical velocity of distribution – from 3.03 to 7.98 m·s^{-1},
- thickness – from 1.83 to 5.04 mm,
- width – from 9.57 to 16.98 mm,
- length – from 16.06 to 27.10 mm,
- sliding friction angle – from 14 to 42°,
- mass – from 0.0350 to 0.5254 g.

Table 1
Statistical parameters of distribution of physical properties of pumpkin seeds

Seeds batch	Physical property	x_{min}	x_{max}	x	S	V_s
D-4.0	v	3.03	7.98	6.96^a	0.795	11.42
	T	2.30	4.62	3.33^b	0.307	9.21
	W	9.57	14.35	12.25^d	0.798	6.51
	L	16.06	23.64	18.75^d	1.065	5.68
	γ	16	32	21.6^c	2.769	12.80
	m_p	0.0444	0.3680	0.236^d	0.041	17.51
D-4.3	v	3.03	7.98	6.71^b	0.908	13.52
	T	1.83	3.72	2.76^d	0.302	10.93
	W	10.14	14.07	12.63^c	0.656	5.20
	L	17.77	24.26	21.43^c	1.109	5.17
	γ	18	42	23.0^b	3.740	16.26
	m_p	0.0351	0.3803	0.269^c	0.049	18.13
D-6.3	v	3.03	7.43	6.12^c	1.380	22.54
	T	1.85	4.45	3.11^c	0.372	11.96
	W	10.90	15.89	13.50^b	0.775	5.74
	L	20.61	27.10	23.66^b	0.940	3.97
	γ	19	40	26.5^a	3.656	13.81
	m_p	0.0350	0.4115	0.297^b	0.091	30.68
D-7.6	v	3.03	7.43	6.61^b	0.892	13.50
	T	2.20	5.04	3.53^a	0.361	10.23
	W	11.01	16.98	14.83^a	0.820	5.53
	L	20.92	26.33	24.09^a	0.912	3.78
	γ	14	32	21.2^c	3.108	14.65
	m_p	0.0963	0.5254	0.368^a	0.066	17.89

a, b, c – different letters refer to statistically significant differences between seeds batches

Analysed seeds on account of dimensions and mass are higher than the ones investigated by Joshi et al. (1993).

Spread of the investigated physical properties of pumpkin seeds is slightly higher than the data presented by Ebrahimzadeh et al. (2013), and lower than the results of Milani et al. (2007). The investigated seeds are bigger than the dimensions and mass of seeds of *cucurbita moschata* (Balkaya et al., 2010; Jocobo-Valenzuela, 2011), *Citrullus colocynthis* (Abu Shieshaa et al., 2007; Bande et al., 2012) and calabash (Pradhan et al., 2013) and comparable with mixtures of *cucurbita moschata* and *cucurbita maxima* (Karaağaç and Balkaya, 2013). Moreover, their size on account of thickness is comparable with watermelon seeds (Seyed et al., 2006; Koocheki et al., 2007) and seeds of the selected grains cultivars (Hebda and Micek, 2005; 2007).

Average values of a given property for particular batches of seeds in majority of cases differ from each other. It was reported that along with the increase of the mass of pumpkin fruit, also average width, length and mass of seeds increases.

Statistical parameters of volume, density and spherical indexes of seeds were presented in Table 2. The lowest value of the coefficient of variability was reported for coefficient K_m. It is within 4.68 to 5.86%. The highest value of the coefficient of variability was reported for the density of seeds from batch D-6.3 (30.56%). When generalizing, one may notice that the analysed indexes of pumpkin seeds are within the following ranges:

– spherical coefficient K_m – 0.440÷0.790,
– spherical coefficient K_w – 0.087÷0.256,
– volume – 0.209÷1.051 cm^3,
– density – 0.120÷1.052 $g \cdot cm^{-3}$.

Table 2
Statistical parameters of distributions of calculated indexes of pumpkin seeds

Seeds batch	Index	x_{min}	x_{max}	x	S	V_s
D-4.0	K_m	0.534	0.790	0.654^a	0.037	5.60
	K_w	0.127	0.256	0.178^a	0.017	9.31
	V	0.224	0.638	0.415^c	0.066	15.97
	ρ	0.124	0.816	0.572^b	0.085	14.78
D-4.3	K_m	0.440	0.686	0.590^c	0.033	5.60
	K_w	0.087	0.184	0.129^d	0.014	11.15
	V	0.209	0.618	0.404^c	0.063	15.61
	ρ	0.150	1.052	0.671^a	0.116	17.34
D-6.3	K_m	0.497	0.647	0.570^d	0.027	4.68
	K_w	0.087	0.186	0.132^c	0.015	11.53
	V	0.248	0.836	0.539^b	0.093	17.31
	ρ	0.141	1.011	0.553^{bc}	0.169	30.56
D-7.6	K_m	0.490	0.778	0.616^b	0.036	5.86
	K_w	0.089	0.220	0.147^b	0.016	10.57
	V	0.341	1.051	0.682^a	0.094	13.73
	ρ	0.120	0.968	0.549^c	0.120	21.92

a, b, c – different letters refer to statistically significant differences between seeds batches

Spread of the value of shape indexes is in accordance with data obtained by Joshi et al. (1993). It also corresponds to the range of changes of the above indexes for seeds of *cucurbita moschata* (Balkaya et al., 2010), *citrullus colocynthis* (Abu Shieshaa et al., 2007) and calabash (Pradhan et al., 2013).

Based on the t test for independent tests (Table 1) it was found that empty and full seeds of cucurbita pepo differ statistically significantly on account of the critical velocity of transportation, thickness, length, sliding friction angle, mass, spherical and density indexes. Statistically significant differences between empty and full seeds were not reported only for their width and volume. On account of proportionally big disproportion of average values of critical velocity of transportation and density of full and empty seeds, the above properties should be treated as possible separative features.

Results of calculations of the separation index of the mixture of full and empty seeds confirms the above (table 3). As it shows, the analysed index assumes very high values for the critical velocity of transportation and density of seeds. Sorting data on account of critical velocity of transportation of seeds proved that at the use of a division border at the level of 5 $m \cdot s^{-1}$ full and empty seeds may be divided almost in 100%. On account of the simplicity of performance of the above separation process for separation of empty seeds from the seed material, it is recommended to use a pneumatic sorter.

Table 3

Average value and standard deviation of physical properties and the separation index δ of empty and full pumpkin seeds

Physical property/index	Empty seeds		Full seeds		δ
	x	S	x	S	
v	3.27[b]	0.476	6.84[a]	0.577	1.132
T	2.78[b]	0.558	3.21[a]	0.418	0.147
W	13.55[a]	1.056	13.28[a]	1.263	0.038
L	23.38[a]	2.199	21.88[b]	2.330	0.111
γ	28.5[a]	4.794	22.7[b]	3.550	0.233
m_p	0.1000[b]	0.038	0.3065[a]	0.064	0.677
K_m	0.580[b]	0.038	0.610[a]	0.046	0.118
K_w	0.119[b]	0.026	0.148[a]	0.024	0.197
V	0.483[a]	0.141	0.512[a]	0.138	0.034
ρ	0.206[b]	0.047	0.614[a]	0.091	0.988

Results of linear correlation analysis corresponding to physical properties of full pumpkin seeds, were presented in Table 4. Critical value of the coefficient of correlation is exceeded at comparing it with a decisive majority of properties. Statistically significant correlation was not reported only for critical velocity of transporting seeds and their thickness, spherical index K_m and mass of seeds with a removed fruit-seeds cover and moreover for the mass of seeds and their sliding friction angle as well as density and for the volume of seeds and their spherical index. The mass of seeds and their length is the most correlated with the mass of seeds without the cover. Coefficient of linear correlation for those couples of properties is respectively 0.757 and 0.735. Joshi et al. reported a very similar value of correlation coefficient between the length of seeds and the mass of seeds with removed fruit-seeds cover (1993). With reference to the mass of seeds and the mass of seeds without a cover, they obtained decisively higher value of the coefficient of correlation, which was 0.96.

Table 4

Pearson's coefficients of correlation between properties and calculated indexes of seeds and seeds without fruit-seed coat

Physical property/index	T	W	L	γ	m_p	K_m	K_w	V	ρ	m_n
v	0.049	-0.230	-0.228	-0.131	-0.064	0.057	0.212	-0.156	0.141	-0.047
T	1	0.452	0.210	-0.197	0.376	0.279	0.686	0.738	-0.776	0.091
W		1	0.745	-0.061	0.799	0.170	-0.174	0.885	-0.427	0.578
L			1	0.143	0.839	-0.528	-0.562	0.769	-0.163	0.735
γ				1	0.041	-0.276	-0.264	-0.078	0.159	0.128
m_p					1	-0.218	-0.302	0.802	-0.049	0.757
K_m						1	0.623	-0.006	-0.311	-0.347
K_w							1	0.047	-0.535	-0.468
V								1	-0.605	0.538
ρ									1	0.114

Critical value of correlation coefficient 0.059

Equations of one variable describing physical properties of seeds and mass of seeds with a removed fruit-seeds coat, for which coefficient of determination is higher than 0.3 were presented in Table 5. As it shows, significant relations occur between such properties as: thickness of seeds, their width and mass as well as mass of seeds without a coat. On account of high value of the coefficient of determination all provided equations may be used at converting some properties into another. Such situation may take place at planning e.g. the processes of cleaning and sorting seeds, where the knowledge of a given property is necessary and on account of the lack of test equipment, a measurement of a completely different property which is properly correlated therewith, is possible. Among the presented equations the highest coefficient of determination (0.704) was obtained for relation of length and the mass of seeds. It corresponds to the results obtained with the use of the analysis of correlation.

Later, it was decided to check whether seeds can be divided according to a specific physical property and whether a levelling of the mass of seeds without a coat can be obtained, as a result of which the seed material will be divided into quality classes of a different market value (e.g. for ripe seeds following removal of fruit-seeds coat – a higher price). It was decided to represent (fig. 1) distribution of the mass of seeds without the coat from 3 fractions of seeds (of almost the same quantity share) for physical properties which are the most correlated with it: the mass of seeds, their length and width. As one can see, any considered physical property of seeds does not guarantee proper division of the seed material into quality classes. Some levelling of this material may be obtained at the use of length of seeds or their mass as a separating property (their distributions are very similar). Separation of the smallest fraction of seeds on account of their length or mass causes that following the removal of the fruit-seed coat from the group of ripe seeds (m_n>0.19 g) approx. 12-13% of material will be reduced and simultaneously 3-4% of seeds, which are not ripe enough, will be there. In the highest class sowing material separated this way only approx. 5% of weakly ripen seeds will occur, which will constitute as much as 60% of seeds in an average class.

Table 5
Equations of one variable describing physical properties of seeds and seeds without fruit-seed coat

Equation	Coefficient of determination R^2	Standard error of estimation
$W = 0.403\,L + 4.454$	0.554	0.843
$W = 15.846\,m_p + 8.421$	0.638	0.760
$W = 20.646\,m_n + 8.792$	0.334	1.030
$L = 1.374\,W + 3.630$	0.554	1.556
$L = 30.709\,m_p + 12.458$	0.704	1.268
$L = 48.427\,m_n + 11.349$	0.540	1.580
$m_p = 0.040\,W - 0.228$	0.638	0.038
$m_p = 0.023\,L - 0.195$	0.704	0.035
$m_p = 1.362\,m_n - 0.011$	0.573	0.042
$m_n = 0.016\,W + 0.002$	0.334	0.029
$m_n = 0.011\,L - 0.027$	0.540	0.024
$m_n = 0.421\,m_p + 0.088$	0.573	0.023

Conclusions

1. The scope of variability of physical properties of pumpkin seeds was within:critical velocity of transportation – 3.03-7.98 $m\cdot s^{-1}$, thickness – 1.83-5.04 mm, width – 9.57-16.98 mm, length – 16.06-27.10 mm, sliding friction angle – 14-42º and mass – 0.0350-0.5254 g.
2. Physical properties, which are the most correlated with each other, are as follows: width, length and the mass of seeds and the mass of seeds without the fruit-seed coat. The introduced equations are characterized with a relatively high coefficient of determination, thus it may be successfully used at converting some properties into another.
3. Empty and full pumpkin seeds differ statistically significantly on account of the critical velocity of transportation, thickness, sliding friction angle, mass, coefficient of shape and density. On account of the simplicity of the execution of the process, the use of pneumatic separator for their separation is suggested. Setting the air stream velocity at the level of 5 $m\cdot s^{-1}$ guarantees almost 100% efficiency of separating empty seeds from sowing material.
4. Length and mass of seeds may be used at separation of seed material into quality classes. Separation of the smallest fraction of seeds allows obtaining more levelled material, where in the highest quality class after the process of removal of the fruit-seed coat, there will be as much as 95% of ripe seeds.

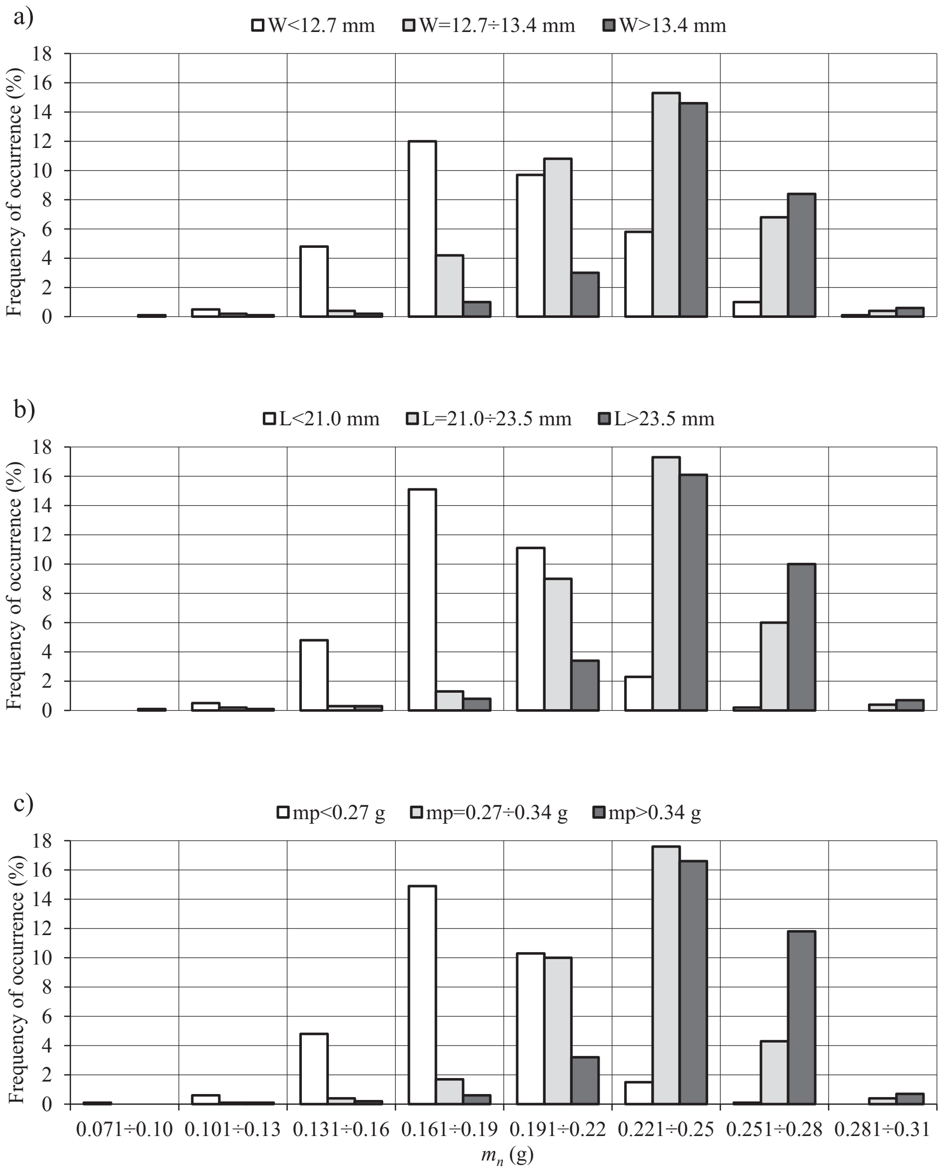

Figure 1. Histograms of mass distribution of seeds without fruit-seed coat for 3 fractions: a – seeds width, b – seeds length, c – seeds mass

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ZMIENNOŚCI I KORELACJA WYBRANYCH CECH FIZYCZNYCH PESTEK DYNI ZWYCZAJNEJ (*CUCURBITA PEPO L.*)

Streszczenie. Określono podstawowe wymiary (długość, szerokość i grubość), prędkość krytyczną unoszenia, kąt tarcia poślizgowego i masę pestek dyni zwyczajnej, pozyskanych z czterech owoców o różnej masie. Na podstawie pomiarów obliczono objętość i gęstość każdej pestki oraz jej wskaźniki sferyczności. Współzależność między badanymi cechami i wskaźnikami oceniono na podstawie testu t dla prób niezależnych, analizy wariancji, korelacji i regresji. Stwierdzono, że cechą fizyczną o największej zmienności jest masa pestek, a o najmniejszej – ich długość. Puste i pełne pestki dyni najlepiej jest rozdzielać za pomocą separatora pneumatycznego, gdzie elementem rozdzielczym jest pionowy strumienia powietrza o prędkości ok. 5 $m \cdot s^{-1}$. Przy rozdzielaniu materiału nasiennego na frakcje jakościowe można wykorzystać jako cechę rozdzielczą długość lub masę pestek. W wyniku oddzielania najmniejszej frakcji pestek można uzyskać materiał nasienny, w którym po procesie usuwania okrywy owocowo-nasiennej znajdować się będzie ok. 95% nasion dorodnych.

Słowa kluczowe: dynia, nasiona, wydzielanie, cechy fizyczne

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MODEL SOLUTIONS OF DISTRIBUTION LOGISTICS WITH REGARD TO ORGANIC PRODUCTS [1]

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ABSTRACT

The objective of the paper was to present model solutions of distribution logistics with regard to organic products in organic farms. Moreover, size and production structure, as well as participation and structure of commodity production divided into departments was defined. The scope of the paper covered the research in 50 organic farms located in the south of Poland. The study was carried out within the development subsidy No NR 12-0165-10 "Innovative impact of technology and IT support of management on production efficiency in organic farms". Total commodity production in the investigated farms was 6009.73 PLN·ha^{-1} which constituted at the average 69.3% of global production. In the structure of plant commodity production, vegetables, grain seeds and fruit constitute a considerable part and in the animal production it was milk and eggs. It was found out that decisions within the scope of model solutions of distribution of organic products mainly concern the selection of proper distribution channels, organization of physical distribution (marketing logistic) and localization of sale points. Four models of organic products distribution were suggested.

Introduction

Organic farming becomes an interesting subject, both among possible consumers as well as producers - farmers. Reasons for such state of affairs should be searched for not only in more frequent negative assessments of intense methods of agricultural production, but also even higher awareness of consumers and rising level of their requirements towards a product and a producer (Kondratowicz-Pozorska, 2006).

Dynamic development of organic farming in Poland, after EU accession in 2004 gave rise to the need of carrying out research and analysis concerning this branch of agriculture. Getting information on production and economic situation of organic farms and their competitiveness has become crucial, especially because the number of agricultural producers interested in the production with organic methods raises systematically (Kowalska 2010).

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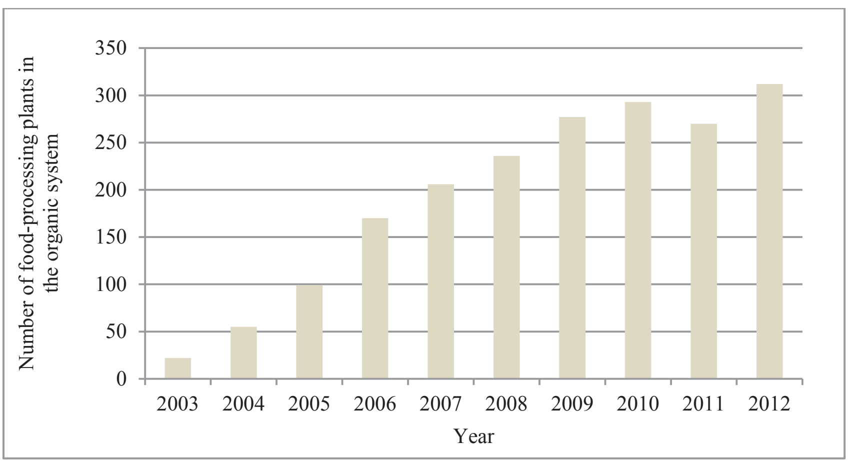
It is estimated that presently organic farming is being developed in approximately 140 countries, whereas the area of organic crops is over 32 mln ha, out of which 1/4 in the European Union countries (Willer and Kichler, 2009). In these countries organic production has been legally based and is subject to support as a part of Common Agricultural Policy of the European Union for many years. The organic food market is characterized there with respectively high demand, wide assortment of the offered products and effective distribution channels. Nevertheless, on the markets of the member states from the Central and East Europe barriers in development occur, especially in the consumption and trade sphere. Thus, there is a need to undertake actions aiming at improvement of distribution and the increase in demand for organic products in these countries (Smoluk-Sikorska, 2010).

Development of organic farming is related to the development of markets of these products. On the part of supply there is a rich assortment of organic products in distributive networks whereas on the part of demand an increasing number of consumers who have high organic awareness can be observed (Komorowska, 2006).

It should be emphasised that in Poland there is no system of suitable organic products distribution and farms which produce this type of food products function more due to subsidies. There are not many enterprises who distribute organic food and the existing ones function only on local, very narrow markets. An outlet of this type of food develops very slowly in Poland, thus entrepreneurs very carefully try on to run businesses within this branch. Development of enterprises which process organic food may be an example. In 2012 number of food processing plants of organic farming products increased three times in comparison to 2004 i.e. from 100 to 312 food processing plants. The highest number of organic food processing plants in 2012 was reported in Mazowieckie Voivodeship (59), Wielkopolskie Voivodeship (42) and Lubelskie Voivodeship (36). Opolskie Voivodeship reported the lowest number of organic food processing plants, that is only 2 plants, in Podlaskie Voivodeship – 5 and Lubuskie Voivodeship – 6.



Source: Raport o stanie rolnictwa ekologicznego, on-line, 2014

Figure 1. Number of food-processing plants within the system of organic farming in Poland in 2003-2012

Markets of majority of EU countries are more developed in comparison to the Polish market. Therefore, majority of production of Polish farms from the branch is exported. Increase of the presence on the Polish market requires development of demand through appropriate shaping of consumers' as well as salesmen's awareness. In the Central and Eastern Europe countries direct sales is the most significant. There, selected fresh products are offered (Poland, Romania, Bulgaria) and sales networks (Czech Republic, Hungary), where processed products are available (mainly grain and fruit-vegetables products). However, often lack of meat and meat processed products is reported. Generally, on the Central and Eastern Europe countries markets, organic food is characterized with low availability and its assortment is rather limited (Łuczka-Bakuła and Smoluk, 2006; Kovacs and Richter, 2005).

An agricultural producer, in order to successfully participate on the European market, must participate in pro-development activities, i.e. inter alia: active marketing, trainings, education, participation in fairs or implementation of innovative processes. Finally, agricultural producers in Poland, in order to obtain high competitive position on the European market must have, first of all, a wide range of activities which enable constant distribution of their own products, out of which the most important are: the use of active promoting campaigns, increase of the quality of products, development of institutions supporting the sale of products and shaping of specialization of their own farms. Moreover, a farmer must be aware that the consumers' requirements increase incessantly and they are reflected in the increased demand for products with special features and unique recipes (Wojcik, 2012).

Organic food cannot be easily found in usual shops and distribution centres. Indeed, specialist shops with organic food and their networks are established but it takes place only in big cities. However, these activities still are on a scale, which is too small to raise the sales in Poland. Surely, high price of organic products in comparison to traditional food is an obstacle in obtaining wider consumers' interest.

Objective, scope and methodology of work

The objective of the paper was to present model solutions of distribution logistics with regard to organic products in organic farms. The scope of the paper covered the research in 50 organic farms located in the south of Poland. The study was carried out within the development subsidy No NR 12-0165-10 "Innovative impact of technology and IT support of management on efficiency of production in organic farms". The collected information was obtained on the basis of a guided survey carried out with a farm owner and detailed two-year studies. Information concerned 2010/12 and the collected data allowed determination of the size and structure of global and commodity production, sales structure of organic products and characteristic of the distribution process.

Research results

Average area of agricultural land in the researched objects was 12.48 ha and was within 3.32 ha and 31.80 ha. Arable land – 53.6% and permanent grasslands – 36.7% prevailed in the general structure of use. Orchards and perennial plantations occupied the remaining part. Grains dominated in the disposition of crops – over 45.8% and then fodder plants – 34.0%, vegetables and root crops. A marginal participation was in case of herbs because it was only 1.8% of the area. Average overall livestock is 0.65 LSU per 1 ha of agricultural land. It is safe livestock for natural environment and even its tripling would not cause negative effects for the environment.

Organic farms of Małopolska region are characterized with high dispersion according to the agrarian structure. Thus, the production scale per one object is small, and therefore, the size of commodity production is also small and it only can decide on the amount of farm revenues. This aspect of assessment of economic activity of the researched objects is significant at creating models of goods distribution as well as production organization models. Simultaneously, it should constitute a source material for persons who undertake modernization and restructuring of production towards organic.

Table 1 and 2 presents a general and unitary size and value of global production divided into farm groups and branches (plant and animal) as well as the value of commodity production.

Table 1
Overall and unit size of global production with division into farm groups and branches (plant and animal)

Farms group	Parameter	Production					
		Plant		Animal		Total	
		GU·farm^{-1}	GU·ha^{-1}	GU·farm^{-1}	GU·ha^{-1}	GU·farm^{-1}	GU·ha^{-1}
Total	Average	353.46	27.21	336.05	25.87	689.51	53.08
	Standard deviation	291.05	16.13	405.57	17.86	625.68	23.21
up to 5 ha	Average	136.74	40.31	76.81	22.65	213.55	62.96
	Standard deviation	106.57	0.93	59.37	14.15	130.04	25.42
5.01-10.00 ha	Average	207.16	30.12	203.26	29.55	410.41	59.67
	Standard deviation	86.14	11.59	141.88	19.25	187.07	25.20
10.01-10.00 ha	Average	426.56	28.18	269.26	17.79	695.82	45.98
	Standard deviation	189.51	14.07	294.46	18.45	290.12	18.40
area 20.00 ha	Average	747.28	24.07	909.35	29.29	1656.63	53.36
	Standard deviation	318.89	12.83	484.86	15.10	652.35	19.65

Source: Kowalski et al. 2014

As the data presented in this table show, a farm produces at the average 689.51 GU which gives a unit production in the amount of 53.08 GU. The biggest farms produce almost 1656.63 GU whereas the smallest farms 8 times less – 213.55 GU. Farms from the second and third group achieve a subjective index respectively on the level of: 410.41 and 695.82 GU·farm^{-1}. However, one should remember that the presented values concern global production, where an internal turnover between production departments exists. And this affects the final production. When comparing both branches of production one may observe that in the scale of whole researched population, plant and animal production give its similar amount – 353.46 and animal production 336.05 GU·farm^{-1}. However, plant production prevails between particular groups – in the first and third group objects. Whereas, animal production – in the fourth group with balance within the second group.

Table 2
Overall and unit size of global and commodity production with division into farm groups and departments (plant and animal) – PLN·ha^{-1}

Farms group	Parameter	Production					
		Plant		Animal		Total	
		Global	Commodity	Global	Commodity	Global	Commodity
Total	Average	5008.35	3922.47	2626.94	2087.28	7635.26	6009.73
	Standard deviation	6962.16	7144.55	3027.17	2837.83	6908.55	7039.20
up to 5 ha	Average	7526.57	6431.35	2110.42	1538.72	9636.75	7969.95
	Standard deviation	8486.46	8776.62	2067.40	1854.05	8811.23	9017.54
5.01-10.00 ha	Average	3856.65	2492.26	3108.25	2522.96	6964.96	5015.25
	Standard deviation	3498.51	3291.82	4176.75	4059.55	4959.47	4615.75
10.01-10.00 ha	Average	7497.32	6871.44	1503.18	1194.88	9000.50	8066.32
	Standard deviation	10043.05	10274.33	2108.35	1766.65	9231.47	9577.97
area 20.00 ha	Average	1425.01	296.73	3640.62	2952.85	5065.63	3249.58
	Standard deviation	1060.08	1126.86	1919.75	1733.67	1932.44	1599.23

Total commodity production in the investigated farms was 6009.73 PLN·ha^{-1}, which constituted at the average 69.3% of global production. Commodity production in the group of objects up to 5 ha and from 10-20 ha – 7969.95 and 8066.32 PLN·ha^{-1}, which constituted respectively 67.0 and 60.5% of global production. In comparison to these objects, in the group of farms from 5-10 ha commodity production was lower by 38% in the biggest farms (area of 20 ha) – by 60%.

When analysing participation of commodity production in particular area groups, it was determined that the highest participation was in farms of area from 10 to 20 ha – 77.97% and the lowest in farms above 20 ha – 60.5%. Whereas, taking into consideration production departments, it was reported that animal commodity production (55.9%) slightly prevailed over plant commodity production (44.1%). The highest participation of animal commodity production occurred in the group of farms with area of 20 ha – 75.9% and the lowest up to 5 ha – 47.3%

Figure 1 and 2 present structure of commodity production expressed in percentages and it was determined based on the value of sold goods.

In the plant production department three main products were reported. They constituted 77% of the whole commodity production value. Vegetables had the highest participation – 27%. Herbs, hay and fodder plants had the lowest participation in the commodity production. In total they constituted 14% of the commodity production value from animal production branch.

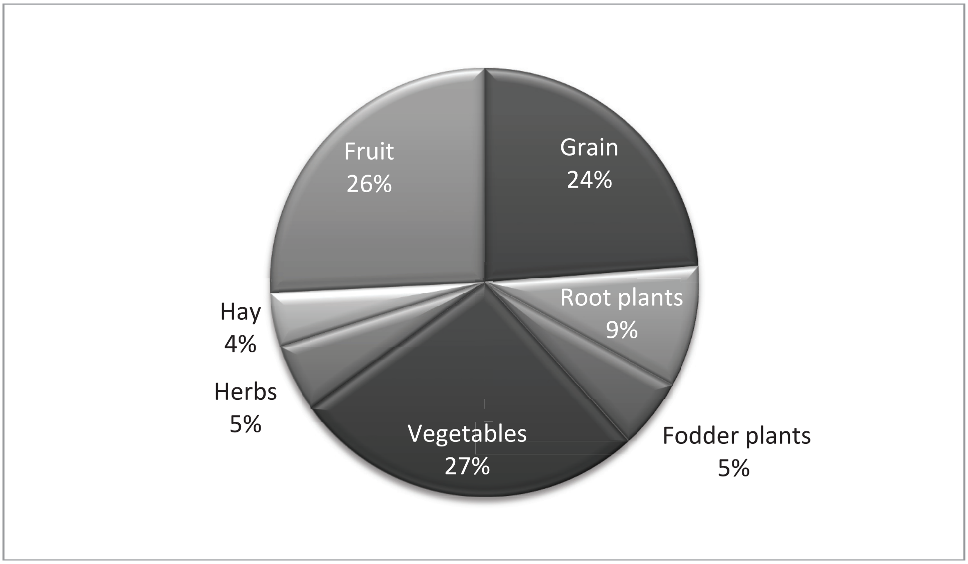


Figure 1. Structure of commodity production – plant production department

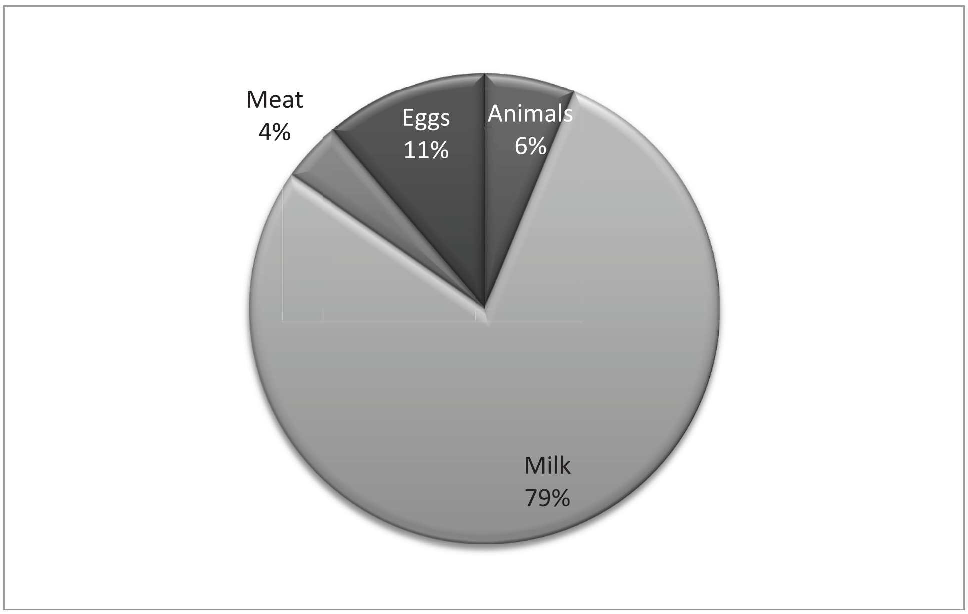


Figure 2. Structure of commodity production – animal production department

In the animal production branch, milk constituted the biggest part of the sold production – 79%. It mainly results from the selection of farm for the research and the production trend, where 12 out of 50 farms selected for detailed research, produced only milk. Pork constituted the lowest participation in the sales of commodity production – 4% and live animals – 6% (cattle, foals, horses).

Distribution next to production is one of the most important elements in the logistics chain, because its task is to make products available in the place and time responding to the clients' needs and expectations.

From the macroeconomics point of view, distribution means the process and structure of shifting goods from producers to target consumers. Thus, it constitutes a selected group of market channels and connections between them. Distribution systems of a particular organization structure and equipped with material-technical factors, which exist in economy, create conditions, which constitute the basis for selection of the manner of relocating products from the production zone to the consumption zone. Features of these systems cause that in a short period, they become an external factor for shaping ways of distribution. In the microeconomics, distribution is often identified with the sales process and the process of supplying products of a particular enterprise to final purchasers. Decisions related to selection of the sale manner are included in each enterprise to strategic decisions, because they finally influence effectiveness of market activities and achieved economic effects (Sikora, 1993; Rutkowski, 2002; Beier and Rutkowski, 2004).

Table 3 presents basic amounts characteristic for the distribution process: multiplicity of sales, average distance on which products were sold and the participation of the service transport in the process of sale.

Table 3
Characteristic of the distribution process of organic products

Specification	Plant production - products						
	Grains	Root plants	Fodder plants	Vegetables	Herbs	Hay	Fruit
Multiplicity of sale (-)	6	15	12	42	2	5	19
Average distance of sale (km)	3	2	4	12	10	8	22
Participation of service transport in the sales process (%)	4	3	3	11	–	1	–

Specification	Animal production - products			
	Animals	Milk	Meat	Eggs
Multiplicity of sale (-)	3	183	3	278
Average distance of sale (km)	18	21	7.5	35
Participation of service transport in the sales process (%)	–	–	–	–

Average multiplicity of plant products sale was 15 and the average distance of sale was 9 km. Vegetables were sold the most often and the herbs and hay less frequently. Distance from outlets was from 2 to 22 km. As one may notice, due to proper equipment of farms in transport means, participation of service transport in the process of products distribution was marginal.

Significantly higher multiplicity of sale was in case of animal products – particularly due to such products as milk and eggs. Average multiplicity was 116 and average distance from outlets was two times higher than in case of plant products. All products were transported with own transport or at the client's cost.

Producers of organic food products should pay attention more often to the changes of consumers' likings and preferred manners of satisfying food needs, e.g. demand for the so-called convenient food products, partially or totally ready for consumption and also to the need of forming new products. This, on the other hand requires the use of new technologies, adjusted to the existing legal regulations with regard to organic farming (Żakowska-Biemans, 2006).

Requiring outlet of agricultural products forces organic food producers to numerous activities, the task of which is to obtain new and maintaining fixed clients. In present times, it is very difficult, because, a present market suggests more and more rich offer of products of foreign origin. Only thorough research of client's needs will create demand for specific products and will allow loyalty to a known product. It should be also emphasised that consumers' awareness rising every year is reflected in the demand for goods which differ with original recipe, which results from the search of extraordinary composition.

According to Wójcik (2012) a modern consumer, taking up a decision on the purchase of food, becomes more requiring, thus an appropriate price and the standard quality is not enough. The basic issue, which becomes more and more significant for a possible client

is a selection of products of suitable parameters, and the most significant are:

- taste and health values,
- known brand name
- production traditions,
- regional origin,
- strict control of the production process.

In case of Poland it is difficult to talk about an organized sale of organic food products. A main obstacle in construction of the distribution network which ensures the flow of goods from a producer to trade is territorial dispersion of farms. Insufficient development of the direct system between a producer and retail is a weak element of the distribution system in Poland.

In Poland direct sale of organic food prevails and sale through specialist channels, which is characteristic for the initial phase of the market development. Contrary to the Western Europe countries, characteristic feature of specialist shops is their small number (approximately 250) and a low variety of assortment. Insufficiently developed indirect cell is an additional weakness (number of specialist warehouses is about 30). While, the number of producers of organic food products increases (farms and food-processing plants) and thus supply of eco-products. At the same time considerable changes occur in the size of demand for organic food products, especially among citizens of big cities (Łuczka-Bakuła and Smoluk-Sikorska, 2009; 2010).

Decisions within the scope of model solutions of distribution of organic products mainly concern the selection of proper distribution channels, organization of physical distribution (marketing logistic) and localization of sale points. It is difficult to clearly determine one, two models of distribution of organic goods on account of specificity of the Polish organic farming. Polish farms are very spread within an area, they have a small number of raw material, a poor assortment, and the existing organization of purchase and sale of organic products does not function like in western countries.

Organic farming may be sold both in traditional channels of distribution as well as in special channels, typical of a given type of products. From among the most popular retail agents there are:
- shops with healthy food,
- specialist shops (e.g. meat processing plants, bakery shops, dairies),
- traditional super and hyper markets.

Depending on the number of agents which occur in the channel and the form of channel organization one may list three types of channels:
- direct and indirect,
- short or long,
- traditional and vertically integrated.

Selection of a proper channel of distribution depends on many factors. The most important are:
- size and nature of the market,
- product type and features,
- clients' behaviour and preferences,
- competition,
- farm size and position.

Model 1

In direct channels of distribution, products are transferred without the participation of agents from an organic farm to consumers. A farmer must reach final recipients with his products at his own cost and risk. As a part of direct sale, plant products are sold to a final consumer i.e. to individual persons and directly to retail shops and catering plants.

Direct sale may take place in various forms. The most frequent methods of agricultural products distribution are:
- direct sale in farms ("at the door") - consumers buy products in a farm any time,
- sale on an agricultural fair – a farmer leases a spot on a fair, sells products on particular weekdays and hours or every day,
- sale by the road – concerns mainly seasonal products, particularly fruit and vegetables, a form which does not require much capital, however, sanitary conditions and sale safety conditions are not favourable,
- sale directly to the consumer's house (“to the door") – products are supplied very often to fixed consumers, who place orders for a particular amount of a product for a specific day of delivery. Such form of sale requires having a proper transport,
- sale through the Internet – carried out in various forms, including individual delivery or shipment to a consumer,

– Sale in a "collect yourself" form – a purchaser has a possibility of harvesting himself from the farmer's field; it is applied in case of soft fruit particularly strawberry, stone fruit, apples, pears, plums. Orchards must be equipped with proper ladders and containers which facilitate harvesting.
– neighbour sale ("from a farmer to a farmer") – may concern both plant products, e.g. grains, hay as well as products for the household needs, which are not produced by a farmer himself but purchased from a neighbour.

Direct sale serves establishing closer and more permanent contacts with purchasers, which allows a faster flow of information between consumers and a producer and also accepting a profit margin of a distributor by a farmer. Direct sale from a farm allows our clients to see where and how products, which they buy, are cultivated. Moreover, a supplier and his products become less anonymous. Also price is then favourable for a client. However, access to farms located far from big city centres may be a problem (Pilarczyk and Nestorowicz, 2010).

Direct channels of sale of organic food products should be used by small farms with dispersed production. They usually have limited possibilities within the scope of other form of sale of their products. Direct sale does not require high investment inputs, endows a producer with a fixed inflow of cash, enables also a close contact with purchasers and obtaining information from them on their needs and preferences. Disadvantage of this form of sale is its local nature. It may be used in farms located near big communication tracks.

Model 2

Sale of organic products in this model is designated for bigger area farms, which have suitable potential and assortment of products, which are production oriented. In indirect channels (the so-called long), there are agents, at least one on each level of the distribution channel. These may be wholesale agents (purchase of agricultural products directly at a producer, wholesale purchase), retail agents and agents who process food (food-processing plants which offer only a ready organic food products).

Sale of organic food products to final consumers in a direct channel may take place in shops with healthy food products in shops which offer traditional food with traditional service, in self-service shops, on-line shops, in specialist shops (e.g. bakeries), in supermarkets and eating establishments.

On one hand this solution gives a farmer:
– a possibility of wider market penetration and potential sale of a product,
– facilitates expansion of a producer-seller to new markets, which have not been available for him so far,
– possibility of reduction of the number of transactions, which may lead to lowering of distribution costs,
– additional advantages related to specialization and carrying on uniform activities on a great scale,
– releasing a producer from construing his own sales network,
– possibility of employing sellers,
– possibility of maintaining stocks on each level of a channel.

However, on the other hand it causes:
– partial or full loss of control over the selection of final clients, prices, product promotion,

- elongation of the payment period for a product, which means slowing down the flow of capital at a producer and sometimes also crediting agents,
- possibility of conflicts of interests in a channel,
- increase of threat which results from improper execution of undertaken obligations, ignoring producer's requirements, or bad work carried by agents.

Model 3

The next distribution model is based on the so-called short channels, where there are not many levels. Both small and bigger agricultural producers of a specialistic or multi-trend commodity production may participate therein. It is a model of commodity distribution where between an agricultural farm and consumers, there is an agricultural organization (agricultural cooperative, producers' group) which group farmers who produce specific food products. Extending and initiating cooperation with other producers - farmers will allow extension of offer and introduction to sale of the so-called complementary goods, that is fuller satisfaction of the client's needs. Having a wide assortment and appropriate number of organic products, one may in a simpler way contact bigger trade networks and thus conclude long-term contracts for the supply of specific products. Short channels have similar advantages as well as disadvantages as indirect channels.

Model 4

The system of distribution of organic products in this model is based on entities (farms, warehouses, food-processing plants) loosely related to each other. Each of them has its own objectives and aims at maximization of its profits. In the moment, when between entities a fixed cooperation will start, then interested entities may be identified with a given channel of distribution, including impact of own decisions and decisions of other links on the effectiveness of functioning of the whole channel of distribution. A belief that reaching aims of all interested entities is related to the need or even necessity of starting special coordination mechanisms in the whole channel may induce to such activity. Shaping of such mechanisms caused development of various forms of cooperation of entities, which function in the market zone and creating adequate organization solutions. This mutual cooperation allows the increase of bidding force, achieving advantages of scale and maximization of the inflow to the market. The existing relations between entities within the so-called vertical integration have the most frequently contract nature (relation of independent entities through conclusion of contract). Producers of organic food products sign contracts for supply of determined amount of their goods to distributors and those undertake to receive these products and supporting them not only within the trade but also counselling related to organic production.

Conslusion

According to Pilarczyk and Nestorowicz (2010) as well as based on authors' own research, it should be determined that the system of distribution of organic products in Poland will develop dynamically if diversification of sale channels will take place. Cooperation of organic producers with big trade networks cannot be avoided. Only increase of sales participation in a conventional channel will allow decrease of distribution costs and profit margins and this will decrease prices for final purchasers, which will facilitate reaching a bigger group of clients. It is difficult to assign a specific distribution model for the investigated organic farms because majority of them carries out a varied production both with regard to the size as well as assortment. Thus, in many cases the investigated farms will have to base on two or three distribution models, the profit from the obtained sale will be a selection criterion.

For Polish farmers who run organic farms, export of products abroad is still the most profitable, thus high dispersion of organic agriculture in Poland may be a problem – foreign clients need big amounts of goods and properly selected assortment. Association of organic farmers or producers' groups may solve this problem.

In the process distribution development, it it is worth to follow certain solutions which can be found on markets of other European states, but at the same time, one should not forget about preconditions typical for Poland, such as the society's wealth level, awareness level and client's education or certain shopping habits, and also farmer's attitudes towards forming cooperatives or producers' groups by them, which result from earlier experiences.

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MODELOWE ROZWIĄZANIA LOGISTYKI DYSTRYBUCJI PRODUKTÓW EKOLOGICZNYCH

Streszczenie. Celem pracy było zaproponowanie modelowych rozwiązań logistyki dystrybucji produktów ekologicznych w gospodarstwach ekologicznych. Określono również wielkość i strukturę produkcji, a także udział i strukturę produkcji towarowej z podziałem na działy. Zakresem pracy objęto badania przeprowadzone w 50 gospodarstwach ekologicznych z rejonu Polski południowej. Pracę wykonano w ramach grantu rozwojowego nr NR 12-0165-10 „Innowacyjne oddziaływanie techniki i technologii oraz informatycznego wspomagania zarządzania na efektywność produkcji w gospodarstwach ekologicznych". Ogółem w badanych gospodarstwach produkcja towarowa wynosiła 6009,73 PLN·ha^{-1}, co stanowiło średnio 69,3% produkcji globalnej. W strukturze roślinnej produkcji towarowej znaczący udział stanowiły warzywa, ziarno zbóż oraz owoce a w produkcji zwierzęcej mleko i jaja. Stwierdzono, że decyzje w zakresie modelowych rozwiązań dystrybucji produktów ekologicznych w głównej mierze dotyczą wyboru odpowiednich kanałów dystrybucji, organizacji fizycznej dystrybucji oraz lokalizacji punktów sprzedaży. Zaproponowano 4 podstawowe modele dystrybucji produktów ekologicznych.

Słowa kluczowe: gospodarstwa ekologiczne, sprzedaż, rynek, model, produkt, dystrybucja

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OPERATING COSTS AND THE USE OF MANUFACTURING CAPACITIES OF THE MACHINERY PARK IN ORGANIC FARMS[1]

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ABSTRACT

The objective of the paper was to determine operating costs of the machinery park in organic farms. Moreover, the level of farms equipment with farm machines and devices was determined and the use of their manufacturing capacities was assessed. The scope of the study covered the research in 50 certified organic farms located in the south Poland in Małopolskie, Podkarpackie and Świętokrzyskie voivodeships. The study was carried out within the development subsidy no NR12-0165-10 "Innovative impact of technology and IT support of management on efficiency of production in organic farms". Average area of AL is 12.48 ha. Operating costs of the machinery park were 30 993 PLN·farm^{-1}which annually per one hectare of AL generates the value of PLN 3 369. Amortization constituted the highest participation in total costs, which was as much as 65.7% and energy carriers related to consumption on production of diesel oil, leaded petrol and electric energy. The highest use of manufacturing capacities of the machinery park of organic farms was reported in case of a manure spreader, presses and windrow collectors. In case of spreaders, 19 years are necessary for their total amortization, and in case of presses and windrow collectors – 20 and 21 years. In the researched organic farms, average annual rate of use of possible manufacturing capacities of the majority of machines was only 0.4-1.3%. It forces to lengthen the operating periods, which constitutes the main brake on progress.

Introduction

Organic farming becomes an interesting subject, both among possible consumers as well as producers – farmers. Reasons for such state of affairs should be searched for not only in more frequent negative assessments of intense methods of agricultural production, but also even higher awareness of consumers and rising level of their requirements towards the product and a producer (Kondratowicz-Pozorska, 2006).

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Dynamic development of organic farming in Poland, after EU accession in 2004 gave rise to the need of carrying out research and analysis concerning the branch of agriculture. Getting information on production and economic situation of organic farms and their competitiveness has become crucial, especially because the number of agricultural producers interested in the production of organic methods rises systematically (Kowalska, 2010).

Huge diversity of factors shaping functioning of such farms should be taken into consideration when assessing activity of agricultural farms. Operating costs of the machinery park and the use of its manufacturing capacities are one of these factors. The time of use of a machine in a year is one of the basic factors which decide on unit operating costs of each machine. Along with the increase of the number of hours the machine works its operating costs decrease (Muzalewski, 2003). In conditions of small farms, individual use of a machine on a small area frequently does not allow a farmer to obtain unit operating costs of a machine similar to the market prices of services. The main factor of such situation is low use of farm tractors (approximately 2/3 of normative use) and farm machines in some cases at the level of few hours per a year (Kocira, 2005). A factor, which will decrease these costs is a selection, suitable to the farm conditions, of machines with work parameters which guarantee their best use, which will allow obtaining a better financial result (Kowalik and Grześ, 2006).

Objective, scope and methodology of work

The objective of the paper was to determine the equipment with the machinery park and its operating costs in organic farms. Assessment of the use of manufacturing capacities of machines and tools, which constitute the equipment of the investigated farms, was carried out. The scope of the study covered the research in 50 certified organic farms located in the south Poland in Małopolskie, Podkarpackie and Świętokrzyskie voivodeships. The study was carried out within the development subsidy NR12-0165-10 "Innovative impact of technology and IT support of management on efficiency of production in organic farms". The collected information was obtained on the basis of a guided survey carried out with the farm owner. Information concerned 2011 and the collected data allowed inter alia to carry out characteristic of farms and determination of costs of exploitation and the real use of farm tractors and machines during a year. For comparative analysis, farms were divided into four area groups on account of the size of the agricultural land area:

- group I – up to 5.00 ha – 12 facilities,
- group II – from 5.01 up to 10 ha – 17 facilities,
- group III – from 10.01 up to 20 ha – 12 facilities,
- group IV – above 20.00 ha – 9 facilities.

For evaluation of the use of manufacturing capacities of the machinery park in the investigated farms, the rate of use of manufacturing capacities was assessed according to the following relation (Tabor and Kmita, 2007; Tabor, 2008):

$$S_w = \frac{W_{rz}}{n} \cdot 100\%$$

where:
S_w – the rate of use of manufacturing capacities (%),
W_{rz} – annual use of a machine (h),
n – service life - the use of a machine during operating period (h).

Description of the researched farms

Table 1 presents the area and structure of agricultural land in the researched organic farms. Average area of AL was 12.48 ha and was within 3.32 ha in the group I to 31.80 ha in group IV. In the total structure of agricultural land, arable land was 53.6% and permanent grassland was 36.7%. In the first three area groups there also were orchards – 0.44 ha and perennial plantations – 0.04 ha (i.e. raspberries, strawberries, blueberries, raspberries), which complemented the structure of agricultural land and their use was marginal. In the group of the biggest farms with the area above 20 ha as much as 69.9% constituted permanent grasslands whereas arable land was 30.1%.

Table 1
Area and structure of agricultural land

Farm group	Parameter	Area and structure of agricultural land								
		AL		Perennial grasslands		Orchards		Perennial plantations		Total agricultural land
		(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
I	Average	1.93	58.4	0.66	19.9	0.65	18.3	0.08	3.4	3.32
	Standard deviation	1.40	–	0.64	–	0.94	–	0.14	–	1.01
II	Average	4.22	62.2	1.97	26.3	0.68	10.9	0.04	0.6	6.91
	Standard deviation	2.04	–	1.94	–	1.29	–	0.09	–	1.53
III	Average	8.23	54.1	6.54	43.3	0.24	2.1	0.05	0.5	15.06
	Standard deviation	5.93	–	5.91	–	0.71	–	0.14	–	3.33
IV	Average	9.64	30.1	22.16	69.9	–	–	–	–	31.80
	Standard deviation	7.47	–	8.25	–	–	–	–	–	8.93
Total (50)	Average	5.61	53.6	6.39	36.7	0.44	8.6	0.04	1.1	12.48
	Standard deviation	5.24	–	8.99	–	0.96	–	0.11	–	10.86

Source: Kwaśniewski et al., 2013

The area of sowing according to plant groups and the livestock was presented in table 2 and the structure of sowing in the researched organic farms was presented in figure 1. In this structure assessed in total for 50 facilities, grains dominated – over 45.8% then fodder plants – 34.0%, vegetables, root plants (potatoes) while the lowest participation was in case of herbs – it was 1.8% of area (occurred only in two facilities). Farms from the group with area ranging from 10.01 to 20.00 ha and farms with area above 20 ha had in their structure of crops a considerable participation of root plants respectively 40.6% to 70.6%.

Table 2
Area of crops acc. to plant groups and livestock

Farm group	Parameter	Arable land	Plant group					Livestock
			Grains	Root crops	Fodder crops	Vegetables	Herbs	
		(ha·farm.$^{-1}$)						(LSU·ha^{-1} AL)
I	Average	1.93	1.29	0.11	0.36	0.07	0.10	0.69
	Standard deviation	1.40	0.90	0.09	0.54	0.09	0.35	0.30
II	Average	4.22	2.20	0.50	1.05	0.47	–	0.76
	Standard deviation	2.04	1.63	0.58	1.26	1.01	–	0.46
III	Average	8.24	3.06	0.62	2.76	1.17	0.63	0.90
	Standard deviation	5.93	4.07	0.85	2.36	1.74	2.17	0.52
IV	Average	9.64	1.41	0.26	7.95	0.02	–	0.79
	Standard deviation	7.47	1.20	0.27	7.78	0.07	–	0.34
Total	Average	5.61	2.05	0.39	2.54	0.46	0.17	0.78
	Standard deviation	5.24	2.34	0.57	4.36	1.10	1.07	0.41

Source: Kwaśniewski et al., 2013

Whereas, the livestock was very balanced and was 0.76 LSU·ha^{-1} AL in group I and III and 0.80 LSU·ha^{-1} AL in group II and IV. In the number structure in all area groups, cattle prevailed and in the biggest farms it was 97.9%. Thus, almost 70% participation of grasslands in this farm group (Kwaśniewski et al., 2013).

Research results

Equipment of the investigated organic farms in farm tractors and transport means and other machines divided according to the user groups was presented in table 3.

Farm tractors constituted a basic energy means and served as the main source of mechanical tractive and driving force as well as transport and loading means. Authors point in papers such universal use of tractors, not only in organic farms (Kowalski et al., 2012; Muzalewski, 2009).

At the average in the researched population there was 1.64 tractor per a farm. When comparing this saturation in the system of area groups, a logical increase of the number of these means per a statistical farm along with the increase of its area is recorded. In the group of the facilities which have the smallest area was 0.92 item·farm^{-1}. One farm did not have a tractor, thus a number lower than a unity. Farms from the second group (5.01 to 10.00 ha) had tractors in the number at the average of 1.47 item·farm^{-1}. Thus, each had one tractor and every second one – two tractors. In the third group (10.01 to 20.00 ha) index of saturation was 1.92 item·farm^{-1}. Thus, it means that almost all farms had two tractors. Even higher index of saturation may be observed in the group of the biggest farms - here the index was as much as 2.56.

Table 3
Equipment of farms in farm machines with the system of usage groups

Farm group	Parameter	Machine group															
		Farm tractors		Delivery trucks		Remaining transport means		Cultivation machines		Fertilization, protection and treatment of plants		Machines for sowing and planting		Machines for green forage harvesting		Machines for crops and root crops harvesting	
		(item·farm^{-1})	(item·ha^{-1})	(item·farm^{-1})	(item·ha^{-1})	(item·farm^{-1})	(item·ha^{-1})	(item·farm^{-1})	(item·ha^{-1})	(item·farm^{-1})	(item·ha^{-1})	(item·farm^{-1})	(item·ha^{-1})	(item·farm^{-1})	(item·ha^{-1})	(item·farm^{-1})	(item·ha^{-1})
I	Average	0.92	0.26	–	–	1.25	0.35	2.92	0.82	1.17	0.30	0.50	0.12	1.08	0.31	0.42	0.12
	Standard deviation	0.51	0.15	–	–	1.36	0.40	2.11	0.54	1.70	0.41	0.80	0.19	0.90	0.26	0.51	0.14
II	Average	1.47	0.21	0.18	0.03	1.24	0.18	3.41	0.52	1.94	0.29	1.41	0.22	2.29	0.33	0.71	0.11
	Standard deviation	0.62	0.08	0.39	0.06	1.03	0.14	1.46	0.25	1.25	0.20	0.87	0.15	1.31	0.18	0.69	0.11
III	Average	1.92	0.13	0.42	0.03	1.17	0.08	3.50	0.25	3.00	0.21	1.25	0.09	3.83	0.25	1.08	0.08
	Standard deviation	0.67	0.05	0.51	0.04	0.58	0.05	1.00	0.11	1.71	0.14	0.87	0.07	2.72	0.18	0.51	0.05
IV	Average	2.56	0.08	–	–	1.67	0.06	3.67	0.12	3.11	0.10	1.11	0.03	5.89	0.18	0.67	0.02
	Standard deviation	1.01	0.03	–	–	1.00	0.03	1.32	0.04	1.62	0.05	0.78	0.02	2.26	0.05	0.71	0.02
Total	Average	1.64	0.18	0.16	0.02	1.30	0.18	3.36	0.45	2.22	0.24	1.10	0.13	3.02	0.28	0.72	0.09
	Standard deviation	0.88	0.11	0.37	0.04	1.02	0.24	1.51	0.39	1.68	0.25	0.89	0.15	2.45	0.19	0.64	0.10

Equipment of organic farms with delivery trucks should be recognized as low. Since, at the average per a farm there was 0.16 item of this vehicle. The farm should be equipped with the remaining transport means in the form of trailers, trucks or pulleys independently from the farm size. The researched population of farms within the subjective technical means is not varied with regard to technology. Frequently one trailer or a horse and cart adapted to a tractor was a multifunctional machine and served for transport of produce in a varied form (volume, loose – e.g. grains, tubers, roots etc.). Thus, only 1.30 items of the remaining transport means was at the average per a farm but in the biggest farms this ratio was 1.67.

Number materials presented in table 3 concerning the number of particular groups and types of machines, explicitly indicate a poor assortment of machines which accompany tractors. At the average 3.36 cultivation machines is per a farm. A situation in case of machines used for sowing and planting as well as harvesting of grains and root crops is unfavourable. Here, at the variability of plants, which are treated by these machine groups, their average number in a farm is only 1.10 item in the first case and 0.72 item in the second case. Whereas, quantity of machines used for harvesting of green forage is favourable – at the average 3.02 item·farm^{-1}.

Operating costs of the machinery park in a unitary view were presented in table 4 and figure 1 presents their structure. Amortization, insurance, energy carriers and costs of spare parts and repairs were included. Costs of labour were not included in the costs. In total, exploitation costs of machines per a statistical farm were 30,993 PLN·farm, which generates the value of PLN 3, 369 per one hectare. Amortization constituted the highest participation in total costs, which was as much as 65.7% and energy carriers related to consumption of diesel oil, leaded petrol and electric energy were at the second place (19.7%). It should be mentioned that very frequently farmers while establishing the production costs or similar services omit amortization of fixed assets mainly machines. Without including amortization costs, production or services efficiency assessed by them, seems to be favourable. However, they are not aware that they "consume" their fixed assets. The remaining components of operating costs of the machinery park have a considerably lower participation.

When comparing the index of amount of unitary costs in the area groups system (table 4) one may mention the decrease along with the increase of average size of the production area – it is a normal phenomenon and does not require additional explanations.

Table 4
Unit costs of machines exploitation

Farm group	Parameter	Average age (years)	Operating costs of machines (PLN·ha^{-1})						
			Machines amortization	Tractors, cars insurance	Energy carriers (fuel, electric energy)	Spare parts	Oils and smears	Ordered repairs	Total costs
I	Average	19	2738	225	910	437	113	141	4564
	Standard deviation	8	1051	163	906	333	75	166	1746
II	Average	21	2711	96	625	278	48	135	3893
	Standard deviation	5	1402	84	319	293	44	188	1752
III	Average	21	2059	42	586	145	26	41	2899
	Standard deviation	5	1567	37	292	108	12	78	1622
IV	Average	16	905	9	318	110	23	46	1411
	Standard deviation	4	313	11	108	171	16	90	554
Total	Average	20	2236	99	629	254	54	98	3369
	Standard deviation	6	1389	121	525	275	56	150	1879

In the discussed table, also an average age of machines according to the accepted division criterion of the researched facilities was presented. The data obtained here explicitly confirm earlier research, where it was found out, that organic farms of Małopolskie voivodeship are equipped with old, exploited equipment frequently purchased on a secondary market. Since, machines are 20 years old at the average.

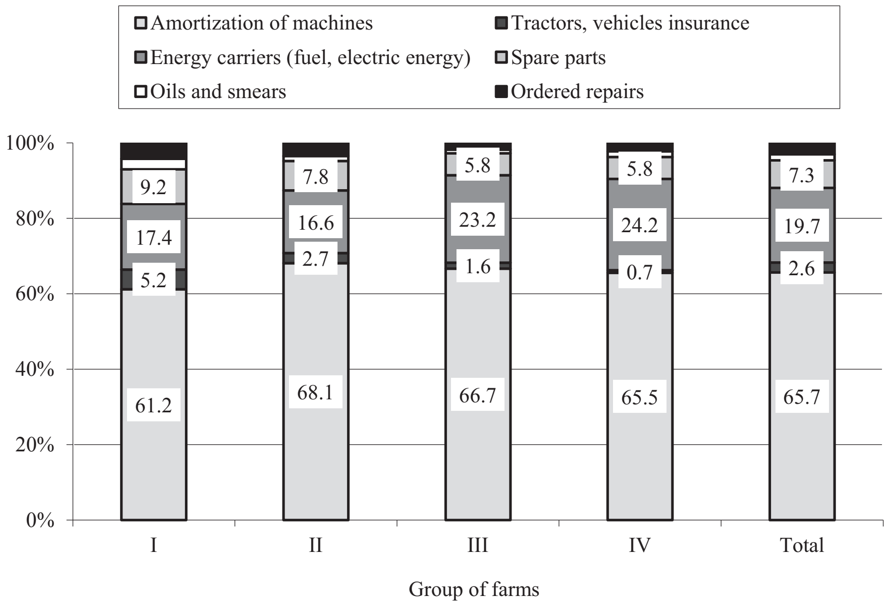

Figure 1. Structure of machines operating costs

Table 5 presents annual use of the machinery park in the investigated organic farms. When assessing the level of use for all farms where given machines were present, from farm tractors, delivery trucks to machines for harvesting produce, one should state that in majority of cases the use was decisively lower than the normative use. Only for manure spreaders, which during a year worked at the average of 92 h – their annual operating time exceeded normative use and in case of presses operated 64 $h \cdot year^{-1}$ it was on the verge of the use predicted by norms. Intense exploitation of manure spreaders resulted from the fact that in many farms they were additionally used as a trailer for transport of produce. Obtained results (table 5) allow assumption that the use of manufacturing capacities of the machinery park in organic farms will be at a very low level.

Table 5
Annual use of the machinery park

Specification	Use (h·year^{-1})				
	Group I	Group II	Group III	Group IV	Total
Delivery trucks	–	440	459	-	450
Farm tractors	127	165	173	171	159
including: 6 kN class	145	188	185	106	156
9 kN class	125	128	195	181	157
14-20 kN class	50	129	110	206	124
Farm trailers	38	56	96	69	65
Tractor trailers	36	37	37	29	35
Dollies	101	40	13	–	51
Ploughs	9	16	20	10	18
Cultivators	4	4	9	7	7
Spike-tooth harrows	5	9	12	17	11
Cultivation aggregates	–	7	9	16	11
Manure spreaders	38	114	19	88	92
Grain drills	5	6	5	2	5
Seeders	1	6	5	2	5
Rotational mowers	67	21	24	28	35
Disc mowers	–	–	17	28	23
Haymakers-rakes	14	17	37	51	30
Combine harvesters	–	16	–	11	14
Presses	–	128	32	32	64
Windrow collector	–	26	129	–	78
Potato spinner	5	7	2	3	5
Elevator-digger	–	7	15	–	11
Potato combine	2	45	47	–	31

The use of manufacturing capacities of the machinery park assessed with the use of indexes of the so-called rate of use expressed with (%) was presented in figure 2 and 3.

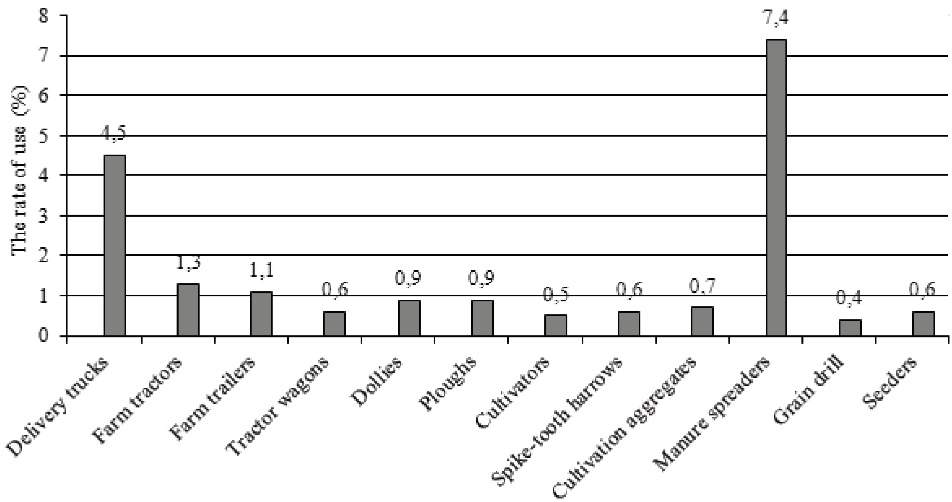

Figure 2. The rate of use of manufacturing capacities of the machinery park (transport means, cultivation machines, fertilization machines, sowing and planting machines)

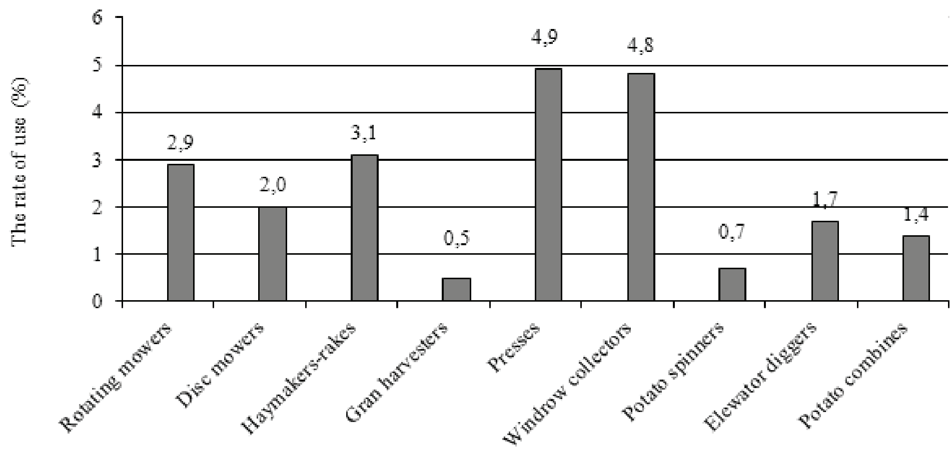

Figure 3. The rate of use of manufacturing capacities of the machinery park (harvesting machine)

For farm tractors the rate of use was at the average only 1.3%. Thus, in order to fully use potential manufacturing capacities of tractors in the investigated farms, they should be operated in such farming conditions (depending on the towing class) within 65 to 78 years. From among the analysed groups of farms, only in the biggest facilities (group IV) real possibilities for rational operation of tractors exist but only for 14-20 kN classes.

It cannot be determined with regard to cultivation tools, for which the rate of use of manufacturing capacities is from 0.5% for cultivators to 0.9% for ploughs. In such cases for their total use respectively 11 and 231 years are necessary. Despite a very low use of these tools, they are eagerly purchased due to a low price. The rate of use of manufacturing capacities for trailers was at the average of 1.1 %. In order to fully use production abilities of trailers, they should be exploited for 93 years. Whereas, the most real possibilities for carrying out rational exploitation exist for manure spreaders, for which the highest use of production abilities exists and the assessed index was the highest – 7.4% (fig. 2). 19 years are necessary for total amortization. While, among machines for harvesting of green forage and produce, the highest rate of use of manufacturing capacities characterized presses and windrow harvesters. Respectively 4.9 and 4.8% (fig. 3). In these examples, in order to completely amortize these type of machines, they should be operated for 20 and 21 years.

The presented results confirmed previous assumption that the use of manufacturing capacities of the machinery park in the investigated organic farms is at a very low level.

Statements and conclusions

1. The investigated farms were characterized by high saturation of equipment with farm tractors. At the average in the researched population there was 1.64 tractor per a farm. These were old tractors, exploited and usually cooperating with equally old equipment (average age 20 years). It considerably influences technologies applied in the investigated farms (old and work-consuming).
2. Operating costs of the machinery park were 30, 993 PLN·farm^{-1} which annually per one hectare of AL generates the value of PLN 3, 369. Amortization constituted the highest participation in total costs, which was as much as 65.7% and energy carriers related to consumption of diesel oil, leaded petrol and electric energy were at the second place (19.7%).
3. The highest use of manufacturing capacities of the machinery park of organic farms was reported in case of a manure spreader, presses and windrow collectors. In case of spreaders, 19 years are necessary for their total amortization, and in case of presses and windrow collectors – 20 and 21 years.
4. At the average over 90 years is necessary to use the manufacturing capacities of the remaining machinery park in many cases, which may limit the introduction of technical progress to organic farms.
5. In the researched organic farms, average annual rate of use of possible manufacturing capacities of the majority of machines was only 0.4-1.3%. It forces to lengthen the operating periods, which constitutes the main brake on progress.

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KOSZTY EKSPLOATACJI A WYKORZYSTANIE ZDOLNOŚCI PRODUKCYJNYCH PARKU MASZYNOWEGO W GOSPODARSTWACH EKOLOGICZNYCH

Streszczenie. Celem pracy było określenie kosztów eksploatacji parku maszynowego w gospodarstwach ekologicznych. Określono również poziom wyposażenia gospodarstw w maszyny i urządzenia rolnicze oraz dokonano oceny wykorzystania ich zdolności produkcyjnych. Zakresem pracy objęto badania przeprowadzone w 50 gospodarstwach ekologicznych z certyfikatem położonych w Polsce południowej, w województwach: małopolskim, podkarpackim i świętokrzyskim. Pracę wykonano w ramach grantu rozwojowego nr NR 12-0165-10 „Innowacyjne oddziaływanie techniki i technologii oraz informatycznego wspomagania zarządzania na efektywność produkcji w gospodarstwach ekologicznych". Średnia powierzchnia UR to 12,48 ha. Koszty eksploatacji parku maszynowego wynosiły rocznie 30 993 PLN·gosp^{-1}, co w przeliczeniu na hektar UR daje wartość 3 369 PLN. Największy udział w kosztach całkowitych, bo aż 65,7% stanowiła amortyzacja, a drugie miejsce (19,7%) zajmują nośniki energii związane ze zużyciem na produkcję oleju napędowego, etyliny i energii elektrycznej. Największe wykorzystanie zdolności produkcyjnych parku maszynowego gospodarstw ekologicznych odnotowano w przypadku roztrząsaczy obornika, pras oraz zbieraczy pokosów. W przypadku roztrząsaczy na całkowite ich zamortyzowanie potrzeba 19 lat, natomiast w przypadku pras i zbieraczy pokosów 20 i 21 lat. W badanych gospodarstwach ekologicznych średnio roczne tempo wykorzystania potencjalnych zdolności produkcyjnych większości maszyn wynosi tylko 0,4-1,3%. Zmusza to do wydłużania okresów eksploatacji, co stanowi główny hamulec postępu.

Słowa kluczowe: gospodarstwa ekologiczne, koszty eksploatacji maszyn, park maszynowy, wykorzystanie zdolności produkcyjnych

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REPLACEMENT VALUE OF FARM BUILDINGS AND COSTS OF THEIR OPERATION IN ORGANIC FARMS[1]

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ABSTRACT

A rising trend in the number of production buildings, mainly livestock buildings, which were given for use in farming, has been at the same level for several years. The paper presents the level and structure of equipment of the selected organic farms with farm buildings and their replacement value and operating costs were calculated. The scope of research included 50 facilities located in the southern Poland, which were granted an organic farm certificate. The investigated facilities were the object of research within the development subsidy titled "Innovative influence of technology and information management supporting system on production efficiency in organic farms". The analysed data concerned 2012. For the purpose of comparative analysis the researched facilities were divided into two groups which specialize in plant and animal production. Average area of buildings was 314.45 m^2 and was comparable in distinguished trend groups. In farms producing plants, storehouses prevailed and in case of animal farms – livestock buildings. Average annual replacement value of buildings was PLN 105.78 thousand and was also comparable in trend groups. In the structure of replacement value, storehouses prevailed, which constituted at the average 43.03% and livestock buildings – 37.68%. Average annual operating costs of buildings were PLN 58.61 thousand. The fact that these costs in animal farms were 2 times higher than in plant farms, should be emphasised. Renovation materials and ordered repairs constituted the highest costs.

Introduction

Organic farming is a farming system which is based on a possibly sustained plant and animal production within a farm. For protection of efficient course of production processes, these farms must have buildings and livestock and storehouse buildings, which are adjusted to the size and type of production and stored material (Tabor and Malaga-Toboła, 2004; Tabor and Kuboń, 2004; Kuboń, 2006; Golka and Wójcicki, 2010). Dynamic development

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of organic farms and necessity of being competitive somehow forces the necessity of investing in new technologies, including new production buildings (Szeptycki, 2005; Lorencowicz and Włodarczyk, 2009; Kocira et al., 2010).

Objective, scope and methodology of work

The objective of paper was to determine the quantity state and structure of equipment of the selected organic farms with farm buildings. Their area, replacement value and operating costs were calculated.

Research in the form of guided survey with a farm owner, who had a certificate of an organic farm, was carried out in 50 facilities located in the region of south Poland. The researched farms participated in a 3-year research project executed by the Institute of Agricultural Engineering and Informatics in Kraków as a part of development subsidy no NR 12-0165-10 "Innovative influence of technology and information management supporting system on production efficiency in organic farms". Data for analysis were accepted for 2012.

Replacement value of farm buildings, including garages and storehouses was calculated using a unit cost of construction of a building:

$$W_{ob} = f_b \cdot k_{jb} \tag{1}$$

where:
- W_{ob} – replacement value of buildings (PLN),
- f_b – surface area of a building (m^2),
- k_{jb} – unit current construction cost of a building ($PLN \cdot m^{-2}$) (GUS, 2012).

Operating costs of farm buildings were calculated as a sum of fixed and variable costs.

$$Ks = Amr + U + P \tag{2}$$

where:
- Ks – fixed costs (PLN),
- Amr – annual amortization ($PLN \cdot year^{-1}$),
- U – insurance of a building (PLN),
- P – tax (PLN).

Amortization of buildings was calculated according to the formula:

$$Amr = \frac{W_{ob}}{t} \tag{3}$$

where:
- Amr – annual amortization ($PLN \cdot year^{-1}$),
- W_{ob} – replacement value of a building (PLN),
- t – amortization period (years).

Amortization period of buildings was determined based on the GUS index.

Insurance was accepted based on information given by a farm owner. Variable costs were assumed acc. to data obtained from a farmer/farm owner as a sum of renovation costs and costs of electric energy consumption.

$$Kz = Kr + Ke \tag{4}$$

where:

- Kz – variable costs (PLN),
- Kr – renovation costs (inter alia material for repairs, costs of ordered and own works, paintings of rooms, spackling, plaster renovation) (PLN),
- Ke – electric energy consumption costs (PLN).

Description of the researched farms

Average area of agricultural land in the researched farms was 12.92 ha (table 1). Area of arable land (5.58 ha) was comparable to the acreage of meadows (5.18 ha), which resulted in a situation that after adding new pastures to them, grasslands prevailed in the structure of use constituting 53.02%. Farms which were emphasised, with regard to the production trend, differed. Area of agricultural land in facilities which specialized with animal production was 1.6 times higher than in the group of plant farms. Moreover, in farms maintaining animals, participation of grasslands was 69.08% whereas in the comparative group – it was only 24.82%.

Table 1
Area and structure of agricultural land

Specification	Production trend				Average	
	Plant production		Animal production			
Number of farms	24		26			
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Arable land	6.62	67.62	4.62	29.20	5.58	43.18
Meadows	1.91	19.51	8.20	51.84	5.18	40.12
Pastures	0.52	5.31	2.73	17.24	1.67	12.90
Orchards (ha)	0.67	6.84	0.25	1.59	0.45	3.50
Perennial plantations (ha)	0.07	0.72	0.02	0.13	0.04	0.31
Agricultural land (had)	9.79	100.00	15.82	100.00	12.92	100.00

In the structure of crops the highest differences concerned fodder plants and vegetables because in plant farms they constituted respectively: 31.87% and 14.35% whereas in facilities which deal with animal production: 62.85% and 3.39% (table 2).

Table 2
Area and structure of crops

Specification	Production trend				Average	
	Plant production		Animal production			
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Grains	2.92	44.11	1.33	28.85	2.10	37.63
Root crops	0.27	4.08	0.23	4.91	0.25	4.48
Fodder crops	2.11	31.87	2.90	62.85	2.52	45.16
Vegetables	0.95	14.35	0.16	3.39	0.54	9.68
Herbs	0.37	5.59	0.00	0.00	0.17	3.05

Average number of headage was 8.81 LSU (livestock unit) whereas livestock – 0.63 $LSU \cdot ha^{-1}$ (table 3). Cattle prevailed in the flock structure and constituted at the average 90% of headage. Plant farms maintained at the average only 2.54 LSU and farms which specialize in animal production almost 6 times more i.e. 14.60 LSU. Thus, livestock was respectively: 0.24 and 0.99 $LSU \cdot ha^{-1}$.

Table 3
Number and livestock

Specification	Production trend				Average	
	Plant production		Animal production			
	($LSU \cdot farm^{-1}$)	($LSU \cdot ha^{-1}$)	($LSU \cdot farm^{-1}$)	($LSU \cdot ha^{-1}$)	($LSU \cdot farm^{-1}$)	($LSU \cdot ha^{-1}$)
Horses	1.25	0.09	0.14	0.04	0.67	0.06
Cattle	1.18	0.12	14.29	0.90	8.00	0.53
Pigs	–	–	0.09	0.03	0.05	0.02
Poultry and others	0.11	0.03	0.08	0.02	0.10	0.02
Total	2.54	0.24	14.60	0.99	8.81	0.63

Research results

Capital, composed of circulating assets and fixed assets, including inter alia buildings and structures, is one of production factors in farming. Intensity of scientific and technical progress and implementation of new technologies in agricultural production, related herewith, induce thus to balancing construction resources and determination of degree of their use (Mulica and Hutnik, 2007; Malaga-Toboła, 2009).

Area of farm buildings in the investigated facilities was at the average 314.45 m^2 (table 4). This area in distinguished groups on account of production trend was comparable and in farm specializing in plant production was 321.79 m^2, and in animal production – 307.38 m^2. Storehouses, the participation of which was at the average of 45.10% and livestock buildings - 30.70% constituted the highest area. These results confirm earlier, obtained by many authors (Kowalski and Tabor, 2003; Kuboń, 2008b, 2011; Kuboń and Tabor, 2010; Malaga-Toboła, 2011) according to which in a great number of farms, both the possessed storehouses and livestock buildings potential, exceeds present demand both for storing and the quantity of livestock. Whereas, their low use causes the increase of production costs. Wasilewski (2004) emphasises that it influences particularly in case of storehouses, since farming is a branch, which characterizes with seasonal stocks.

However, a predicted, high area variety of particular types of buildings in trend groups was not reported. It is a fact that the participation of livestock buildings, on account of area in farms which specialize in animal production was by 10% higher than in plant farms. While, participation of storehouses in plant farms was higher by 14.53% in comparison to facilities which specialize in animal production.

Table 4
Area and structure of farm buildings

Specification	Production trend				Average	
	Plant production		Animal production			
	(m^2)	(%)	(m^2)	(%)	(m^2)	(%)
Livestock buildings	82.38	25.60	110.15	35.84	96.54	30.70
Storehouses	168.42	52.34	116.23	37.81	141.81	45.10
Garages	35.00	10.88	38.46	12.51	36.76	11.69
Carports	36.00	11.19	42.54	13.84	39.33	12.51
Buildings in total	321.79	100.00	307.38	100.00	314.45	100.00

Average replacement value of buildings with reference to a farm was PLN 105.78 thousand and to a hectare – PLN 8.63 thousand. (table 5). This index, in the first case was comparable in trend groups whereas in the second one differed considerably. Replacement value of buildings in farms, which specialize in plant production was by PLN 3.76 thousand$\cdot ha^{-1}$ higher than in comparison to the second analysed trend group. It mainly followed from a higher by 52.19 m^2surface area of storehouses in these facilities. This condition is correct, since the storehouses play a very significant function at storing produce, especially if these are organic products, which when stored in improper conditions lose their properties quickly.

Participation of the replacement value of storehouses in the group of farms, where plant production dominated was as much as 49.8% (figure 1). The fact that livestock buildings in animal farms, had the highest participation (43.3%) in the replacement value structure, is also correct. Replacement value of garages and carports was comparable in the analysed trend groups and its participation was respectively at the average: 11.0 and 8.2%.

Table 5
Replacement value of farm buildings

Specification	Production trend				Average	
	Plant production		Animal production			
	(thousand PLN·farm^{-1})	(thousand PLN·ha^{-1})	(thousand PLN·farm^{-1})	(thousand PLN·ha^{-1})	(thousand PLN·farm^{-1})	(thousand PLN·ha^{-1})
Livestock buildings	34.08	3.48	46.95	3.13	39.86	3.26
Storehouses	53.53	5.46	39.57	2.64	45.52	3.70
Garages	11.47	1.17	12.32	0.82	11.68	0.95
Carports	8.30	0.85	9.47	0.63	8.72	0.71
Total	107.37	10.98	108.32	7.22	105.78	8.63

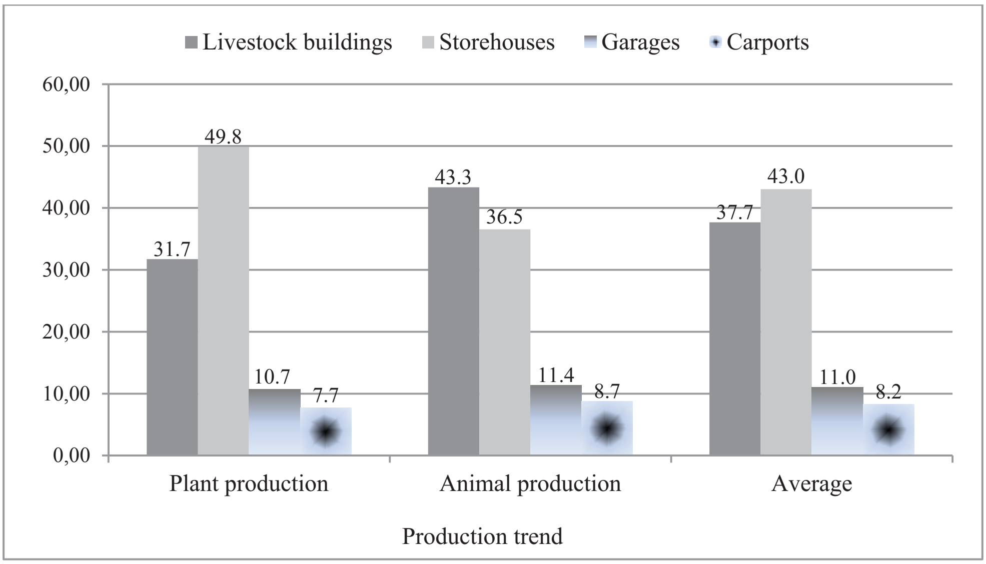

Figure 1. Structure of the replacement value of farm buildings

Total operating costs of buildings were PLN 58.61 thousand. (table 6). Average 67% of their value was per an animal farm (figure 2).

Table 6
Operating costs of farm buildings (thousand PLN·farm^{-1})

Specification	Amortization	Insurance	Insuran-ce	Raw mate-rials for repairs	Ordered repairs	Own work	Total costs
			Plant production				
Livestock buildings	0.70	0.30	0.70	4.10	7.50	0.06	13.36
Storehouses	0.70	0.20	0.30	1.90	2.00	0.07	5.17
Garages	0.23	0.05	0.20	–	–	–	0.48
Carports	0.25	0.03	0.10	–	–	–	0.38
Buildings in total	1.88	0.59	1.29	6.00	9.50	0.12	19.38
			Animal production				
Livestock buildings	0.94	0.26	1.87	11.35	7.50	0.08	21.99
Storehouses	0.53	2.29	0.92	5.03	5.00	0.07	13.83
Garages	0.25	0.09	0.40	1.60	0.50	0.02	2.86
Carports	0.27	0.16	0.12	–	–	–	0.54
Buildings in total	1.98	2.79	3.32	17.97	13.00	0.17	39.23
			Total				
Livestock buildings	1.64	0.56	2.57	15.45	15.00	0.13	35.35
Storehouses	1.23	2.49	1.22	6.93	7.00	0.14	19.00
Garages	0.48	0.14	0.60	1.60	0.50	0.02	3.34
Carports	0.52	0.19	0.21	–	–	–	0.92
Buildings in total	3.86	3.38	4.61	23.97	22.50	0.29	58.61

From among the components of costs, only amortization was comparable in the investigated trend farms and its participation was 51.4% and 48.6%, respectively for facilities which specialized in animal and plant production. The remaining components of operating costs were decisively higher in farms, which maintained livestock animals and the scope of their participation was from 82.7% in case of insurance to 57.7% in case of ordered repairs and own work related to inter alia with painting rooms, spackling (fig. 2).

Repair materials (40.9%) and ordered repairs (38.4%) constituted the highest participation in total operating costs of buildings (figure 3). Many farmers, being aware of competitiveness, invest in farm development, in big part in modernization of livestock buildings, storehouses and garages. Thus, materials used for renovations of livestock buildings constituted 43.7% of storehouses – 36.4% and garages – 47.9% (fig. 3). Whereas, costs of ordered repairs were respectively: 42.4; 36.8 and 15.0%.

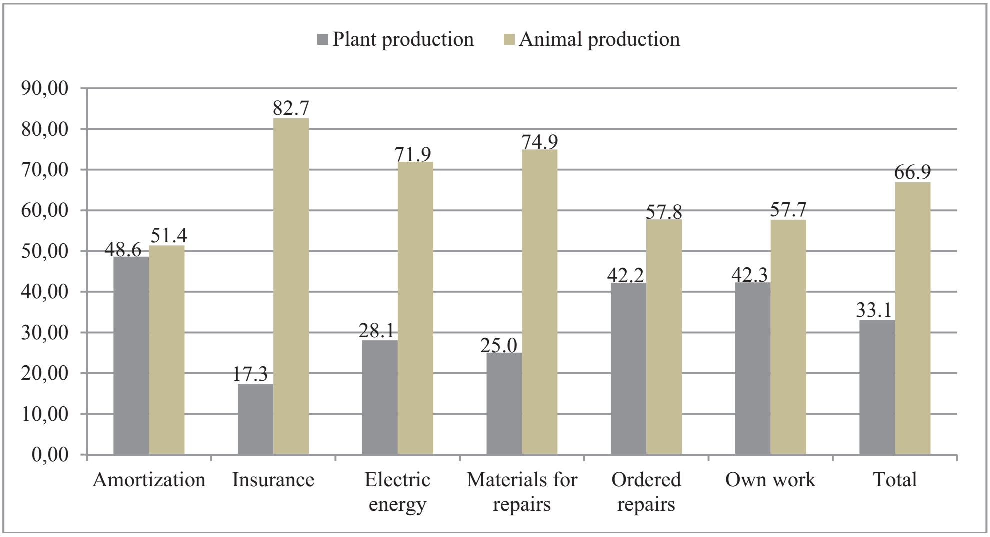

Figure 2. Structure of operating costs of buildings in trend groups

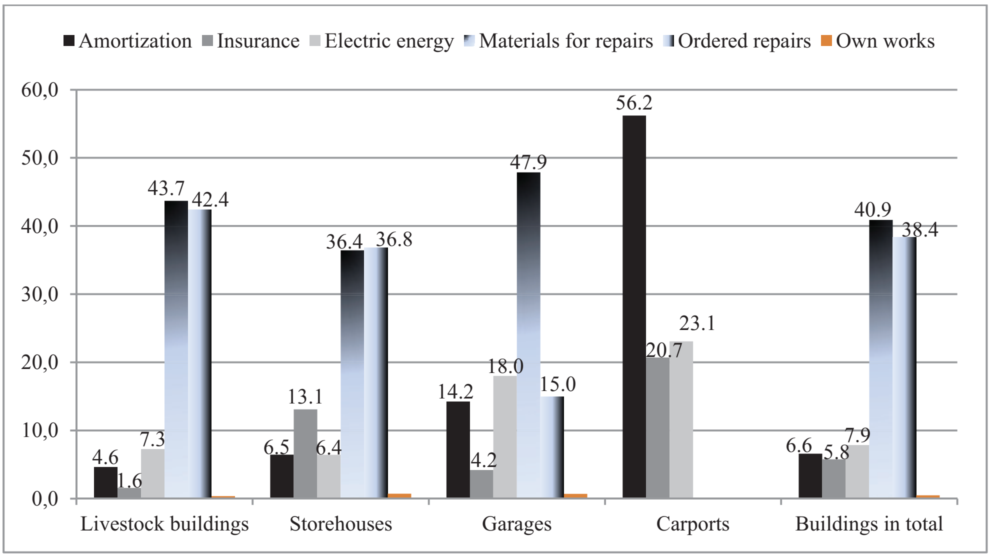

Figure 3. Structure of operating costs of buildings depending on their type

Participation of the remaining composing costs did not exceed 10%. Only, operating costs of carports shaped differently because only their 3 components occurred, that is: amortization, insurance and electric energy.

Costs of electric energy consumption compose the operating costs of buildings. Research show that the sector of construction is responsible for over 40% of energy consumption in the European Union and livestock buildings are characterized with one of the highest indexes of energy consumption (Myczko et al., 2003). Thus, with regard to energy aspects, specialists suggest designing livestock buildings.

Conclusion

Average area of farm buildings in the investigated facilities was 314.45 m^2 and was comparable in the distinguished trend groups. In plant farms, storehouses occupied the biggest area and in case of animal farms - livestock buildings.

Average replacement value of buildings was PLN 105.78 thousand and with reference to a farm, it was also comparable in trend groups. Whereas, per an area unit of agricultural land, this value was considerably higher in facilities which specialized in plant production. In the structure of replacement value storehouses and livestock buildings prevailed, which constituted at the average 43.03% and 37.68%.

Facilities which maintained livestock animals incurred decisively higher operating costs of buildings. Participation of their particular components was within 51% to 83%. Average operating costs of buildings were 58.61thousand PLN·$farm^{-1}$, whereas with reference to a hectare of AL – PLN 4.54 thousand. The fact that the these costs in livestock animal farms were 2 times higher than in plant farms, should be emphasised (PLN 39.23 thousand) than in plant farms (PLN 19.38 thousand). Renovation materials and ordered works constituted the highest costs.

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WARTOŚĆ ODTWORZENIOWA BUDYNKÓW GOSPODARSKICH I KOSZTY ICH EKSPLOATACJI W GOSPODARSTWACH EKOLOGICZNYCH

Streszczenie. Od kilku lat utrzymuje się tendencja wzrostowa w ilości oddawanych do użytku budynków produkcyjnych w rolnictwie, głównie obiektów inwentarskich. W pracy określono poziom i strukturę wyposażenia wybranych gospodarstw ekologicznych w budynki gospodarskie oraz obliczono ich wartość odtworzeniową i koszty eksploatacji. Zakresem badań objęto 50 obiektów położonych w rejonie Polski południowej, posiadających certyfikat gospodarstwa ekologicznego. Badane obiekty były przedmiotem badań w grancie rozwojowym pt. „Innowacyjne oddziaływanie techniki i technologii oraz informatycznego wspomagania zarządzania na efektywność produkcji w gospodarstwach ekologicznych". Analizowane dane dotyczyły roku 2012. W celu analizy porównawczej badane obiekty podzielono na dwie grupy: specjalizujące się w produkcji roślinnej i zwierzęcej. Średnia powierzchnia budynków wynosiła 314,45m^2 i była porównywalna w wyróżnionych grupach kierunkowych. W gospodarstwach ukierunkowanych na produkcję roślinną przeważały magazyny, a w przypadku gospodarstw utrzymujących zwierzęta – budynki inwentarskie. Średnia roczna wartość odtworzeniowa budynków wynosiła 105,78 tys. PLN i również była porównywalna w grupach kierunkowych. W strukturze wartości odtworzeniowej przeważały magazyny, które średnio stanowiły 43,03%, a 37,68% budynki inwentarskie. Średnie roczne koszty eksploatacji budynków wynosiły 58,61 tys. PLN. Na uwagę zasługuje fakt, że koszty te w gospodarstwach utrzymujących zwierzęta były 2-krotnie wyższe, niż w obiektach z produkcją roślinną. Największe koszty stanowiły materiały remontowe oraz naprawy zlecone.

Słowa kluczowe: gospodarstwa ekologiczne, budynki gospodarskie, wartość odtworzeniowa, koszty eksploatacji

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IMPACT OF WORKING PARAMETERS OF THE PIN SOWING UNIT AND SOWING PARAMETERS ON THE REGULARITY OF DOSING OATS SEEDS

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ABSTRACT

The paper presents the research results concerning the impact of rotational speed of a sowing shaft (4-34 rot·min^{-1}), width of a sowing opening (1-5 mm) in a pin sowing unit and width of interrows (7-15 cm) and sowing speed (4-12 km·h^{-1}) on the regularity of dosing Flämingsprof oat seeds at the fixed amount of sowing 156 kg·ha^{-1}, which results from the accepted, recommended stock density of 400 seeds·m^{-2}. Tests were carried out on the laboratory stand in two stages. In the first one, measurements related to determination of the performance characteristic of the tested sowing unit was carried out, in the second one, measurements related to determination of the longitudinal irregularity index of seeds sowing was performed. It was proved that from among the investigated factors, regularity of dosing seeds has significant impact (α=0.05) on the width of interrows, rotational speed of the sowing shaft and the width of the sowing opening. From analysis of regression of many variables with stepwise procedure of elimination of non-significant variables, a second degree equation was obtained, which included independent variables - the width of interrows and the width of the sowing opening. The value of irregularity index of seeds sowing at the change of interrows width from 7 to 15 cm decreased by approx. 35% – from value 0.72 to 0.46.

Introduction and the objective of the paper

Sowing, next to soil cultivation, fertilization and plant protection treatments is an agrotechnical treatment, which influences the size and quality of plant cropping. The quality of its performance is particularly important i.e. maintenance of the constancy of the accepted amount of dissemination and regularity of seeds distribution in soil - in vertical and horizontal plane of a field and performance of sowing within optimal time limit is particularly significant.

The basis for assessment of the quality of sowing grains and plants, similar to grains sown with seed drills (universal), is regularity of their distribution in a row, i.e. maintenance of constant or close to constant distance between seeds in a row. However, due to lack of proper mathematical formula which allows determination of the index of seeds sowing regularity, regularity is determined indirectly through determination of the dosing (or sowing) irregularity index (PN-84/R-55050):

$$\delta = \frac{\sqrt{\frac{\sum_{j=1}^{k} x_j^2 f_j}{\sum_{j=1}^{k} f_j} - \bar{x}^2}}{\bar{x}_a} \tag{1}$$

where:

- f_j – number of line segments with X_i (class variant) number of seeds
- x_j – number of seeds in a row on f_j 0.1 m line segments,
- $\bar{x}_a$ – arithmetic mean of the number of seeds in a row, for a line segment f_j,
- $\bar{x}$ – mean value.

Arithmetic mean of the number of seeds in a row $\bar{x}_a$, per a line segment f_j is calculated from the formula:

$$\bar{x}_a = \frac{\sum_{j=1}^{k} x_j f_j}{\sum_{j=1}^{k} f_j} \tag{2}$$

Procedure of testing irregularities of dissemination acc. to the Polish Norm (PN-84/R-55050) consists in: dissemination of seeds on a plate which is at least 2.20 long, the surface of which is covered with smear in order to immobilize sown seeds. A measurement plate should be divided into twenty 10-cm elementary fields (sections). After sowing of seeds, their number is counted on 20 line segments and the obtained results are collated into number classes x_j, which contain from the lowest to the highest number of seeds, stating multiplicity f_j of their occurrence, e.g.: 6 seeds disseminated in 2 sections, 8 seeds in 4 sections, etc.

Value of index is affected by structural features of working elements of a seed drill (a sowing unit, seed conduit and a drill opener), physical properties of seeds as well as working parameters of a seed drill, i.e. sowing speed, or width of interrows (Kogut, 1998; Rawa and Markowski, 2001).

From among seed drill components which influence the manner of seeds distribution in a row (value of the index of irregularity of dosing seeds), the sowing unit is the most significant (Heege, 1993; Lipiński, 2001; Kogut, 2005; Grudnik, 2006). Thus, increased interest in improvement of structure of sowing units and sowing techniques has been reported in recent years. However, there is not much information concerning the impact of structural and working parameters of the sowing unit on the quality of its performance (Lejman and Owsiak, 1994; Rawa and Lipiński, 2001; Rawa and Markowski, 2001; Lipiński et al., 2004, Rawa et al., 2005; Markowski and Rawa, 2009b; 2010). Mainly, general recommendations stated in user's manuals for seed drills concerning settings of the sowing unit during dissemination of specific variety of seeds, are known.

Therefore, the objective of this paper was assessment of the impact of working elements of the selected pin sowing unit and width of interrows and sowing speed on the regularity of dosing oat seeds for the same stocking density of seeds on a field which results from the accepted size of sowing 156 kg·ha^{-1}.

Object and methodology of research

Laboratory experiment was carried out on the research position (Markowski et al., 2007) comprising a single pin sowing unit produced by PIMR (Markowski and Rawa, 2008) with a seed box, a unit of a sticky tape "endless" with a measuring end for determination of sowing regularity of 2 metres length and a driveline on the first and the second unit. All controls which occur in a typical universal seed drill were maintained in a sowing unit. A sowing unit was driven from an electric engine by the v-belt transmission unit. Siemens „Micromaster 420" frequency converter was used for the change of rotational speed of the sowing unit whereas for the drive of sticky belt an electric engine controlled by frequency converter „Invertron GMI S13".

Experimental material comprised oat seeds of *Flämingsprof* variety purchased in Olsztyńska Hodowla Ziemniaka i Nasiennictwa OLZNAS-CN Sp. z o.o. of 100% cleanness, 13.0% moisture and thousand seeds mass of 38.93 g.

The following results were accepted in the research:

1. Constants:
- amount of sowing Q – 156 kg·ha^{-1}, resulting from the accepted stock density 400 seeds·m^{-2},
- height of a supplying slot in the seed box s_z – 35 mm.

2. Variables:
- width of the sowing slot (working) s_w – 1-5 mm, in step manner every 1 mm,
- width of interrrows m_m – 7-15 cm, in step manner every 2 cm,
- sowing speed (sticky tape) v_s – 4-12 km·h^{-1}, changes in stepwise manner every 2 km·h^{-1},
- rotational speed of the pin sowing shaft by PIMR n_w – arranged in an experiment so the amount of sowing in each combination of factors was constant.

3. Resultant:
- irregularity of dosing seeds – δ.

Research was carried out in two stages. In the first stage of research, measurements related to determination of performance characteristics of the pin sowing unit by PIMR were carried out, based on which, rotational speeds of a sowing shaft at the maintenance of the accepted amount of sowing of 156 kg·ha^{-1} were determined for the accepted working parameters (speed of a sticky tape – which simulates the seed drill motion, width of the sowing opening and the width of interrows). On the second stage related to determination of irregularities of dosing seeds, research was carried out in three repeats pursuant to norm PN-84/R-55050. Ordinates of seeds location on a two-meter measurement length of a sticky tape, werte determined with precision up to 1 mm, positioning the index with a milimetre scale over the geometrical centre of a seed and then a readout of location of the index was carried out on the sticky tape with precision to 1 mm (corresponding to the seed location). Before a subsequent test the tape was cleaned of seeds and then covered with a thin (approx. 1-2 mm) layer of smear. Moreover, level of seeds was supplemented in the seed box, maintaining their fixed level during research.

The results of measurements were subjected to statistical analysis in which analysis of variance, analysis of correlation of factors and analysis of regression of many second degree variables with the stepwise procedure of elimination of insignificant variables and the degree of polynomial, were included

Research results

The analysis of correlation of factors shows that the performance of the sowing is infleunced by only one variable – rotational speed of the sowing shaft (coefficient of correlation 0.99 - at the critical value approx. 0.19). The second factor – width of the sowing slot – at the level of statistical significance α=0.05, has no significant impact (coefficient of correlation 0.15). Thus, the performance of the sowing unit may be described by the linear equation with one independent variable (rotational speed of the sowing shaft). The equation obtained from the analysis of linear regression of many variables, is characterized with high percentage of the explained variability – above 97%.

Table 1 presents rotational speeds of the dosing shaft indispensable for obtaining the accepted (156 $kg \cdot ha^{-1}$) amount of oat seeds sowing depending on the accepted speed of sowing (speed of the sticky tape), width of interrows and set width of a working opening of the sowing unit of a seed drill. For the whole experiment, rotational speeds of the sowing shaft were within 4.0 and 34.0 $rot \cdot min^{-1}$. The lowest rotational speed of the shaft was used respectively for the lowest speed of sowing and the interrows width and the highest width of w sowing opening used in the research (5 mm). Whereas, the maximum rotational speed was used for the highest width of itnerrows and sowing speed (respectively 12 $km \cdot h^{-1}$ and 15 cm) and the lowest width of a sowing slot (1 mm). The value of the index of irregularity of dosing seeds for the whole experiment is within approx. 0.28 and approx. 0.99 but its mean value is approx. 0.56 (tab. 2). The lowest value of index was obtained from the biggest (15 cm) and the highest for the smallest width of interrows (7-9 cm).

When analysing the value of standard deviation and coefficient of variability for the interrows widths used in the research, one may notice that they are similar and they do not depend on the intterrows width accepted in the research. The lowest values of these statistical parameters were obtained for the biggest interrows widths i.e. 13 and 15 cm.

Table 1
Rotational speed of the sowing shaft n_w for the amount of sowing oat seeds 156 kg·ha^{-1}

Sowing opening width s_w (mm)	Sowing speed v_s (km·h^{-1})	Interrows width m_m (cm)				
		7	9	11	13	15
		Rotational speed of a sowing shaft n_w (rot·min^{-1})				
1	4	5.3	6.8	8.3	9.8	11.4
	6	8.0	10.2	12.5	14.7	17.0
	8	10.6	13.6	16.6	19.6	22.6
	10	13.2	17.0	20.8	24.5	28.3
	12	15.9	20.4	24.9	29.4	**34.0**
2	4	4.9	6.4	7.8	9.2	10.7
	6	7.5	9.6	11.7	13.9	16.0
	8	10.0	12.8	15.7	18.5	21.4
	10	12.5	16.0	19.6	22.5	26.8
	12	15.0	19.3	23.5	27.8	32.1
3	4	4.6	6.0	7.3	8.7	10.1
	6	7.0	9.0	11.1	13.1	15.2
	8	9.2	12.1	14.8	17.5	20.2
	10	11.8	15.2	18.6	22.0	25.4
	12	14.1	18.2	22.3	26.4	30.5
4	4	4.3	5.6	6.9	8.2	9.5
	6	6.6	8.5	10.5	12.4	14.4
	8	8.8	11.4	14.0	16.6	19.2
	10	11.1	14.4	17.6	20.9	24.1
	12	13.4	17.3	21.5	25.1	29.0
5	4	**4.0**	5.3	6.5	7.7	9.0
	6	6.2	8.0	9.9	11.8	13.6
	8	8.4	10.8	13.3	15.8	18.3
	10	10.5	13.6	16.7	19.8	23.0
	12	12.7	16.4	20.2	23.9	27.6

Table 2
Statistical parameters δ of irregularity index of dosing oat seeds at the amount of sowing of 156 kg·ha^{-1}, sowing speed within the scope of 4-12 km·h^{-1}, the width of a supplying opening in the sowing unit 1-5 mm and rotational speed of the sowing shaft 4-34 rot·min^{-1}

Interrows width m_m (cm)	Index of regularity of dosing seeds δ (–)				
	min. value	max. value	mean value	standard deviation	coefficient of variation (%)
7	0.4232	0.9985	0.7145	0.1291	18.07
9	0.3662	0.9368	0.6143	0.1231	20.04
11	0.3222	0.8562	0.5292	0.1129	21.33
13	0.2898	0.6961	0.5010	0.0903	18.03
15	0.2778	0.6845	0.4612	0.0845	18.33
mean	0.3358	0.8344	0.5640	–	–

Analysis of factors correlation (tab. 3) shows that the interrows width (coefficient of correlation - approx. -0.62) and rotational speed of the sowing shaft (coefficient of correlation – approx. -0.46) have the biggest impact on the irregularity of dosing oat seeds. Negative value of correlation coefficient for both independent variables shows that along with the increase of rotational speed of the dosing shaft the value of the index of sowing irregularity decreases and thus regularity of sowing improves. It results form higher intensity of influence of pulling elements of the dosing shaft on the sown stream of seeds and thus their more regular feed to the seed conduit (smaller pulsation of the seed stream). Also a third variable i.e. width of a sowing slot (coefficient of correlation 0.31) have significant impact on the regularity of dosing oat seeds. In case of this independent variable, positive value of the index of irregularity of sowing seeds indicates that along with the increase of the size of the sowing opening, regularity of sowing deteriorates. It follows from the nature of moving seeds in the outside layer (which includes the space between outside edges of pulling elements of the dosing shaft and the edge of a bottom) as a result of friction between seeds. Too high value of the opening is a reason for even less motion of seeds in the outside layer and thus deterioration of the regularity of dosing seeds. Impact of the fourth independent variable (sowing speed) proved to be insignificant at the level of statistical significance α=0.05. It should be emphasised that from among four factors, accepted as independent variables, the following couples are strongly and significantly correlated: the sowing speed and rotational speed of the sowing shaft (coefficient of correlation – approx. 0.78) and the interrows width and rotational speed of the sowing shaft (coefficient of correlation – approx. 0.57). Second degree equation was obtained from the analysis of regression of many variables with stepwise procedure of insignificant variables elimination (table 3) where interrows width and width of the sowing opening appear as independent variables. The third factor - rotational speed of the sowing shaft - significantly correlated with irregularity of dosing seeds with a pin sowing unit was eliminated from the equation in the stepwise procedure of regression analysis because it is considerably correlated with the speed of a sticky tape (coefficient of correlation 0.78) and the width of interrows (0.56) and less with the width of the sowing slot (-0.17). Graphic image of the regression equation given in table 3 was presented in figure 1.

Table 3
Analysis of correlation and regression of irregularity of dosing oat seeds for four variable factors at the amount of sowing of 156 kg·ha^{-1}

Item	Variable	Mean value	Standard deviation	Coefficient of variation (%)
1.	Width of sowing opening s_w (mm)	3.00	1.4161	47.20
2.	Sticky tape speed (sowing) v_s (km·h^{-1})	8.00	2.8322	35.40
3.	Interrows width m_m (cm)	11.00	2.8322	25.75
4.	Rotational speed of a sowing shaft n_w (rot·min^{-1})	14.89	6.8417	45.95
5.	Irregularity of dosing seeds δ	0.5640	0.1416	25.10

Correlation matrix

	s_w	v_s	m_m	n_w	δ
s_w	1.000	0.000	0.000	-0.169	0.308
v_s	0.000	1.000	0.000	0.779	-0.086
m_m	0.000	0.000	1.000	0.556	-0.620
n_w	-0.169	0.779	0.566	1.000	-0.456
δ	0.308	-0.086	-0.620	-0.456	1.000

Verification of hypothesis on the significance of regression equation coefficients

The accepted level of significance	0.05
Critical value of correlation coefficient	0.1013
Value of statistics F172.3700	
Probability of exceeding F statistics	p(F)=0.0000
Percent of explained variability	48.10
Standard deviation of remainders	0.1021

Regression equation

$$\delta = -0.0310 \cdot m_m + 0.0051 \cdot s_w^{\ 2} + 0.8490$$

As it can be seen (fig. 1) irregularity of dosing oat seeds below the required value of 0.45 included in PN-84/R-55050 is obtained at the interrows width above 15 cm. It should be added that the obtained value of seeds dosing irregularity refers to the same sowing unit without a seed conduit and a drill opener. Research carried out by Lejman and Owsiak (1994) proves that at their use, irregularity of dissemination of seeds should improve by approx. 10%. Then, upon including favourable impact of a seed conduit and a drill opener requirements concerning the quality of sowing with the sowing unit used in the research should be met as soon as from the interrrows width which is approx. 12.5 cm. Thus, for interrows width below 12.5 cm it is recommended to use sowing shafts of a multi-sectional structure with three or more sections (Rawa and Markowski, 2001; Markowski and Rawa, 2009a). In such shafts during dosing seeds in reduced amounts there is a possibility of excluding specific sections and thus adjustment of their working volume to the amount of sown seeds. The use of additional elements in the form of screens for reduction of active length of pulling pins is another solution which allows reduction of the working space of dosing shafts (Rawa and Markowski, 2001). Backward shafts mounted directly behind the sowing unit designated for equalization of the stream of seeds, known from mechanical and pneumatic seeders by Sulky company, may also be used (Markowski et al. 2011, 2012).

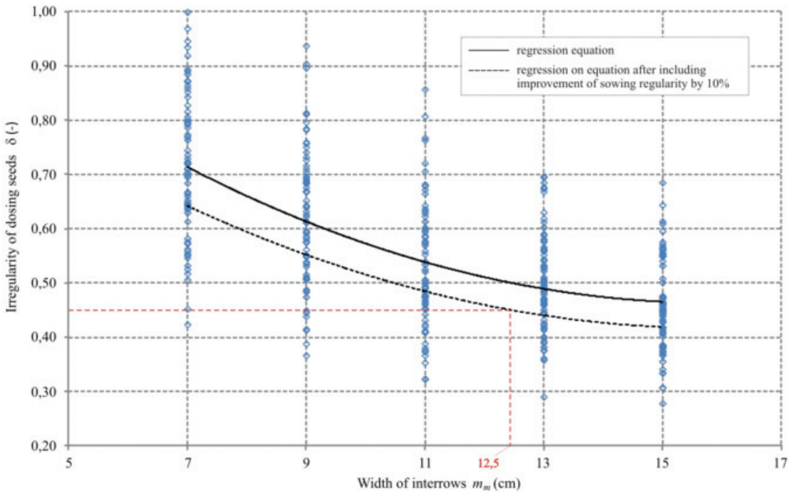

Figure 1. Coefficient δ of irregularity of dosing oat seeds with a pin sowing unit at the amount of sowing 156 kg·ha^{-1} depending on the width m_m of interrows

Due to low percentage of the explained variability – approx. 48% the obtained regression equation has a low suitability for forecasting regularity of dosing seeds. Thus, analysis of variance was carried out with the use of double classification with interaction (table 4) considering the following statistical hypotheses:

1. For the width of the sowing opening s_w:

Hypothesis H_0 – mean values of irregularity of dosing oat seeds at five various widths of a sowing opening are equal,

2. For the sowing speed (sticky tape) v_s:

Hypothesis H_0 – mean values of irregularity of dosing oat seeds at five various speeds of sowing are equal,

3. For interaction of the width of a sowing opening s_w and sowing speed v_s:

Hipothesis H_0 – mean values of irregularity of dosing oat seeds at five various widths of a sowing opening and five sowing speeds are equal,

For such hypotheses H_0 alternative hypotheses H_1 on the lack of equality of mean values of irregularity of dosing oat seeds at accepted levels of variability of independent variables were considered.

Results of statistical analysis presented in table 4 also confirm the significant impact on irregularities of dosing oat seeds, presented in the linear correlation analysis. It presents that mean irregularity of dosing seeds obtained at the sowing opening width of 4 and 5 mm is significantly (α=0.05) and highly significantly different than the obtained at the sowing opening width of 1, 2 and 3 mm. In case of the other change – the width of interrows – highly significant differences (α=0.01) occur between the smallest width (7 cm) and the remaining interrows widths and also between interrrows of 9 cm width and interrows of widths 11, 13 and 15 cm and between an interrow of 11 cm width and interrows with widths of 13 and 15 cm. On the other hand, a significant difference at the level of α=0.05 was reported between the widest interrows used in the experiment i.e. between 13 and 15 cm. Moreover, the analysis of variance with interraction of two independent variables i.e. the width of a sowing opening and the width of interrows did not prove their significant impact on average value of the index of irregularity of dosing oat seeds.

Table 4

Irregularity analysis of variance of dosing oat seeds with a pin sowing unit of PIMR structure (double classification – fixed orthogonal model)

Item	Sowing opening width s_w (mm) Factor A	Number	Mean value (–)	Standard deviation (–)	Coefficient of variation (%)
S1	1	75	0.5154	0.1274	24.71
S2	2	75	0.5233	0.1233	23.57
S3	3	75	0.5456	0.1331	24.39
S4	4	75	0.6104	0.1492	24.45
S5	5	75	0.6256	0.1396	22.32
Item	Interrows width m_m (cm) Factor B	Number	Mean value (–)	Standard deviation (–)	Coefficient of variation (%)
M1	7	75	0.7145	0.1291	18.07
M2	9	75	0.6143	0.1231	20.04
M3	11	75	0.5292	0.1129	21.33
M4	13	75	0.5010	0.0903	18.03
M5	15	75	0.4612	0.0845	18.33

Accepted significance level α	0.05
Value of statistics F_A for factor A	19.5674
Probability of exceeding value F_A	0.0000
Because $p(F_A) < \alpha$ – hypothesis H_0 should be rejected for the benefit of alternative hypothesis H_1	
Results of significance of differences (of Duncan's test): S4, S5 > S1, S2, S3*	
Value of statistics F_B for factor B	77.6966
Probability of exceeding value F_B	0.0000
Because $p(F_B) < \alpha$ – hypothesis H_0 should be rejected for the benefit of alternative hypothesis H_1	
Results of significance of differences (of Duncan's test): M1 > M2, M3, M4, M5* M2 > M3, M4, M5* M3 > 5* M4 > M5**	
Value of statistic F_{AB} for combination of factors A×B	1.2727
Probability of exceeding value $_{FAB}$	0.2116
Because $p(F_{AB}) > \alpha$ – has no basis for rejection of zero hypothesis H_0	

* – statistically significant differences at the significance level α = 0.01

** – statistically significant differences at the significance level α = 0.05

Conclusions

1. From among four factors – the interrows width, sowing speed (of sticky tape), rotational speed of a sowing shaft and sowing opening width – three factors: interrows width, width of a sowing opening and rotational speed of a sowing shaft have significant impact on irregularity of dosing oat seeds with a pin sowing unit at the size of dissemination of 156 $kg\cdot ha^{-1}$.
2. Irregularity of dosing seeds with a pin sowing unit may be described with a second degree polynomial, where interrows width and width of a sowing opening appear as independent variables. The third from among the factors, that is rotational speed of the sowing shaft – significantly correlated with irregularity of dosing seeds – in the analysis of regression with stepwise procedure, was not added to the equation due to its correlation with the interrows width, sowing speed and width of the sowing opening.
3. A pin sowing unit by PIMR at sowing oat seeds in the amount of 156 $kg\cdot ha^{-1}$ meets the requirements of the Polish Norm (PN-84/R-55050), acc. to which coefficient of lengthwise irregularity of sowing should be below the value of 0.45 only at the interrows width above 12.5 cm.

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WPŁYW PARAMETRÓW ROBOCZYCH KOŁECZKOWEGO ZESPOŁU WYSIEWAJĄCEGO ORAZ PARAMETRÓW SIEWU NA RÓWNOMIERNOŚĆ DOZOWANIA NASION OWSA

Streszczenie. W pracy przedstawiono wyniki badań dotyczące wpływu prędkości obrotowej wałka wysiewającego (4-34 obr·min^{-1}), szerokości szczeliny wysiewającej (1-5 mm) w kołeczkowym zespole wysiewającym oraz szerokości międzyrzędzi (7-15 cm) i prędkości siewu (4-12 km·h^{-1}) na równomierność dozowania nasion owsa odmiany *Flämingsprof* przy stałej ilości wysiewu 156 kg·ha^{-1}, wynikającej z przyjętej, zalecanej obsady 400 nasion·m^{-2}. Badania przeprowadzono na stanowisku laboratoryjnym w dwóch etapach. W pierwszym wykonano pomiary związane z wyznaczeniem charakterystyki wydajnościowej badanego zespołu wysiewającego, w drugim przeprowadzono pomiary związane z wyznaczeniem wskaźnika nierównomierności podłużnej wysiewu nasion. Wykazano, że spośród badanych czynników istotny wpływ (α=0,05) na równomierność dozowania nasion, ma szerokość międzyrzędzi, prędkość obrotowa wałka wysiewającego oraz szerokość szczeliny wysiewającej. Z analizy regresji wielu zmiennych z krokową procedurą eliminacji zmiennych nieistotnych otrzymano równanie stopnia drugiego, zawierające dwie zmienne niezależne – szerokość międzyrzędzi i szerokość szczeliny wysiewającej. Wartość wskaźnika nierównomierności wysiewu nasion przy zmianie szerokości międzyrzędzi z 7 na 15 cm zmniejszyła się o ok. 35% – z wartości 0,72 do 0,46.

Słowa kluczowe: kołeczkowy zespół wysiewający, nasiona, owies, równomierność dozowania

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MINIMIZATION OF LABOUR INPUTS IN EARLY CABBAGE PRODUCTION TECHNOLOGY

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ABSTRACT

The objective of the paper was determination of the optimum variant of technology of production of early cabbage on supply of the fresh vegetables market from among developed four variants of technology suggested for use in small-area horticultural farms. The scope of the study covered horticultural farms, where the area of cabbage cultivation was in a four-year period from 1.5 to 2.3 hectare. A technology, based on manual work and machinery used earlier for agricultural production in small-area horticultural farms was assumed as a typical carrot production technology. Minimal inputs of human labour and machine labour were accepted as a criteria of optimisation. The 4th variant was an optimal variant from among the analysed. Total inputs of human labour and machine work in this variant were 788.9 h·ha^{-1} and were respectively lower by: 555.1, 568.9 and 659.1 h·ha^{-1} than the estimated for the 3rd, 2nd and 1st variant. Manual work inputs in this variant were lower in comparison to the inputs incurred in the 3rd variant by 533.4 man-hour·ha^{-1}, in the 2nd variant by 544.8 man-hour·ha^{-1} and in the 1st variant by 696.1 man-hour·ha^{-1}, and machines respectively lower by 21.7 mh·ha^{-1} for the 3rd and 24.1 mh·ha^{-1} for the 2nd variant and higher by 37 mh·ha^{-1} in comparison to the 1st variant.

Introduction and the objective of the paper

National production of cabbage, which was in 2011 approx. 1.1 million tonnes is carried out on the area of approximately 34 thousands of hectares. It places Poland at the first place in Europe, and at the eighth in the world (Rocznik Statystyczny, 2011). China is the biggest cabbage producer in the world, with production over 33 million tonnes (which constitutes half of the global production). In the country, the biggest areas of cultivation of cabbage are in Małopolskie voivodeship and Mazowieckie voivodeship and the lowest in Opolskie voivodeship. Average crop in Poland is 35 t·ha^{-1} and it should be recognized as relatively low because presently at the use of new technologies and technique with the use of hydration in highly specialized farms, the obtained crops are at the level of up to 70 t·ha^{-1} (Rocznik Statystyczny, 2011; Bardczak, 2007; Kierczyńska, 2006; Kaniszewski, 2007).

In the country, a trend to introduce new technological and organizational solutions in production of cabbage and other vegetables is visible, and it aims at lowering the inputs of human and machine work and to raise the efficiency of their production (Kowalczuk and Leszczyński, 2006; Kurpaska and Tabor, 2006).

Departing from direct sowing of seeds in soil and moving towards the seedling production and planting in the field of already well developed plants is a new direction in the technology of cabbage production. It allows obtaining considerable savings of seeds because at sowing directly to the soil, 30-40% more of them is sown than it is required. Producing cabbage from seedling may also accelerate harvesting (Adamicki et al., 2005). Simultaneously a shift from the cheapest and prevailing seedling with uncovered root system for the benefit of pot seedling is reported (Babik, 2006). Production of seedling is considerably mechanized, which facilitates the whole process of cabbage production and thus enables reduction of work inputs (Kunicki, 2005).

Planting seedling on a field is a work consuming process in cabbage production, for which various types of planters are used. In small-area farms, the simplest plate planters, which place seedling in a furrow, ploughed out with a drill opener, are used. Gripper planters, which may be used for planting seedlings with uncovered and covered root system in a muskeg cube are also used. Carousel planters, which are equipped with plates with seats may also be used. Seedlings are placed in the shield seats, which while rotating moves them over a leading funnel, through which seedlings get to the bottom of a furrow, made by a drill opener. Big-area farms use a new generation of automatic gripper planters, introduced into the market by Italian company Ferrari Costrzioni Meccaniche under the name Futura. One person shall suffice for its operation, whose task is to give plates. Seedlings are precisely gripped by a root nodule with grippers and placed on conveyors and then in soil. A computer controls the spacing of plants, in which few spacing of rows and planting various cultivars of plants may be set, which considerably facilitates the work. Also, a Swedish company BCC AB implements fully automatic planter. In this machine, plants are ejected by pushers and placed in tunnels, through which they are transported to soil (Podymniak, 2009).

Harvesting is the most burdensome treatment in the cabbage production process. In small-area farms it is an activity fully performed manually. For facilitation of this operation, sometimes belt conveyors are used, which are mounted on a trailer or a tractor. Employees, manually cut cabbage and place it on a belt, therefrom is is transported on trailer, where it is loosely arranged or to box pallets.

A combine may be used in big-area farms for harvesting cabbage. Harvesting of cabbage with this type of machine causes considerable damage to its head and it is the most frequently harvested for food processing, but it allows harvesting cabbage during one day from approximately one hectare.

The presented pre-conditions of cabbage production indicate that in small-area farms in Poland, a competitive cabbage production in comparison to big-area farms is possible, but carried out for direct supply of market in fresh vegetables.

The objective of the paper was comparison of work inputs and indication of the optimal variant of early cabbage production from among the developed four technological variants of a different level of works mechanization suggested for use in small-area horticultural farms. Minimal inputs of human labour and machine labour were accepted as a criteria of optimisation.

Object and the research method

The research was carried out in 2006-2009 in a horticultural farm of cultivation area 7.1 ha located in the southern part of Poland in Baborów municipality. The cultivation area of cabbage in this farm in a four-year period was within 1.5 and 2.3 ha. Based on the analysis of the size of inputs of manual and machine work occurring in the estimated technological variants starting from the initial, subsequent variants were developed, which were carried out in the following years, the assumption of which was to reduce the human and machine work inputs. The characteristic of conditions for the research and methodology was presented in detail in Molendowski et al.'s paper. (2010, 2011). Work inputs on particular technological operations in the researched variants were determined based on the records kept in a current documentation of a farm and timing of human and machine work.

A technology, based on manual work and machinery used earlier for agricultural production in small-area horticultural farms was assumed as a typical carrot production technology. Technological operations within this technology and the manner of their performance were presented in table 1. In this technology after ploughing with a 4-furrow field plough aggregated with Ursus 1212 tractor, further treatments were carried out with the use of Ursus C330 tractor. After ploughing, treatment of soil with a soil miller and seedling planting was performed with the use of a plate five-section planter. The following treatments: herbicide and fungicide spraying with a sprayer with 300 litres container, manual weeding, fertilization by means of a suspended plate centrifugal distributor were carried out.

In the 2nd, 3rd and 4th variant (table 2, 3 and 4) for cultivation works a turning four-furrow plough and a subsoiler were used. In the 2nd variant for treatment of soil a cultivation aggregate aggregated with Ursus C330 tractor was used and in the 3rd variant the same cultivation aggregate but cooperating with Steyr 6660 tractor. In the 3rd and 4th variant for plant protection treatments a sprayer with a 400-litres container was used.

In the process of harvesting and transport in the 1st variant for transportation of boxes to a field a delivery truck, on to which boxes were loaded manually was used. In the process of harvesting of cabbage, crowns were placed in boxes, which were loaded on the transport mean. A delivery truck transported cabbage to the packing place, where boxes with cabbage were manually unloaded and prepared to shipment for consignees. In the 2nd variant a tractor with a trailer and box pallets were used for transport. Box pallets were loaded on a trailer with a fork lift truck and transported to a field. Cabbage after manual harvesting was loaded to box pallets, which were transported to the place of preparing for sale, where box pallets with cabbage were unloaded with a fork lift truck and subjected to further treatment carried out as in the 1st variant.

In the 4th variant (table 4) belt conveyors mounted on a trailer were used for loading cabbage. Employees manually cut out cabbage heads and placed on the conveyor's belt, which transported them to box pallets placed on a trailer.

Research results

Results of the research of work inputs in the researched variants of production technology of early cabbage were presented in table 1-4. In the 1st variant (table 1), which is based on a great participation of manual work and machines used so far in agricultural production and assumed as the basic one for small-area farms, the highest input of manual cultivation work, planting and treatment at planting (150 man-hour·ha^{-1}) and on double weeding (80 man-hour·ha^{-1}). The remaining technological operations have a relatively low participation in the total cultivation work input, planting and treatment, which was 254.2 man-hour·ha^{-1} (fig.1).

Table 1
The list of technological operations and human and mechanical work inputs in the process of cultivation, treatment and cropping and transport of early cabbage for the 1st variant

Process	Technological operation	Manner of performance	Inputs of human work (man-hour·ha^{-1})	Inputs of human work (man-hour·ha^{-1})
Field cultivation, planting and treatment	Ploughing	Tractor 1212+4-furrow field plough	3.5	3.5
	Soil treatment	Tractor C330 + plough	8	8
	Planting	Tractor C330+planter	150	25
	Spraying with herbicide	Tractor C 330 + sprayer 300 l	1.7	1.7
	Double weeding	Manually	80	0
	Spraying with fungicide	Tractor C 330 + sprayer 300 l	6	6
	Operation of fertilization	Manually	2	0
	Fertilization	Tractor C330+spreader	3	3
Harvesting and transport	Loading of boxes	Manually	40	0
	Transport of boxes to a field	Delivery truck	40	13.3
	Cutting out cabbage	Manually	400	0
	Loading cabbage	Manually	400	0
	Transport from a field	Delivery truck	40	13.3
	Unloading and packing	Manually	200	0
Total in technology			1374.2	73.8

Total inputs of manual work in harvesting and transport of early cabbage are approximately 5.4 times higher than in works related to cultivation, planting, treatment and are 1120 man-hour·ha^{-1} (fig.1). The highest work consumption is characterised by activities related to harvesting (400 man-hour·ha^{-1}) and loading (400 man-hour·ha^{-1}) and unloading and packing (200 man-hour·ha^{-1}). It results from the fact that cabbage is arranged in a row close to the place of the transport mean crossing and then it is transferred to a transport mean. After transporting cabbage is unloaded, packed and prepared for transport to a consignee.

Total manual work inputs in the 1st technological variant, which was 1374.2 man-hour·ha^{-1} shall be recognized as very high. Whereas, inputs of mechanized work incurred are relatively low because in this variant these are inputs for field cultivation, planting and treatment – 47.2 mh·ha^{-1}, harvesting and transport 26.6 mh·ha^{-1}, which in total gives 73.8 mh·ha^{-1}.

Based on the determined work inputs in the 1st variant activities for their reduction were undertaken. In the 2nd variant (table 2) for cultivation works, tractors of a higher power were used, which allowed reduction of work inputs.

Table 2
The list of technological operations and human and mechanical work inputs in the process of cultivation, treatment and cropping and transport of early cabbage for the 2nd variant

Process	Technological operation	Manner of performance	Inputs of human work (man-hour·ha^{-1})	Inputs of human work (man-hour·ha^{-1})
Field cultivation, planting and treatment	Ploughing	Tractor Fendt 110+4-furrow field turning plough	2	2
	Soil treatment	Tractor C330 + cultivation aggregate	4	4
	Planting	Tractor C330+planter	150	25
	Spraying with herbicide	Tractor C 330 + sprayer 300 l	1.7	1.7
	Double weeding	Manually	80	0
	Spraying with fungicide	Tractor C 330 + sprayer 300 l	6	6
	Operation of fertilization	Manually	2	0
	Fertilization	Tractor C330+spreader	3	3
Harvesting and transport	Loading of box pallets	Fork lift truck	13.3	13.3
	Transport of box pallets to a field	Tractor C330 + trailer	13.3	13.3
	Cutting out cabbage	Manually	400	0
	Loading cabbage	Manually	400	0
	Transport from a field	Tractor C330 + trailer	40	13.3
	Unloading and packing	Fork lift truck and manually	106.6	53.3
Total in technology			1221.9	134.9

The use of cultivation aggregate in this variant for treatment of soil reduced the work inputs by 4 man-hour·ha^{-1}. The use of a forklift truck for loading of box pallets onto a farm trailer allowed the reduction of work inputs by 26.7 man-hour·ha^{-1}. The use of C330 tractor and a farm trailer for transport into a field and box pallets from a field instead if a delivery truck allowed reduction of work consumption of this operation in total by 53.4 man-hour·ha^{-1}. The use of a forklift truck for unloading of box pallets in the packing object allowed the reduction of work inputs by 93.4 man-hour·ha^{-1}.

Inputs of manual work in the 2nd variant achieved: for field cultivation, planting and treatment 248.7 man-hour·ha^{-1} (fig.1), harvesting and transport 973.2 man-hour·ha^{-1} (fig.1), i.e. in total 1221.9 man-hour·ha^{-1} and were lower by 152.3 man-hour·ha^{-1} than the one incurred in the 1st variant. As a result of the introduced changes, used technical means of mechanized work input in cultivation, planting and treatment in the 2nd variant were

41.7 mh·ha^{-1} (fig.1) and decreased by 5.5 mh·ha^{-1} in comparison to the 1st variant, whereas in the harvesting and transport processes they were 93.2 mh·ha^{-1} (fig.1) and increased by 66.6 mh·ha^{-1}. Total inputs of human work and mechanized per a hectare in the 2nd variant were 1,356.8 hours and were lower by 91.2 hours in comparison to the 1st variant.

In the 3rd variant (table 3) in soil cultivation, tractor C330 was replaced with a tractor of a greater power of Steyr 660 type and the 300 l sprayer was replaced with a sprayer of a newer structure and with a bigger 400 litres container. These changes allowed reduction of work inputs on soil cultivation by 5 man-hour·ha^{-1} and 5 mh·ha^{-1},

Table 3

The list of technological operations and human and mechanical work inputs in the process of cultivation, treatment and cropping and transport of early cabbage for the 3rd variant

Process	Technological operation	Manner of performance	Inputs of human work (man-hour·ha^{-1})	Inputs of human work (man-hour·ha^{-1})
Field cultivation, planting and treatment	Ploughing	Tractor Fendt 110+4-furrow field turning plough	2	2
	Soil treatment	Tractor Steyr 6660 + cultivation aggregate	3	3
	Planting	Tractor C330+planter	150	25
	Spraying with herbicide	Tractor C 330 + sprayer 400 l	1.3	1.3
	Double weeding	Manually	72	0
	Spraying with fungicide	Tractor C 330 + sprayer 400 l	5	5
	Operation of fertilizing	Manually	2	0
	Fertilization	Tractor C330+spreader	3	3
Harvesting and transport	Loading of box pallets	Fork lift truck	13.3	13.3
	Transport of box pallets to a field	Tractor C330 + trailer	13.3	13.3
	Cutting out cabbage	Manually	400	0
	Loading cabbage	Manually	400	0
	Transport from a field	Tractor C330 + trailer	40	13.3
	Unloading and packing	Fork lift truck and manually	106.6	53.3
Total in technology			1211.5	132.5

The use of a more modern sprayer caused that spraying with herbicide was more careful and as a result work inputs on weeding were lower by 8 man-hour·ha^{-1}. Human work inputs in the 3rd variant achieved for: cultivation, planting and treatment 238.3 man-hour·ha^{-1} (fig.1), harvesting and transport 973.2 man-hour·ha^{-1} (fig.1), and in total 1211.5 man-hour·ha^{-1} and were lower by 10.4 man-hour·ha^{-1} than the incurred in the 2nd variant and by 162.7 man-hour·ha^{-1} than those in the 1st variant. Total human work and machine inputs per hectare in the 3rd variant were 1344 hours and were lower by 104 and 12.9 hours in comparison to the 1st and 2nd variant.

The increase of the acreage of cultivated cabbage in the 4th variant (table 4), forced out the need for further improvement of the production process of this vegetable through a replacement of the plate planter used for planting seedlings, a carousel and bucket planter as well as a belt conveyor mounted on a trailer for transport of cut off cabbage. During a crossing with a trailer, where such conveyor was mounted, an employee cut off cabbage and placed it on a conveyor's belt and transported it directly to box pallets. It eliminated a burdensome activity related to loading (manual throwing) of cabbage heads onto a trailer.

Table 4
The list of technological operations and human and mechanical work inputs in the process of cultivation, treatment and cropping and transport of early cabbage for the 4th variant

Process	Technological operation	Manner of performance	Inputs of human work (man-hour·ha^{-1})	Inputs of human work (man-hour·ha^{-1})
Field cultivation, planting and treatment	Ploughing	Tractor Fendt 110+4-furrow field turning plough	2	2
	Soil treatment	Tractor Steyr 6660 + cultivation aggregate	3	3
	Planting	Tractor C330+ carousel planter	16.6	3.3
	Spraying with herbicide	Tractor C 330 + sprayer 400 l	1.3	1.3
	Double weeding	Manually	72	0
	Spraying with fungicide	Tractor C 330 + sprayer 400 l	5	5
	Operation of fertilization	Manually	2	0
	Fertilization	Tractor C330+spreader	3	3
Harvesting and transport	Loading of box pallets	Fork lift truck	13.3	13.3
	Transport of box pallets to a field	Tractor C330 + trailer	13.3	13.3
	Cutting out cabbage and loading	Manually + belt conveyor	400	0
	Transport from a field	Tractor C330 + trailer	40	13.3
	Unloading and packing	Fork lift truck and manually	106.6	53.3
Total in technology			678. 1	110.8

The introduced innovations allow reduction of planting work consumption in this variant by 133.4 man-hour·ha^{-1},and cutting out cabbage crowns and their loading to box pallets by 400 man-hour·ha^{-1}. Inputs of manual work in the 4th variant at cultivation, planting and treatment 104.9 man-hour·ha^{-1} (fig.1), harvesting and transport 573.2 man-hour·ha^{-1} (fig.1). This figure also presents the set of results of research on manual and machine work inputs for remaining variants.

Total inputs of human work in the 4th technology were 678.1 man-hour·ha^{-1} and were lower by 696.1 man-hour·ha^{-1}, 543.8 man-hour·ha^{-1} and 533.4 man-hour·ha^{-1} than those in the 1st, 2nd and 3rd variant. Total inputs of machinery work in the 4th technology are 110.8 mh·ha^{-1}. They were lower than inputs for the 3rd variant by 22 mh·ha^{-1}, for the 2nd variant by 24.1 mh·ha^{-1} and were higher than the determined for the 1st variant – by 37 mh·ha^{-1}.

To sum up, one may state that the 4th variant is the most optimal variant of early cabbage production on account of the assumed criterion, the lowest inputs of human and machine work, for supply of fresh vegetables market from among the analysed. Total inputs of human and machine work in this variant were 788.9 h·ha^{-1} and were lower respectively by 555.1, 568.9 and 659.1 hours than the determined for the 3rd, 2nd and 1st variant.

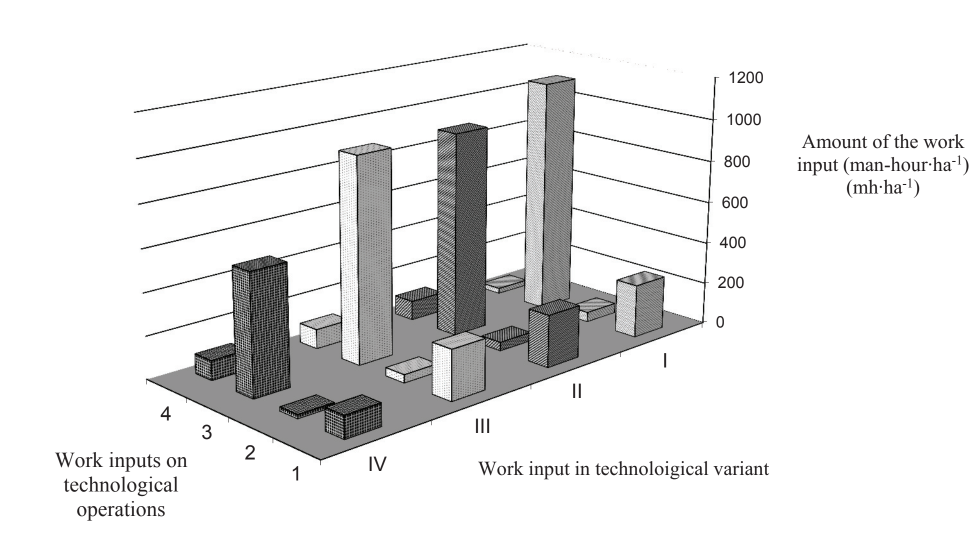

Figure 1. The list of test results on work inputs related to field cultivation, treatment and transport of early cabbage: 1 – manual work inputs in the cropping, sowing and treatment (man-hour·ha^{-1}), 2 – machinery operation inputs in the cropping, sowing and treatment (mh·ha^{-1}), 3 – manual work inputs in the harvesting and transport processes (man-hour·ha^{-1}), 4 – machinery work inputs in the cropping and transport processes (mh·ha^{-1}).

Conclusions

1. 4th technological variant, where the lowest human and machine work inputs occurred amounting to 788.9 h·ha^{-1} was an optimal technology of early cabbage production, where minimization of work inputs was reported.
2. As a result of the innovative changes of early cabbage production technology, reduction of the cost of human work inputs in technology in the optimal technology was obtained (4th variant). In comparison to the 3rd variant by 533.4 man-hour·ha^{-1}, to the 2nd by 544 man-hour·ha^{-1} and to the 1st by 696.1 man-hour·ha^{-1}, and machines respectively by 22 mh·ha^{-1} and 24.1 mh·ha^{-1}. To the 1st variant increase by 37 mh·ha^{-1}was reported.

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MINIMALIZACJA NAKŁADÓW PRACY W TECHNOLOGII PRODUKCJI KAPUSTY WCZESNEJ

Streszczenie. Celem pracy było wyznaczenie optymalnego wariantu technologii produkcji kapusty wczesnej na zaopatrzenie rynku warzyw świeżych spośród opracowanych czterech wariantów technologii proponowanych do stosowania w małoobszarowych gospodarstwach ogrodniczych. Zakresem badań objęto gospodarstwo ogrodnicze, w którym powierzchnia uprawy kapusty wynosiła w okresie czteroletnim od 1,5 do 2,3 ha. Za typową (wyjściową) technologię produkcji kapusty przyjęto technologię opartą na dużym udziale pracy ręcznej i maszynach stosowanych wcześniej do produkcji rolniczej w gospodarstwach małoobszarowych. Za kryterium optymalizacji przyjęto minimalne nakłady pracy ludzkiej i maszynowej. Optymalnym wariantem spośród analizowanych uznano wariant IV. Łączne nakłady pracy ludzkiej i maszyn w tym wariancie wyniosły 788,9 $h \cdot ha^{-1}$ i były niższe odpowiednio: o 555,1, 568,9 i 659,1 $h \cdot ha^{-1}$ od oszacowanych dla wariantów III, II i I. Nakłady pracy ręcznej w tym wariancie były niższe w stosunku do ponoszonych w wariancie III o 533,4 $rbh \cdot ha^{-1}$, w II o 544,8 $rbh \cdot ha^{-1}$ i w I o 696,1 $rbh \cdot ha^{-1}$, a maszyn odpowiednio mniejsze o – 21,7 $mh \cdot ha^{-1}$ dla III i 24,1 $mh \cdot ha^{-1}$ dla II oraz większe o 37 $mh \cdot ha^{-1}$ w porównaniu do wariantu I.

Słowa kluczowe: produkcja kapusty wczesnej, nakłady pracy, technologia optymalna

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VARIANTS OF CARROT PRODUCTION TECHNOLOGY AND COSTS OF MANUAL AND MECHANICAL WORKS

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ABSTRACT

Cost analysis of manual and machine works related to production of carrots was carried out in the context of supply of the fresh vegetables market for four technological variants of a varied level of works mechanization in a horticultural farm, where the surface of carrot crop was 3.67 ha. Technology based on the use of machines applied previously for agricultural production in small-area farms with a great participation of human labour was accepted as a basic carrot production technology. Based on the analysis of possibilities of using new solutions of machines in the previous production technology, variants were developed, the assumption of which was reduction of costs of manual and mechanical works. For the developed four variants of carrot production technology, incurred human labour costs and costs of machines and tools exploitation were determined. Minimal costs of human labour and machine exploitation were accepted as a criterion of selection of the best variant. 4th variant, which was characterized with the lowest costs of human labour and machines exploitation, which constituted 12,570 PLN·ha^{-1} was recognized as optimal, from among four developed and recommended for use in small area horticultural farms. Costs of human labour and machines exploitation in this variant were lower than the costs incurred in the 3rd variant by 5,100 PLN·ha^{-1}, in the 2nd variant by 9,995 PLN·ha^{-1}, and by 13,536 PLN·ha^{-1} than calculated in the 1st variant.

Introduction and the objective of the paper

Horticultural production requires high work inputs, which considerably increases its costs. In relation to the variety of cultivated plants, they are 10 to 20 times higher than for grains calculated into the area unit. Therefore, mechanization of the most labour consuming works related to field cultivation, plant protection and preparation for sale plays a significant role in the development of this production department (Hołownicki, 2006).

Production of vegetables in Polish conditions is carried out most frequently in small farms of the area not exceeding 10 hectares which prevents the use of more efficient machines and consequently a considerable part of works in this production is carried out manually. Thus, in small horticultural farms which produce vegetables, labour costs, particularly of human work as well as costs of machines exploitation are a significant problem (Borcz and Kowalczyk, 1997; Kowalczuk and Leszczyński, 2006; Kowalczyk, 2003; Kowalczyk and Wnęk, 2007; Michałek and Kowalczyk, 2000).

In Poland recently, even in horticultural farms of a small acreage, a considerable progress in implementation of new, with regard to structure, machines and organizational solutions in the carrot production process is noticeable, which allows the increase of its yield from a hectare, to improve the quality of the product offered for sale, to decrease the incurred inputs and raise the efficiency of production (Adamicki et al., 2004; Kowalczuk, 2005; Kowalczuk and Leszczyński, 2005; Kokoszka and Tabor, 2006; Kurpaska and Tabor, 2006; Kaniszewski, 2007).

It justifies accepting the research assumption that in the standard technology used in the carrot production for supply of fresh vegetables market, particularly in small area garden farms, there is a possibility of reducing costs of human work and costs of exploitation of machines by organizational operations and introduction of new structure of machines.

Knowing differences in the size of costs of human and machine work in new variants of carrot production technology in comparison to recently used, may serve for assessment of usability of a given variant and recommendations to its wider use in garden production.

The objective of the research was to carry out comparative analysis of carrot production costs for supply of fresh vegetables market for four technological variants of a very diverse level of mechanization of works and determination of the optimal variant of technology of its production for use in small area garden farms.

The object and the research method

The research on costs in four technological variants of carrot production were carried out in a garden farm in 2006-2009, with total area of arable land of 9.62 ha and the area of carrot cultivation was 3.67 hectare, located in Opolskie voivodeship in the town Bobrów. Based on the analysis of the size of work inputs, occurring in the estimated technological variant starting with the basic one, subsequent variant performed in the following years were drawn up, the assumption of which was to reduce the costs of human work and exploitation of tools and machines. The characteristic of conditions for the research and methodology was presented in Molendowski et al.'s paper. (2010, 2012).

In order to determine the costs of human work and costs of machines exploitation for the prepared variants of carrot production a record of time inputs of manual and machine works for specific technological operations was maintained. Since, the farm functions within the producer's group, in which mutual availability of machines and tools for the group members occurs, accounting rate of costs for an hour of use of technical means and for human work were assumed. Based on the determined time of manual and machine works and hour rates for manual works and the use of technical means, cost of particular technological operations was determined.

From among the researched variants of carrot production technology a variant, in which costs of human work and machines exploitation reached the lowest values, should be recognized as optimal.

Characteristic of the researched technological variants of carrot production was presented in table 1. Technology based on the manual work and machines used earlier for agricultural production in small area agricultural farms was assumed as the basic carrot production technology (1st variant). Technological operations within this technology and the manner of its execution were presented in table 1. In this technology after ploughing with a 4-furrow field plough aggregated with Ursus 1212 tractor and harrowing, further treatments (fertilization, sowing, spraying) were carried out with the use of Ursus C330 tractor. Then, fertilization was carried out with the use of a suspended shield distributor and for formation of ridges a potato seeders S204. On the performed ridges, sowing of seeds was carried out with the use of a brush 2- row seeder. For chemical protection in the first variant, the sprayer Pilmet 312 of the volume of the container of 300 dm^3 was used and in the remaining variants Pilmet 400LM with a container of 400 litres.

In the 2nd, 3rd and 4th variant for field works, tractor Fendt 110 was used, with which a 4-furrow field plough was aggregated and a subsoiler, for formation of ridges – an active harrow Struik 4RF320 and for sowing seeds – a point seeder by Monosem MS company equipped with shields for sowing two rows of carrot at one ridge.

In the processes of harvesting and transport in the 1st variant, roots were ploughed and leaves were manually removed and loaded to boxes, which also were manually loaded on the supply truck of the admissible load of 1.5 tonne. Carrot was transported to a farm, where it was washed in a drum washer and then packed to 10 kilo bags. In the 2nd variant, carrot after manual collection of ploughed roots was loaded to box pallets, which were loaded to a tractor trailer with a forklift truck and then transported to further treatment performed in the 1st variant. In the 3rd variant a one-row combine Dewulf P3C purchased at the secondary market was used to wash a washing line. In the 4th variant, a new combine Dewulf P3K was used for harvesting and a washing line was equipped with a vegetable bagging unit.

Results of the research

Results of the cost research in the estimated variants of carrot production technology were presented in table 1. In the 1st technological variant, which was assumed as the first one for the small-area farms, the highest cost of human work in the process of field cultivation, sowing and treatment, is incurred on double weeding (440 $PLN \cdot ha^{-1}$), operation of tools for ridges formation (143 $PLN \cdot ha^{-1}$) and sowing of seeds (132 $PLN \cdot ha^{-1}$). The remaining technological operations of the field cultivation, sowing and treatment, had a proportionally low participation in the total cost of human work amounting to 1006 $PLN \cdot ha^{-1}$ (fig. 1).

Total costs of human work in operations related to harvesting and transport of carrot are over fifteen times higher than in cultivation works, sowing and treatment and amount to 15,730 PLN·ha^{-1} (fig.1). Collecting affected so high costs of human work (6,600 PLN·ha^{-1}) and washing and packing (5,500 PLN·ha^{-1}) (tab. 1). Also costs of exploitation of machines in this variant, amounting to 8,970 PLN·ha^{-1} should be considered as high and they result from costs incurred in the field cultivation and treatment 3,670 PLN·ha^{-1} and harvesting and transport 5,300 PLN·ha^{-1} (fig. 1). Total cost of human work and exploitation of machines in the 1st technological variant amounting to 25,706 PLN·ha^{-1} (fig. 1) should be considered very high.

Table 1
The list of technological operations and costs of manual and mechanical work in the researched technologies of carrot production

Technology		Technological operation	Manner of performance	Costs of human work (PLN·ha^{-1})	Costs of machines exploitation (PLN·ha^{-1})
1	2	3	4	5	6
Technological variant – I	Cultivation, sowing and treatment	Ploughing	Tractor C1212+4-furrow field plough	38	420
		Harrowing	Tractor C1212+light harrow	44	480
		Loading of fertilizers	Manually	22	0
		Fertilization	Tractor C330+spreader	22	120
		Formation of ridges	Tractor C330+ potato planter	143	910
		Sowing of seeds	Tractor C330+2-row brush seeder	132	840
		Spraying with herbicide	Tractor C 330 + sprayer 3001	66	360
		Spraying with fungicide			
		Double weeding	Tractor C 330 + sprayer 3001	99	540
			Manually	440	0
	Harvesting and transport	Loading of boxes	Manually	825	0
		Transport to a field	Delivery truck	440	650
		Roots ploughing	Tractor C330 + plough	275	2 000
		Harvesting and cleaning			
		Transport from a field	Manually	6 600	0
		Unloading of boxes	Delivery truck	440	650
		Washing and packing			
			Manually	1 650	0
			Drum washer, manual packing	5 500	2 000
Total in technology				16 736	8 970

Technology		Technological operation	Manner of performance	Costs of human work (PLN·ha^{-1})	Costs of machines exploitation (PLN·ha^{-1})
1	2	3	4	5	6
2nd technological variant	Cultivation, sowing and treatment	Ploughing	Tractor Fendt 110+4-furrow field plough	22	240
		Subsoiling	Tractor Fendt 110 + subsoiler	13.2	120
		Loading of fertilizers	Manually	22	0
		Fertilization	Tractor C330+distributor	22	120
		Formation of ridges	Tractor Fendt 110 + harrow Striuk 4RF320	24.2	220
		Sowing of seeds	Tractor C330+2-row brush seeder	132	840
		Spraying with herbicide	Tractor C 330 + sprayer 400 l	52.8	288
		Spraying with fungicide	Tractor C 330 + sprayer 400 l	99	540
		Double weeding	Manually	440	0
	Harvesting and transport	Loading of box pallets	Forklift truck	110	400
		Transport to a field	Tractor C330 + trailer	110	550
		Roots ploughing	Tractor C330 + plough	275	2 000
		Harvesting and cleaning	Manually	6 600	0
		Transport from a field	Tractor C330 + trailer	110	550
		Unloading	Forklift truck	165	600
		Washing and packing	Drum washer, manual packing	5 500	2 000
Total in technology				13 697	8 468

3rd Technological variant	Cultivation, sowing and treatment	Ploughing	Tractor Fendt 110+4-furrow field plough	22	240
		Subsoiling	Tractor Fendt 110 + subsoiler	13.2	120
		Loading of fertilizers	Manually	22	0
		Fertilization	Tractor C330+spreader	22	120
		Formation of ridges	Tractor Fendt 110 + harrow Striuk 4RF320	24.2	220
		Sowing of seeds	Tractor C330+4-row seeder Monosem MS	22	260
		Spraying with herbicide	Tractor C 330 + sprayer 400 l	52.8	288
		Spraying with fungicide	Tractor C 330 + sprayer 400 l	99	540
		Double weeding	Manually	440	0
	Harvesting and transport	Loading of box pallets	Forklift truck	110	400
		Transport to a field	Tractor C330 + trailer	110	550
		Collection of roots	Combine Dewulf P3C	1 320	3 600
		Repeated collection of roots	Manually	550	0
		Transport from a field	Tractor C330 + trailer	110	550
		Unloading	Forklift truck	165	600
		Washing and packing	Washing line, manual packing	2 200	4 500
Total in technology				5 282	11 988
4th technological variant	Cultivation, sowing and treatment	Ploughing	Tractor Fendt 110+4-furrow field plough	22	240
		Subsoiling	Tractor Fendt 110 + subsoiler	13.2	120
		Loading of fertilizers	Manually	22	0
		Fertilization	Tractor C330+spreader	22	120
		Formation of ridges	Tractor Fendt 110 + harrow Striuk 4RF320	24.2	220
		Sowing of seeds	Tractor C330+4-row seeder Monosem MS	22	260
		Spraying with herbicide	Tractor C 330 + sprayer 400 l	52.8	288
		Spraying with fungicide	Tractor C 330 + sprayer 400 l	99	540
		Double weeding	Manually	440	0
	Harvesting and transport	Loading of box pallets			
		Transport to a field	Forklift truck	110	400
		Collection of roots	Tractor C330 + trailer	82.5	412.5
		Repeated collection of roots	Combine Dewulf P3K	330	3 200
		Transport from a field	Manually	55	0
		Unloading	Tractor C330 + trailer	82.5	412.5
		Washing and packing			
			Forklift truck	220	400
			Wash Line and bagging unit	660	3,300
Total in technology				2 257	9 913

Costs of human work in the 2nd variant achieved for field cultivation, sowing and treatment 827 PLN·ha^{-1}, harvesting and transport 12 870 PLN·ha^{-1}, and in total 13,697 PLN·ha^{-1} and were lower respectively by 179 PLN·ha^{-1}, 2 860 PLN·ha^{-1} and 3039 PLN·ha^{-1} than estimated in the 1st variant. Reduction of costs of human work in this variant were obtained inter alia as a result of the change of manual loading and unloading of boxes onto a transport mean and the use of box pallets and a forklift truck for this purpose (715 PLN·ha^{-1} and 1 485 PLN·ha^{-1}).

The use of a tractor and a low-suspension trailer for transport instead of a delivery truck proved to be advantageous since it allowed reduction of the cost of this operation from 1 090 PLN·ha^{-1} to 660 PLN·ha^{-1}.

Costs of exploitation of machines and tools in the 2nd variant for field cultivation, sowing and treatment reached 2 368 PLN·ha^{-1}, for harvesting and transport 6 100 PLN·ha^{-1} (fig.1) and in total 8 468 PLN·ha^{-1} and were respectively lower by 1 302 PLN·ha^{-1} and higher by 800 PLN·ha^{-1} and 502 PLN·ha^{-1} than the estimated in the 1st variant. Reduction of costs of exploitation of field cultivation, sowing and treatment machines, resulted inter alia from using a tractor Fendt 110 for ploughing with a 4-furrow field plough in the 2nd variant, which allowed shortening the exploitation time and as a consequence the cost of exploitation of tools during ploughing was lower by 180 PLN·ha^{-1} than in the 1st variant performed with a tractor Ursus 1212 aggregated with a 4-furrow non-field plough. Similar relations occurred at the use in the 2nd variant of a tractor with a greater power, Fendt 110 and harrow Striuk 4RF320 – a tool of higher performance for formation of ridges instead of a tractor Ursus C330 and a potato seeder as in the 1st variant, as a result of which the time of exploitation was shorter and the costs were lower by 690 PLN·ha^{-1}. At the same time a better quality of the performed treatment was obtained. A higher cost of exploitation of machines for collection and transport and total costs in the 2nd variant than in the first one, results from the cost of exploitation of a forklift truck used in this variant for unloading and loading of box pallets. As a result of the changes which were carried out in the carrot production technology in the 2nd variant a total cost of human work and machines and tools exploitation was lower than the costs incurred in the 1st variant by 3 541 PLN·ha^{-1} and was 22,165 PLN·ha^{-1}.

In the 3rd variant the use of a combine for harvesting of carrot influenced the reduction of costs of human work by 5,280 PLN·ha^{-1} and increase of costs of exploitation of machines by 3,600 PLN·ha^{-1} in comparison to the 2nd variant. However, total costs of human work and exploitation of machines for harvesting of carrots were lower by 1,680 PLN·ha^{-1} than in the 2nd variant. Similar relations occurred in case of using in the 3rd variant a washing line (comprising the brush washer and dosing devices and conveyors for loading and unloading of carrot (2nd variant). As a result of using a washing line in the 3rd variant, costs of human work were reduced by 3 300 PLN·ha^{-1} and increased the costs of machines exploitation by 2 500 PLN·ha^{-1} and total costs of human work and machines exploitation were lower by 800 PLN·ha^{-1} than in the 2nd variant. Costs of exploitation of machines in the 3rd variant were 11,988 and due to the above presented reasons were higher than the ones occurring in the 1st variant by 3 018 PLN·ha^{-1} and by 3 520 PLN·ha^{-1} in the 2nd variant.

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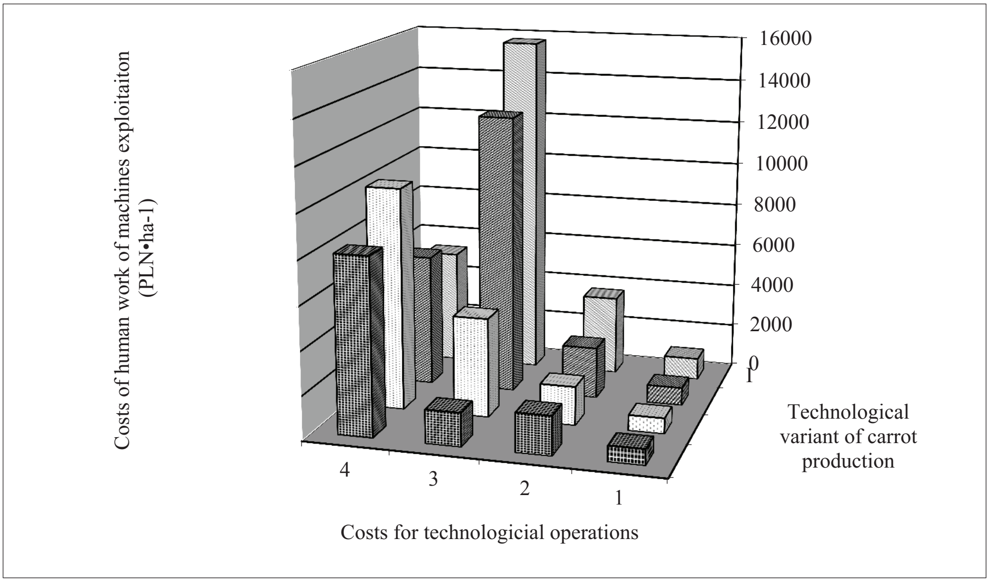

Figure 1. The list of results of studies on costs of field cultivation, sowing and treatment, crop and transport and packaging of carrot: 1 – human work inputs in the cropping, sowing and treatment (PLN·ha^{-1}), 2 – costs of machines and tools exploitation in the processes of cropping, sowing and treatment (PLN·ha^{-1}), 3 – costs of human labour in the harvesting, transport and packing processes (PLN·ha^{-1}), 4 – machinery work inputs in the cropping and transport processes (PLN·ha^{-1}).

In this variant costs of exploitation of machines and tools for field cultivation, sowing and treatment amounted to 1 788 PLN·ha^{-1} and were lower than those in the 1st variant by 1 882 PLN·ha^{-1} and in the 2nd variant by 580 PLN·ha^{-1} and total amounted to 2 505 PLN·ha^{-1} and which were lower than the incurred in the 2nd variant. In the 3rd variant costs of human work incurred during harvesting, transport, washing and packing were 4 565 PLN·ha^{-1} and as a result of the introduced changes of the machinery park, they were considerably lower than the calculated in the 1st variant by 11 165 PLN·ha^{-1} and by 8 305 PLN·ha^{-1} in the 1st variant. Also total costs of human work, which were 5,282 PLN·ha^{-1} were lower than in the 1st variant by 11 454 PLN·ha^{-1} and in the 2nd variant by 8 415 PLN·ha^{-1}. Total costs of human work and exploitation of machines and tools in this technology were 17,270 PLN·ha^{-1} and were lower as a result of the used machines by 8,414 PLN·ha^{-1} than the one determined in the 1st variant and by 4 895 man hour·ha^{-1} in the 2nd variant.

The use in the 4th variant of a more efficient and modern combine Dewulf P3K instead of Dewulf P3C (3rd variant), with which the harvested carrot was loaded to box pallets placed on a trailer affected reduction of the work time during harvesting and as a consequence of human work costs by 990 PLN·ha^{-1} and costs of machines exploitation by

400 PLN·ha^{-1}, although the cost of an hour of exploitation of a new combine was approximately two times higher than the combine used in the 3rd variant. Introduction of the washing and packing line in the 4th variant allowed reduction of the cost of human work by 1 540 PLN·ha^{-1} and exploitation of machines by 1 200 PLN·ha^{-1} in comparison to the 3rd variant. Costs of human work of harvesting and packing in the 4th variant were 1 540 PLN·ha^{-1} and were lower in comparison to the ones from the 1st, 2nd and 3rd variant by respectively: 14 190 PLN·ha^{-1}, 11 330 PLN·ha^{-1} and 3 025 PLN·ha^{-1} Whereas, a total cost of exploitation of a harvesting machine, transport and packing in this variant was 8 125 PLN·ha^{-1} and were higher respectively by: 2 825 PLN·ha^{-1}, 2 025 PLN·ha^{-1} and lower by 2,075 PLN·ha^{-1} than the ones occurring in the 1st, 2nd and 3rd variant. The cost of human work in this technology was 2,257 and was lower than the determined in the 1st, 2nd and 3rd variant by respectively: 14 479 PLN·ha^{-1}, 11 440 PLN·ha^{-1} and 3,025 PLN·ha^{-1}. The cost of exploitation of a machine in this technology was 9 913 and was higher respectively by: 943 PLN·ha^{-1}, 1 145 PLN·ha^{-1} and lower by 2 075 PLN·ha^{-1} than the one occurring in the 1st, 2nd and 3rd variant.

Concluding, one may say that the 4th variant of carrot production technology from among the researched ones is optimal and it characterizes with the lowest cost of human work and machines exploitation. Total cost of human work and exploitation of machines and tools in this variant was 12 570 PLN·ha^{-1} and was lower respectively by: 13 536 PLN·ha^{-1}, 9 995 PLN·ha^{-1} and lower by 5 100 PLN·ha^{-1} than the ones occurring in the 1st, 2nd and 3rd variant.

Conclusions

1. From among the assessed technologies of carrot production for supply of fresh vegetable market, the most optimal is variant 4th with the lowest total costs of human work and machines exploitation of 12,170 PLN·ha^{-1} and were lower respectively: by 13 536 PLN·ha^{-1}, 9 995 PLN·ha^{-1} and 5 100 PLN·ha^{-1} from the determined in the 1st, 2nd and 3rd variant.
2. As a result of the innovative changes of carrot production technology, reduction of the cost of human work in technology 4th in comparison to the following variants, was obtained: 3rd by 3 025 PLN·ha^{-1}, 2nd by 11 440 PLN·ha^{-1} and by 14 479 PLN·ha^{-1}, and the costs of exploitation of machines by 2 075 PLN·ha^{-1}, and by increase by PLN·ha^{-1} and 943 PLN·ha^{-1}.

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WARIANTY TECHNOLOGII PRODUKCJI MARCHWI A KOSZTY PRAC RĘCZNYCH I MECHANICZNYCH

Streszczenie. Przeprowadzono analizę kosztów prac ręcznych i maszynowych produkcji marchwi na zaopatrzenie rynku warzyw świeżych dla czterech wariantów technologicznych o zróżnicowanym poziomie zmechanizowania prac w gospodarstwie ogrodniczym, w którym powierzchnia uprawy marchwi wynosiła 3,67 ha. Za podstawową technologię produkcji marchwi przyjęto technologię opartą na wykorzystaniu maszyn stosowanych wcześniej do produkcji rolniczej w gospodarstwach małoobszarowych z dużym udziałem pracy ludzkiej. Na podstawie analizy możliwości zastosowania w dotychczasowej technologii produkcji nowych rozwiązań maszyn, opracowano warianty, których założeniem było zmniejszenie kosztów prac ręcznych i mechanicznych. Dla opracowanych czterech wariantów technologii produkcji marchwi określono poniesione koszty pracy ludzkiej i koszty eksploatacji maszyn i narzędzi. Za kryterium wyboru najlepszego wariantu przyjęto minimalne koszty pracy ludzkiej i eksploatacji maszyn. Za optymalny, spośród czterech opracowanych i zalecanych do stosowania w małoobszarowych gospodarstwach ogrodniczych, uznano wariant IV, charakteryzujący się najniższymi kosztami pracy ludzkiej i eksploatacji maszyn wynoszącymi 12 570 $zł \cdot ha^{-1}$. Koszty pracy ludzkiej i eksploatacji maszyn w tym wariancie były niższe od ponoszonych w wariancie III o 5 100 $zł \cdot ha^{-1}$, w II o 9 995 $zł \cdot ha^{-1}$, i o 13 536 $zł \cdot ha^{-1}$ od wyliczonych w wariancie I.

Słowa kluczowe: koszty pracy ludzkiej i mechanicznej, produkcja marchwi, warianty technologii

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ASSESSMENT OF ENERGY CONSUMPTION OF PELLETS AND BRIQUETTES PRODUCTION IN COMPRESSING DEVICES[1]

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ABSTRACT

Assessment of energy consumption of pellets and briquettes production from plant raw materials was presented. Wheat, rye, rape straw and meadow hay were used for their production. The investigated raw materials were ground before briquetting with the use of a station drum straw cutter and theoretical length of cutting of 20 mm, whereas before pelleting – with the use of a beater grinder equipped with sieves of 6 mm meshes diameter. Analysis of moisture of raw materials and their calorific value were carried out according to binding norms. Moisture of compacted raw materials was within 10.1-13.3%, whereas the calorific value was from 16.1 to 17.9 MJ·kg^{-1}. Pellets were produced in a pelleting machine with an immobile flat matrix and driven compressing rolls, whereas briquettes were produced in a screw briquetting machine with a heated compressing chamber. The following values of temperature of the compressing chamber of a briquetting machine were assumed: 200, 225 and 250°C. For measurement of energy consumption of the raw materials compression process power, time and electric energy converter Lumel 3000 was used. Average values of energy consumption during production of pellets were from 0.145 kWh·kg^{-1} for rape straw to 0.176 kW·kg^{-1} for meadow hay. In case of production of briquettes the lowest value of energy intake was reported for wheat straw compressed in temperature 250°C (0.128 kWh·kg^{-1}), whereas the highest value of energy intake for meadow hay compressed in temperature 200°C (0.182 kWh·kg^{-1}).

Introduction

Renewable energy sources are included in the sources of energy, the resources of which are renewed in natural processes. They are more frequently used for production of heat and electric energy and the main reason of their growing popularity is a non-harmful impact on the natural environment and practical infinity. Whereas, in case of conventional sources,

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their exploitation leads to climatic changes of a globe and to their complete exhaustion in future. Thus, economic development should be based on a sustainable model, in which economic reasons will constitute a balance for ecological reasons. Taking into consideration the above facts, alternative energy sources are more frequently searched for (Grzybek, 2004; Kołodziej and Matyka, 2012).

Production of the so-called "green energy" brings many positive properties for development of national economy. It is commonly considered that development of the power industry based on renewable sources may cause solution of many problems resulting from conventional power industry. Thus, one may aim to introduce technology of energy plants cultivation and the use of what remains after agricultural production. Special attention is paid to the possibility of solid biofuels production from materials of plant production. Fuels, which were formed in the process of agglomeration, compete with their properties with conventional fuels and their excavation is cheaper. Thus, in times when depletion of non-renewable energy sources is possible, production of pellets and briquettes from plant raw material may play a significant role in protection of environment and energy production in the country (Denisiuk, 2007; Frączek 2010; Hejft 2006; Kowalik, 2003; Niedziółka and Szpryngiel 2012; Winnicka et al., 2005).

Biomass, which is in majority obtained from side products of forestry and agriculture, is the biggest source of renewable energy. In order to increase the possibility of obtaining biomass, also energy plants, which are characterized with a big increase in a year and low soil demands are cultivated. Solid biofuels, obtained from plant material provide ca. 11% of total world energy, due to which they belong to a group of the most important energy sources. Such materials as: firewood and wood waste, energy crops, agricultural crops, municipal waste and waste of paper industry, which may be combusted in various technologies are included there. On account of the above, the assumed objectives of Directive 28/2009/EC forced on the territory of the EU countries, specific actions which lead to minimization of fossil fuel consumption, which increased the demand for biomass (Niedziółka and Zaklika 2012; Stolarski et al., 2008, Szyszlak-Bargłowicz et al., 2012; Terlikowski, 2012).

In order to use the chance, which biomass management for energy purposes provides, machines and devices, which facilitate and considerably speed up cropping and plant processing designated for this purpose, are necessary. It is however related to high financial and energy inputs, which the most frequently closes the way for many farmers and producers interested in obtaining green energy. Therefore it is important to introduce appropriate legal provisions enabling setting up a plantation, obtaining funds and solid fuels circulation as a result of biomass management (Grzybek, 2004; Gałecki, 2004; Nowak, 2005; Zarajczyk, 2013).

Assessment of energy consumption of pellets and briquettes production from selected plant raw materials was the objective of the paper.

Methodology and conditions for research

For production of pellets and briquettes the following types of plant material was used: wheat straw, rye and rape straw and meadow hay. Plant material was ground before briquetting with a station straw drum cutter with a theoretical cut length of 20 mm, whereas before pelleting with the use of a beater grinder equipped with two sieves of the meshes diameter of 6 mm. Pellets were produced in a pelleting machine with an immobile flat matrix and driven compressing rolls, whereas briquettes were produced in a screw briquetting machine with a heated compressing chamber. Three values of temperature of the compressing chamber of a briquetting machine were assumed: 200, 225 and 250ºC. Technical and exploitation data of compressing devices were presented in table 1 and 2.

Table 1

Technical-exploitation data of a pelleting machine with a flat matrix

Specification	Unit of measure	Parameters
Diameter of pellets	(mm)	8.0
Diameter of a matrix	(mm)	225.0
Thickness of matrix	(mm)	25.0
Length of compressing rollers	(mm)	50.0
Diameter of rollers	(mm)	100.0
Rotational speed of rollers	($rot \cdot min^{-1}$)	110.0
Engine output	(kW)	7.5
Performance of a pelleting machine	($kg \cdot h^{-1}$)	100-150
Dimensions of a pelleting machine (L×B×H)	(mm)	1300×650×1020
Mass of a pelleting machine	(kg)	250

Table 2

Technical-exploitation data of a screw briquetting machine

Specification	Unit of measure	Parameters
Type of a briquetting machine	(-)	JW- 08
Diameter of a compression chamber	(mm)	80.0
Length of a guide which stabilizes briquettes	(m)	5.0
Output of an engine of a compression screw	(kW)	4.0
Output of an engine of a raw material feeder	(kW)	1.1
Output of electric heaters	(kW)	3.0
Productivity of a briquetting machine	($kg \cdot h^{-1}$)	60-100
Dimensions of a briquetting machine (L×B×H)	(mm)	1200×1000×1300
Mass of a briquetting machine	(kg)	320

A special measurement system was used for the measurement of energy consumption of the compression process of the investigated plant materials (fig. 1). In this system, a converter of power, time and electric energy Lumel 3000 type which cooperates with a computer recording instantaneous power intake, was used. Measurements of active power intake were recorded following achieving an assumed temperature by a compression chamber of a briquetting machine. Measurements of total intake of electric energy during heating the compression chamber and during the process of raw material compression were also recorded with the use of a three-phase current meter. The obtained results of measurements of electric energy intake were calculated per a unit of mass of the produced agglomerate.

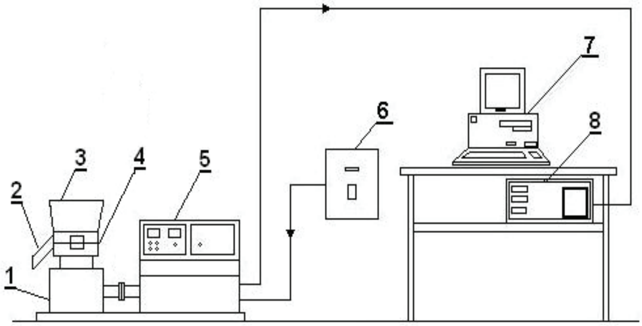

Figure 1. Schematic representation of the measurement stand: 1 – toothed gear, 2 – pellets spout, 3 – charging hopper, 4 – compressing mechanism, 5 – control cabinet with electric engine, 6 – frequency transducer of electric power, 7 – computer, 8 – recorder of active power

Figure 2 presents pellets produced of the investigated plant material.

Figure 2. Pellets produced of the investigated plant raw material: a) wheat straw, b) rye straw, c) rape straw, d) meadow hay

Figure 3 presents briquettes produced of the investigated plant material.

Figure 3. Briquettes produced of the investigated raw materials: a) wheat straw, b) rye straw, c) rape straw, d) meadow hay

The obtained results of measurement of energy consumption of producing pellets and briquettes from the researched raw plant material were subjected to statistical analysis with the use of analysis of variance and Tukey's test. In all analyses the level of significance was assumed as $\alpha=0.05$. For this purpose statistic programme SAS Enterprise Guide 5.1. The obtained results were presented in tables of analysis of variance and tables which include appropriate means along with determination of their impact on statistically significant differences of analysed properties.

Research results

Characteristic of agglomerated plant material was placed in table 3. Average moisture of raw material in a fresh state was within 16.8% for meadow hay to 21.2% for rye hay. While, average moisture of dry raw material was from 11.2% for rye straw to 12.3% for the remaining raw material. Whereas, average calorific value was within 16.2 MJ·kg^{-1} for rye straw to 17.5 MJ·kg^{-1} in case of rape straw.

Table 3
Properties of agglomerated plant raw materials

Type of raw material	Moisture in a fresh state, (%)	Moisture in a dry state, (%)	Calorific value in a dry state, (MJ·kg^{-1})
Wheat straw	18.4-20.6	11.5-12.8	16.7-17.4
Rye straw	20.3-22.4	10.1-12.4	16.1-16.6
Rape straw	17.6-19.8	11.2-13.3	17.2-17.9
Meadow hay	16.3-17.5	12.0-12.8	16.3-16.8

The analysis of variance which was carried out proved that the plant material, used in the research, significantly influence the energy intake during the process of pelleting (tab. 4). Statistically significant differences were found in case of energy intake during production of pellets for all agglomerated plant material (tab. 5).

Table 4
Analysis of variance of energy intake during production of pellets from the investigated raw materials

Source of variability	Degrees of freedom	Sum of squares	Root mean square	Value F_0	p ($F > F_0$)
Raw material	3	0.00326	0.00109	47.71	<0.0001
Error	20	0.00045	0.00002		
Total	23	0.00371			

Table 5
Comparison of average values of energy intake during production of pellets (kWh·kg^{-1})

Type of raw material	Wheat straw	Rye straw	Rape straw	Meadow hay
Average	0.153^{A}	0.164^{B}	0.145^{C}	0.176^{D}
Standard deviation	0.0068	0.0047	0.0035	0.0032

Figure 4 presents results of the research of energy consumption of pellets production depending on the type of agglomerated plant material. The lowest energy consumption was in case of pellets produced from rape straw (0.145 kWh·kg^{-1}), wheat straw pellets with a slightly higher (0.153 kWh·kg^{-1}) and rye straw (0.164 kWh·kg^{-1}), and pellets from meadow hay with the highest (0.176 kWh·kg^{-1}). Increase of energy intake in case of pellets from wheat straw was approx. 5% for pellets made of wheat straw, for rye straw pellets approx. 13%, whereas for meadow hay pellets approx. 21% with reference to energy intake for rape straw pellets.

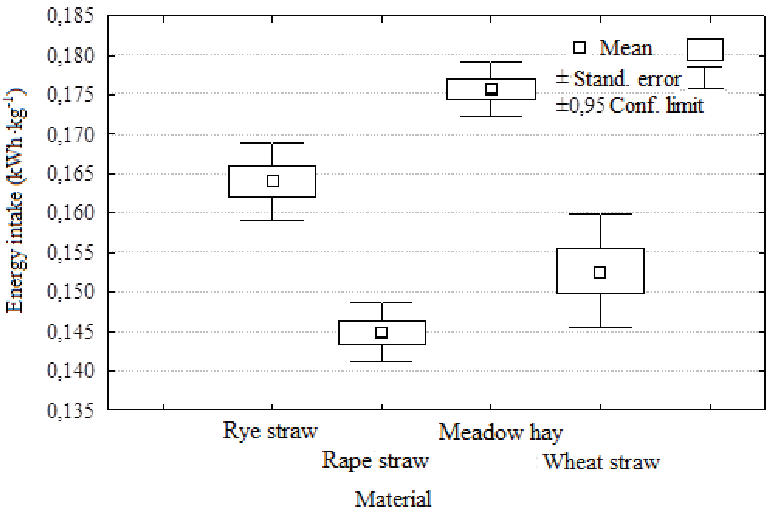

Figure 4. Values of energy intake during production of pellets from the investigated raw materials

The analysis of variance, which was carried out proved that both the researched material as well as the accepted temperature and their interactions significantly differentiate the energy intake of production of briquettes (tab. 7). Statistically significant differences were reported in case of energy consumption of a briquetting process for all agglomerated plant materials. Increase of energy intake in case of briquettes from rye straw was approx. 5% for briquettes made of rape straw approx. 13%, whereas for meadow hay briquettes approx. 23% with reference to energy intake for wheat straw pellets. Moreover, statistically significant differences were reported in case of energy intake during the process of briquette production in temperature 200, 225 and 250ºC. Decrease of energy intake was approx. 7% in case of temperature 225ºC and approx. 16% for temperature 250ºC in comparison to 200ºC (tab. 8).

Table 7

Analysis of variance of energy intake during production of briquettes from the investigated raw materials in the accepted compression temperature

Source of variability	Degrees of freedom	Sum of squares	Root mean square	Value F_0	p ($F > F_0$)
Temperature	2	0.00583	0.00291	146.09	<0.0001
Raw material	3	0.01128	0.00376	188.38	<0.0001
Temperature×Raw material	6	0.00034	0.00005	2.90	0.0149
Error	60	0.00119	0.00001		
Total	71	0.01866			

Table 8

Comparison of average values of energy intake during production of briquettes for the investigated raw material and compression temperature

Type of raw material	Wheat straw	Rye straw	Rape straw	Meadow hay
Average	0.137^{A}	0.142^{B}	0.159^{C}	0.168^{D}
Temperature (°C)	200		225	250
Average	0.162^{A}		0.151^{B}	0.140^{C}

When analysing the impact of temperature in the compression chamber of a briquetting machine on the energy consumption of the process of production of briquettes, it was reported that the highest values were obtained for temperature 200ºC (0.145-0.182 $kWh \cdot kg^{-1}$), lower for temperature 225ºC (0.138 to 0.169 $kWh \cdot kg^{-1}$), and the lowest for temperature 250ºC (0.128 to 0.152 $kWh \cdot kg^{-1}$) – respectively for wheat straw and meadow hay (tab. 9). Difference in the energy intake for the investigated plant material in the chamber temperature of 200ºC was approx. 25%, in the chamber temperature of 225ºC (approx. 22%) and in the chamber temperature of 250ºC (approx. 19%).

Table 9

Average values of energy intake during production of briquettes from the investigated raw materials

Type of raw material	Temperature (ºC)	Energy intake ($kWh \cdot kg^{-1}$)	Standard deviation
Wheat straw	200	0.145	0.0073
	225	0.138	0.0035
	250	0.128	0.0021
Rye straw	200	0.152	0.0047
	225	0.141	0.0044
	250	0.133	0.0060
Rape straw	200	0.171	0.0053
	225	0.157	0.0026
	250	0.149	0.0050
Meadow hay	200	0.182	0.0043
	225	0.169	0.0025
	250	0.152	0.0026

Figure 5 presents the results of measurements of energy intake depending on the temperature of the compression chamber of a briquetting machine and agglomerated plant material. Along with the increase of temperature in the compression chamber, the energy consumption of the raw material briquetting process decreased. The highest energy consumption was for briquettes produced of meadow hay compressed in temperature of 200ºC (0.182 $kWh \cdot kg^{-1}$), whereas the lowest energy consumption was in case of briquettes obtained from wheat straw in temperature of 250ºC (0.128 $kWh \cdot kg^{-1}$).

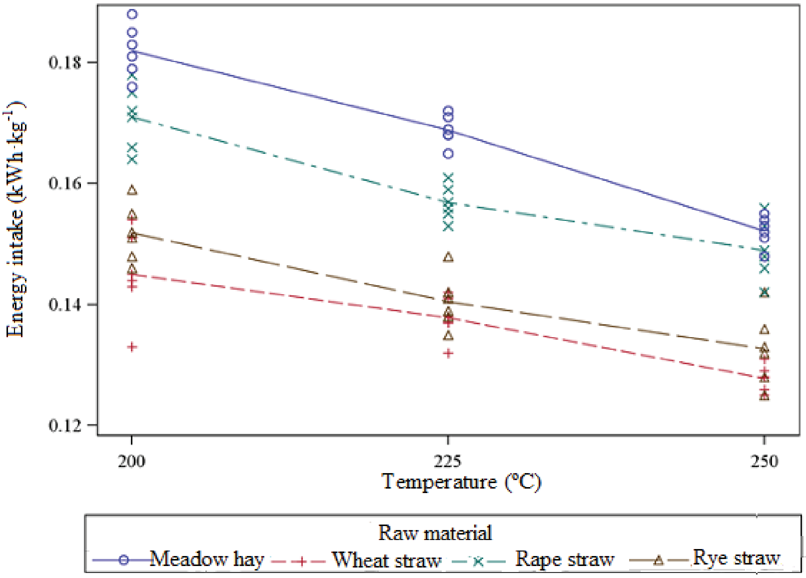

Figure 5. Relation of the energy intake to the temperature of the compression chamber of agglomerated plant raw material

Conclusions

1. When analysing the obtained research results it was reported that energy consumption of the production process both of pellets and briquettes depended on the type of agglomerated plant material and on the accepted values of temperature in the compression chamber of a briquetting machine for production of briquettes.
2. Unit consumption of electric energy during the process of pelleting plant materials was within 0.245 to 0.176 kWh·kg^{-1}. The lowest energy consumption was during the rape straw compression, higher for wheat straw by 5.5% and rye straw by 13% whereas for meadow hay by 21%.
3. Unit consumption of electric energy during the process of briquetting decreased along with the increase of temperature in the compression chamber. The lowest energy consumption was during briquetting of wheat and rye straw, whereas considerably higher for rape straw and hay. Along with the increase of temperature from 200 to 250ºC, decrease of electric energy intake was from 13 to 15% for wheat, rye and rape straw and 20% for meadow hay.

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OCENA ENERGOCHŁONNOŚCI WYTWARZANIA PELETÓW I BRYKIETÓW W URZĄDZENIACH ZAGĘSZCZAJĄCYCH

Streszczenie. Przedstawiono ocenę energochłonności wytwarzania peletów i brykietów z wybranych surowców roślinnych. Do ich produkcji użyto słomy pszennej, żytniej i rzepakowej oraz siana łąkowego. Badane surowce przed brykietowaniem rozdrabniano przy użyciu stacyjnej sieczkarni bębnowej i teoretycznej długości cięcia 20 mm, natomiast przed peletowaniem – za pomocą rozdrabniacza bijakowego wyposażonego w sita o średnicy otworów 6 mm. Analizy wilgotności surowców i ich wartości opałowej przeprowadzono zgodnie z obowiązującymi normami. Wilgotność zagęszczanych surowców wahała się w przedziale 10,1-13,3%, natomiast wartość opałowa od 16,1 do 17,9 $MJ \cdot kg^{-1}$. Pelety wytwarzane były w peleciarce z nieruchomą matrycą płaską i napędzanymi rolkami zagęszczającymi, natomiast brykiety wytwarzano w brykieciarce ślimakowej z podgrzewaną komorą zagęszczania. Przyjęto następujące wartości temperatury komory zagęszczającej brykieciarki: 200, 225 i 250°C. Do pomiaru energochłonności procesu zagęszczania surowców wykorzystano przetwornik mocy, czasu i energii elektrycznej typu Lumel 3000. Średnie wartości poboru energii podczas wytwarzania peletów wynosiły od 0,145 $kWh \cdot kg^{-1}$ dla słomy rzepakowej do 0,176 $kWh \cdot kg^{-1}$ dla siana łąkowego. W przypadku wytwarzania brykietów najniższą wartość poboru energii odnotowano dla słomy pszennej zagęszczanej w temperaturze 250°C (0,128 $kWh \cdot kg^{-1}$), natomiast najwyższą wartość poboru energii dla siana łąkowego zagęszczanego w temperaturze 200°C (0,182 $kWh \cdot kg^{-1}$).

Słowa kluczowe: biomasa roślinna, pelety, brykiety, energochłonność wytwarzania

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EXPERIMENTAL AND THEORETICAL METHOD OF DETERMINATION OF LOADS FOR CUTTING UNITS

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ABSTRACT

The paper presents assumptions which allow determination of energy demand of a machine which uses a simple guillotine cutting of a specific material of low elasticity e.g. soft wood. A simple manner of experimental determination of cutting resistance and a coefficient which characterizes properties of material and a cutting device has been suggested. A numerical value of coefficient was determined based on the principle of maintaining mechanical energy and the principle of labour and mechanical energy balance. Based on the determined coefficient, average load and the power of a cutting unit of a shredder for energy willow were determined.

Introduction

From the beginning of its existence, a man had to deal with cutting biological material (plants and animals). Cutting was used during construction of houses, hunting, preparation of food and waging wars. Having no knowledge on theory of cutting, a man constructed various tools designated for cutting a material. Supposedly, a stone knife was the first tool. By means of intuition and experiments he determined that cutting ability depends on the degree of sharpening a tool and its efficiency on the blade speed. Speed of movement of the blade could be enhanced by placing it at the end of a lever. Thus, tools, which are still used nowadays, were constructed: a scythe, a poleaxe, a chopper, an axe. Cold steel – e.g. swords and sabres, is a variety of these tools. Light blades e.g. scythes, light swords, sabres were used for cutting relatively soft materials, and for cutting hard materials heavy blades were necessary, e.g. axes, halberds, heavy swords which were able to cut the warrior's armour. Today, one may say that it was practically and theoretically justifiable. Rotating blades in today's chaff-cutters, buzz-saws, milling machines or blades mowing with translational motion in bandsawing machines and chain saws use the oldest known property, according to which efficiency of cutting depends on the speed of cutting. Energy is necessary to perform any work. In case of cutting soft materials, high resistance of a blade was unnecessary. The required energy of cutting was obtained by placing a blade in high speed, which in case of small mass was possible (e.g. swords). Whereas, in case of cutting hard materials, resistance of a blade needed to be higher, therefore, more massive and heavier tools placed on longer handles were used in order to place a tool in appropriate speed (e.g. axes, halberds). Practice proves that efficiency of a light axe is low. In other words, kinetic energy of movement of a cutting tool decides on the efficiency of cutting, which depends on the square of the tool speed and its mass.

Cutting biological materials is the most frequently performed activity in direct food production – e.g. cutting fruit, vegetables, meat and indirect – e.g. grass, straw. Although, this activity is popular, no general theory of cutting plant materials, which would allow determination of basic geometrical, kinematic and dynamic parameters, e.g. such as; dimensions of a tool, speed of the tool's motion, values of forces related to cutting depending on kinematic parameters have been yet developed. In many works, attempts to describe mathematical phenomenon of cutting limited to a selected cut material (meat, stalk of a plant) and a cutting tool were made (Diakun, 1985; Dowgiałło, 2002; Żuk, 2007). As soon as at the stage of determining the forces necessary to cut a specific material, problems with determination of parameters which influence its value, occurred. Mutually exclusive theories and opinions were formulated, with which it is hard to agree, e.g. in Kanafojski's work (Kanafojski, 1980) a statement was made that at cutting plants, cutting resistance and the value of work do not depend on the size of the obtained area of cross-section. Based on the so-called Goriaczkin's formula, which determines a unit pressure of the blade length p made on material as a function of speed of perpendicular cutting v_{on} and contact cutting v_{ot} one may assume that the force of infinite value is needed.

Any of the known computational models of cutting resistance is not enough precise to be applied in the process of designing a processing machine (Dowgiałło, 2002). It seems that construction of a general model of cutting is impossible since the phenomenon itself is difficult to be mathematically described on account of depending on many parameters and factors. Impact on energy demand depends on the type and variety of the cut material which has a wide range of properties such as hardness, elasticity, viscosity, anisotropic properties and the type of a cutting tool, its geometry of the cross-section of a blade and geometry of the blade line.

Description of the phenomenon which depends on many parameters is very difficult and frequently even impossible. Then, simplified and experimental methods are used.

In this paper a simple way of experimental determination of a coefficient was used, which characterizes resistance of cutting of the selected material with a specific cutting tool. The principle of maintaining mechanical energy and the principle of equivalence of work and mechanical energy was applied. A simple guillotine cut (perpendicular) was assumed. Then, based on the determined coefficient, the course of loads for an exemplary cutting unit of a shredder for energy willow was determined.

Experimental determination of the cutting resistance coefficient

Oppositely to shear strength, the determined size was called a coefficient of cutting resistance because it describes stresses, which are formed during cutting a material with a specific cutting tool. Coefficient of cutting resistance is determined on a simple research position which operates similarly to a known Charpy's single-blow impact testing machine, differing only with the material of the pendulum arm, which is made of a light material. A knife is mounted at the end of an arm – figure 1. Due to the fact that the mass of a pendulum is focused at the end of an arm is considered as mathematical. The knife blade line is horizontal and at the same time perpendicularly to the motion plane of the pendulum that is a simple guillotine cut is performed. A sample of the tested material of a rectangular cross-section is mounted immobile at the place of placing a balance for a pendulum. Following a hit from a given angle, a depth g_w and width b_w of the knife cut into a tested sample is measured.

The research position is assumed to be designated for determination of an approximate cutting resistance of a specific material with a knife used in a specific machine which cuts layers of materials of a given thickness g_w. Then, deflection of a pendulum increases gradually as to the moment of cutting the whole layer. In case, when the kinetic energy is too low at the moment of hit for the maximum deflection (horizontal location of an arm), the increase of potential energy is possible by adding an additional mass at the end of the pendulum.

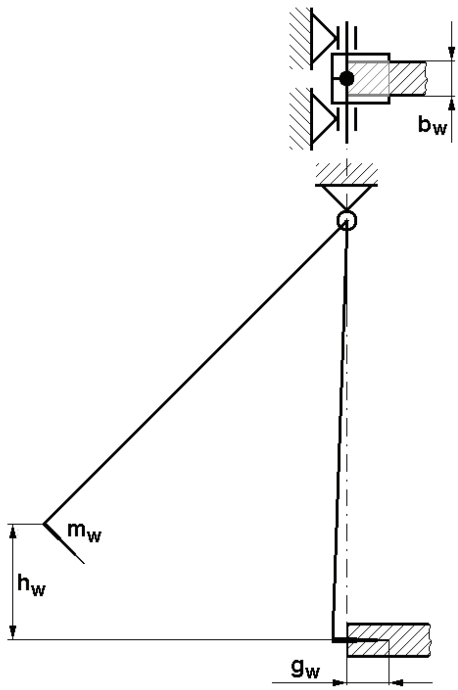

Figure 1. Schematic representation for determination of the cutting resistance coefficient

Theoretical bases

It is known that the force necessary for cutting a material depends directly proportionally on the cut cross-sectional area. To cut the material, the condition must be met (Wolny, 2002)

$$\tau_t = \frac{F_w}{s_{mt}} \geq k_{mt} \tag{1}$$

where:
- F_w – force necessary to cut material, in the section plane (N),
- k_{mt} – resistance of material to shear (MPa),
- s_{mt} – area of the cut cross-section (m^2),
- τ_t – shear stress at shearing (MPa).

The above condition assumes that in the moment of shear, the whole area of the cut cross-section is moved at the same time, i.e. the whole cross-sectional area is displaced. During cutting material with a knife the whole cut cross-section is dislocated. In case of a static pressure of a knife on the loose cut material, movement of a knife through a material will start at the moment of exceeding admissible pressures of the cut material through an area of a pressing knife, which is difficult to be determined, that is a cut material is subject to surface pressure. It may be assumed that after exceeding the strength to surface pressure, a knife will "flow" through the cut cross-section but also in this case the force necessary for cutting will increase along with the thickness of the cut layer of a material – figure 2.

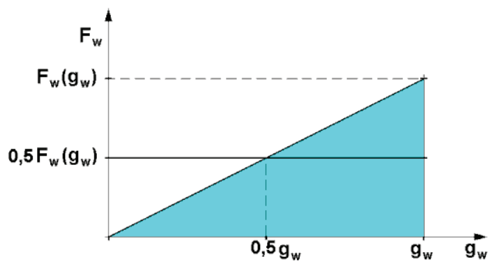

Figure 2. The course of the cutting force as a function of the thickness of the cut layer

The following dependence expresses the performed work of cutting a layer of a rectangular cross-section

$$W_w = 0.5 F_w g_w \tag{2}$$

where:
- g_w – thickness of the cut layer (m),
- W_w – work necessary to cut material (J).

that is after including dependence (1) we will obtain

$$W_w = 0.5 k_{mt} s_{mt} g_w = 0.5 k_{mt} b_w g_w^2 \tag{3}$$

where:
- b_w – active length of a knife (width of a sample) (m).

From the principle of the performed work and energy the following is obtained

$$W_w = E_w = gm_w h_w \tag{4}$$

where
E_w – energy of cutting (J),
g – gravitational acceleration ($m \cdot s^{-2}$).

thus, a coefficient of strength of shear with a specific knife may be determined according to the dependence.

$$k_{mt} = \frac{2gm_w h_w}{b_w g_w^2} \tag{5}$$

The force necessary to cut material based on (1) may be determined according to the dependence.

$$F_w = k_{mt} b_w g_w \,. \tag{6}$$

Determination of machine loads

Material for shredding energy willow is fed by two rotating shafts (3) between a counter-cutting edge (2) and mobile blades placed along the element of the rotating shaft (1) – figure 3 driven by an electric motor.

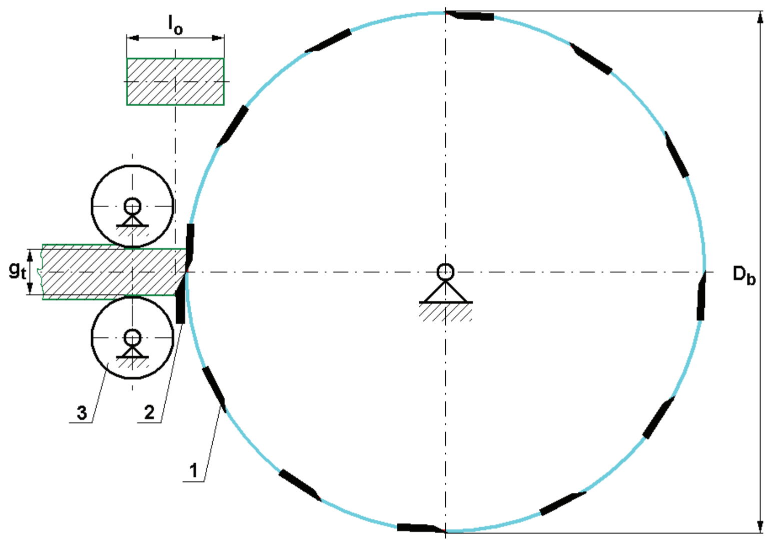

Figure 3. Schematic representation of a shredder for energy willow

Total work of cutting forces of blades placed at the circumference of a drum including a counter-cutting edge

$$W_{to} = \pi D_b F_{ts} = 0.125 k_{mt} l_o {g_t}^2 z \tag{7}$$

where:
- D_b – diameter of a drum (m),
- F_{ts} – average cutting force (N),
- g_t – thickness of the cut layer (m),
- l_o – length of the active blade (m),
- W_{to} – work of cutting forces at the circumference of a drum (J),
- z – number of blades at the circumference.

thus, the value of average cutting force may be expressed with the dependence

$$F_{ts} = \frac{k_{mt} l_o {g_t}^2 z}{8\pi D_b} \tag{8}$$

whereas, the moment of forces loading a driveline

$$M_t = 0.5 F_{ts} D_b = \frac{k_{mt} l_o {g_t}^2 z}{16\pi} \tag{9}$$

Required minimum power of the driving motor

$$N_t = F_{ts} v_t = \frac{k_{mt} l_o {g_t}^2 z \omega_s}{16\pi} \tag{10}$$

or

$$N_t = F_{ts} v_t = \frac{k_{mt} l_o {g_t}^2 z n_s}{480} \tag{11}$$

where:
- M_t – moment of forces loading the driveline (N·m),
- N_t – power of the driving motor (W),
- n_s – rotational speed of a drum (rot·min^{-1}),
- v_t – peripheral speed of a drum (m·s^{-1}),
- ω_s – angular velocity of a drum (rad·s^{-1}).

Numerical example

A pressed layer of shoots of energy willow of a rectangular cross-section and dimensions $b_w \times g_w$ = 0.1 m × 0.03 m was cut with a knife of similar geometry used in a machine for shredding energy willow. Total mass of a knife along with a load m_w=5 kg was placed at the end of the pendulum deflected to the value of h_w=1.5 m.

Based on dependence (5), the value of coefficient of the cutting resistance

$$k_{mt} = \frac{2gm_w h_w}{b_w g_w^2} = \frac{2 \cdot 9.81 \cdot 5 \cdot 1{,}5}{0.1 \cdot 0.03^2} = 1.64 \text{ MPa}$$

A shredder for energy willow, with knives in the number of z=12 placed at the circumference of the rotating drum of a diameter of D_b=0.5 m rotating with a rotational speed of n_s=500 rot·min^{-1}, cuts the layer of $l_o \times g_t$ = 0.2 m × 0.06 m.

Value of average cutting force based on dependence (8)

$$F_{ts} = \frac{k_{mt} l_o g_t^{\,2} z}{8\pi D_b} = \frac{1.64 \cdot 10^6 \cdot 0.2 \cdot 0.06^2 \cdot 12}{8\pi \cdot 0.5} = 1128\text{N}$$

The moment of forces loading the driveline based on the dependence (9)

$$M_t = 0.5 F_{ts} D_b = 0.5 \cdot 1{,}128 \cdot 0.5 = 282\text{Nm}$$

whereas the required minimum power of the driveline based on the dependence (11)

$$N_t = \frac{k_{mt}}{480} l_o g_t^2 n_s z = \frac{1.64 \cdot 10^6}{480} 0.2 \cdot 0.06^2 \cdot 500 \cdot 12 = 14.8 \text{ kW}$$

Conclusion

The value of the coefficient of cutting resistance physically describes relation between the energy of movement of the specific cutting tool and the obtained cross-sectional area. The coefficient may be described as a dynamic coefficient of cutting resistance since it was determined during dynamic (impact) cutting attempt. Depends on the type of cut material and geometry of a cutting tool, that is, it should not be compared to shear strength. The suggested method allows only approximate determination of average load and the power of the driveline of the cutting device. It may be used for initial determination of parameters of the machine at the design stage, because periodical changes of load, which occur during machine work, movement resistance in the driveline and dynamics of the movement of the knife drum were not included. The determined value of power is comparable to the power of engines used in this type of devices of similar dimensions and efficiency.

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DOŚWIADCZALNO-TEORETYCZNA METODA WYZNACZANIA OBCIĄŻEŃ ZESPOŁÓW TNĄCYCH

Streszczenie. W pracy przedstawiono założenia pozwalające na określenie zapotrzebownia energetycznego maszyny wykorzystującej proste cięcie gilotynowe określonego materiału o małej sprężystości, np. miękkiego drewna. Zaproponowano prosty sposób doświadczalnego wyznaczania oporów cięcia oraz współczynnika charakteryzującego właściwości materiału i narzędzia tnącego. Liczbową wartość współczynnika wyznaczono na podstawie zasady zachowania energii mechanicznej oraz zasady równoważności pracy i energii mechanicznej. Na podstawie wyznaczonego współczynnika, określono średnie obciążenie i moc zespołu tnącego rozdrabniarki do wierzby energetycznej.

Słowa kluczowe: cięcie gilotynowe, współczynnik oporu cięcia, praca cięcia, zespół tnący

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DISTRIBUTION OF SURFACE PRESSURE OF AVOCADO FRUIT AT IMPACT LOADS

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ABSTRACT

The paper presents the results of measurements of surface pressure of Fuerte *avocado with the use of Tekscan system in impact loading conditions were presented. Contour lines of thrusts for two variants of loading which differ with speed and energy in the moment of crash were determined. Average values measured during the test were determined and statistical analysis was carried out for them. It was determined that the increase of speed and energy results in the increase of value of the maximum surface pressure but does not influence significantly their distribution on the resistance surface. It was proved that in the central area of contact mainly elastic strains appeared at the lack of plastic strains of tissue.*

Avocado fruit (Polish name: *smaczliwka*) comes from the Central America from Mexico. In the South America it has been known for thousand years. Avocado was brought to Europe by conquistadors, where it has become commonly available in the sixties of the 20th century. Presently, avocado is cultivated at the industrial scale mainly in the USA, Mexico, Brasil, Indonesia, New Zealand, Israel and the Republic of South Africa. In Poland in recent years import of avocado fruit has increased few dozens times.

Avocado during transshipment, transport, sorting and other treatments indispensable for obtaining the final product are subject to various static, dynamic and impact loads. Impact loads may mainly be a result of bruises which cause losses for entrepreneurs. Avocado is transported as non-ripen which considerably increases its resistance to mechanical damage. However, during supply of avocado directly to the final consignee, fruit must have proper degree of ripeness. Edward A. Baryeh (2000) when conducting research on the impact of the ripeness degree of avocado on resistance to bruises with the use of a penetrator determined that after 15 days from the moment of harvesting fruit, force necessary to place a penetrator by 5 mm was four times reduced.

At impact loads biological material behaves like material of elastic nature. Liquid and air which fill in inter cell spaces have no time to move to another regions with lower load (Gołacki, 2008). It causes exceed of cells strength and release of stresses in the form of crashes and damages to tissue. At low speed of load, biological material proves visco-elastic properties. In the initial stage of load after displacing gases and filling cell spaces, the process of migration of liquid takes place which causes strains of cell walls (Blachowec, 1985). A type of material strengthening is formed, which results from transferring loads by plant tissue components of higher strength, that is cell walls (Konstankiwicz et al., 1996; 1998; Lippert, 1995). As a result this type of load enables achievement of higher values of breaking stresses than at impact loads.

On account of avocado shape, analysis of contact loads may be one of the parameters which allow determination of resistance of mechanical damage. Contact issues referred to biological materials have been well described for apples at quasi-static loads. The most frequent is research, which tend to indicate changes of the surface area of apple contact with a working element of a testing machine influenced by external forces (Herold et al., 2001; Rabelo et al., 2001; Lewis et al., 2008). Acican (2007) carried out interesting research on apples at dynamic loads. Van Zeebroeck (2003) carried out investigation on apples with the use of a device which used the principle of a pendulum and executed discrete models of final elements which allow determination of the impact of transport conditions on the losses caused by damage to apples (Van Zeebroeck, 2007).

Frequently Hertz formulas are used for determination of surface pressure, however, they do not provide satisfying effects. On account of mechanical development of modelling methods which allow, to a higher extent, including properties which are characteristic for biological materials, determination of surface thrusts may constitute a basis for carrying out experimental verification of developed models (Stopa, 2011).

The objective of the research

The objective of the research was to determine contour layers and distribution of surface pressure of *Fuerte* avocado fruit by means of experiment in conditions of impact loads for two various speeds and energy of the impact.

Methodology and object of the research

The measurements were taken in the Department of Agricultural Engineering of the University of Life Sciences in Wrocław. A test rigs operating with the use of free pendulum principle equipped with a foil sensor of *Tekscan* system was used for research.

Carefully selected avocado fruit of Fuerte cultivar from plantations located in the Central America were designated for tests. Tests were carried out for fruit directly from a fruit store. The selected fruit during measurements were stored in a cool room in temperature approx. 3ºC and air humidity at the level of 90-95%. They attempted to select fruit of a similar shape and weight (mass approx. of 210 g) and the same relation of height and diameter of $h/\phi = 0.5$. Geometric and strength dimensions of the research object were presented in table 1.

Test research position (fig. 1) was built of a rigid frame, the bottom fragment of which was made of a resistance flat surface. Structure of a frame allowed elimination of an effect of vibrations in the moment of impact. Impact load was performed with the use of a free pendulum mechanism. The research position allowed speed and impact energy control through change of the initial angle of location of the pendulum arm.

Table 1
Geometrical dimensions and strength properties of avocado fruit

Fruit mass m_o (g)	Stone mass m_p (g)	Fruit diameter φ (mm)	Fruit height h (mm)	Module of pulp elasticity Em (MPa)	Module of stone elasticity Ep (MPa)
210	50	70	140	0.98	695

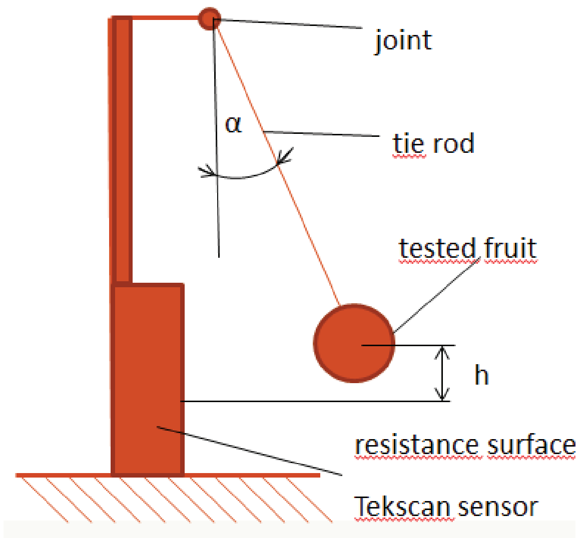


Figure 1. Measurement stand for impact research

A sensor used in tests had working surface with dimensions of 71.1x71.1 mm and average density of sensors which was 3.9 cm^{-2} (Table 2). Along with proper software it enabled collection of data with frequency reaching approx. 5000Hz.

Table 2
Technical data of a foil sensor

Sensor dimensions		Lengthwise direction		Crosswise direction		Number of sensors (items)	Density of sensors (item·cm^{-2})
Length (mm)	Width (mm)	Spacing (mm)	Number (items)	Spacing (mm)	Number (items)		
71.1	71.1	5.1	14	5.1	14	196	3.9

Source: www.tekscan.com

Test of impact load of avocado fruit was carried out for two different variants of test parameters (Table 3), which were obtained through the change of angle α of inclination of a test rigs pendulum arm. The change of impact from v=1.4 $m \cdot s^{-1}$ do v=2.0 4$m \cdot s^{-1}$ and energy of impact from E=0.5J to E=1.0J was obtained through the change of angle α from α=30 degrees to α=45. Ten repeats for each variant of load was carried out and statistical analysis for the maximum values of surface pressure were carried out.

Table 3
Exemplary test parameters

Variants	Mass m (kg)	Height Height (m)	Speed v ($m\cdot s^{-1}$)	Energy E (J)	Angle α (°)
1st variant	0.5	0.1	1.4	0.5	30°
2nd variant	0.5	0.2	2.0	1.0	45°

Results of measurements were subjected to statistical treatment with the use of Statistica software. 60 observations were analysed out of which 30 was for speed and energy of impact. For each value of particular properties a mean value of standard deviation and 95% confidence interval for a mean value were calculated. Table 3 and 4 present exemplary results of statistical analysis, which include determination of surface thrusts for two speeds and energy of impact.

Errors related to the shape of samples, measurement of the pressure force and determination of the contact surface constituted a part of total error of experimental determination of surface pressure. On account of very careful preparation of samples for research, the error of shape as a systematic error may be omitted. Measurement of force, measurement of the surface area of contact and the value of surface pressure was determined with the use of Tekscan system of the following parameters: system precision <±4%, blinearity error<±3%, repeatability of results<±3.5%, hysteresis<±4.5% and drifting: <5%.

Research results and their analysis

A pendulum device after setting an inclination angle of an arm, was moved by releasing a lock mounted to the structure of test rigs. Avocado fruit upon hitting an obstacle was bounced several times to complete stop. Figure 2 presents subsequent impulses calibrated in surface pressure as time function. In case of the 1st variant of the impact parameters (table 1) to the total stop of a pendulum, 6 impacts of avocado at a resistance surface were indispensable. Values of maximum surface pressure decreased in subsequent impulses from p=0.48 MPa to p=0.11 MPa, whereas the force of impact was changing within F=141 N to F=4 N.

Each impulse of force was composed of two characteristic stages which divide an impulse into two parts (figure 3a). The first stage including 4.75 ms was characterised with violent increase of impact force and then upon reaching the maximum value with an explicit decrease but without the contact of avocado fruit with the surface of a resistance surface. The second stage of impulse lasting 6.41 ms started from the increase of the impact force from the minimum value achieved at the end of the 1st stage to the maximum value not higher than the maximum value obtained in the 1st stage. The final stage of force impulse was a gradual decrease of the impact force to the loss of contact of avocado with a resistance surface. Similarly, values of surface thrusts change during a single force impulse (fig. 3b). However, on account of deformation of avocado fruit pulp and thus the change of the surface of contact of a fruit with a resistance surface, the course of pressure changes is milder. Values of pressures obtained in the second stage of an impulse are clearly lower than in the first one.

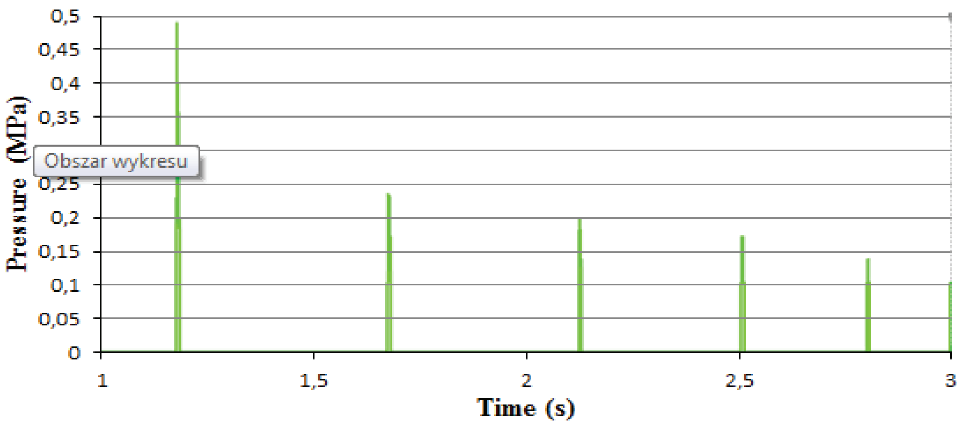
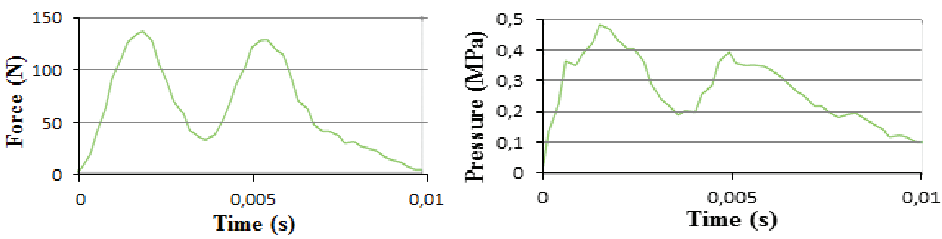


Figure 2. Subsequent impulses of surface pressure as the time function (1st variant)



a) impulse of force b) impulse of surface thrusts

Figure 3a and b. Impulse of force and surface pressure as a function of time (1st variant)

Total time of contact of fruit with a resistance surface from the moment of commencement of contact to its end during the first impulse was 11.16ms. Such behaviour of avocado fruit during the impact may be explained by interaction of a stone, the mass of which is approx. 25% of the mass of the whole fruit and the module of elasticity is 700 times higher than the module of the pulp elasticity (table 1).

When analysing contour layers of surface thrusts (figure 4) for the 1st variant of load (table 3) in the first stage of impact (after 2.24 ms from the beginning of contact), one may report that the maximum values of surface thrusts are in the central zone of contact and decrease when getting closer to border areas of contact. In the cross-section distribution of surface thrusts has a shape of even curve with the maximum in the central point of contact of avocado fruit with a bumper. The maximum surface pressure achieve value to p= 0.699 MPa and their mean is p=0.449 MPa (Table 4).

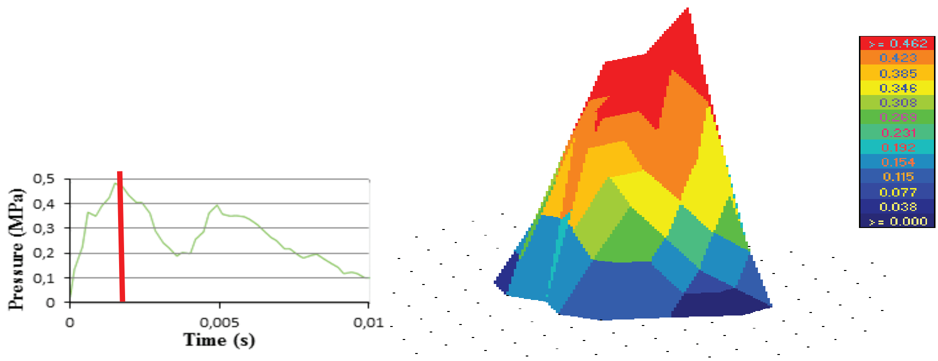


Figure 4. Contour layers of surface pressure – the first variant of load (Δt =2.24ms)

In the bounce phase for the first stage of force impulses (figure 5) after 4.51 ms from the beginning of contact the image of surface pressures in the contact area has not significantly changed. Values of surface thrusts and the contact surface but the system of contour layers has not changed. The maximum value of surface pressure in the final bounce phase was p=0.205 MPa.

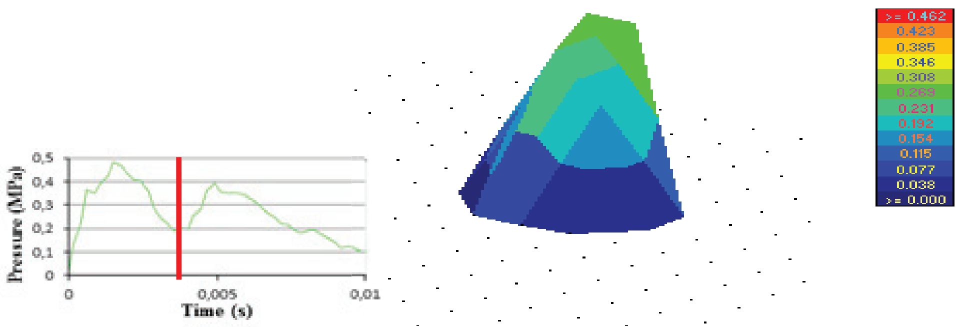


Figure 5. Contour layers of surface pressure – the first variant of load (Δt =4.51ms)

In the second stage of impact force impulse, the system of contour layers of surface pressure (fig. 6) has a shape similar to the system of the first stage of force impulse. Maximum values are in the central contact zone but both force and value of pressures were reduced. The maximum value of surface thrusts on this stage of force impulse operation was p=0.595 MPa, at the impact load of F=131 N.

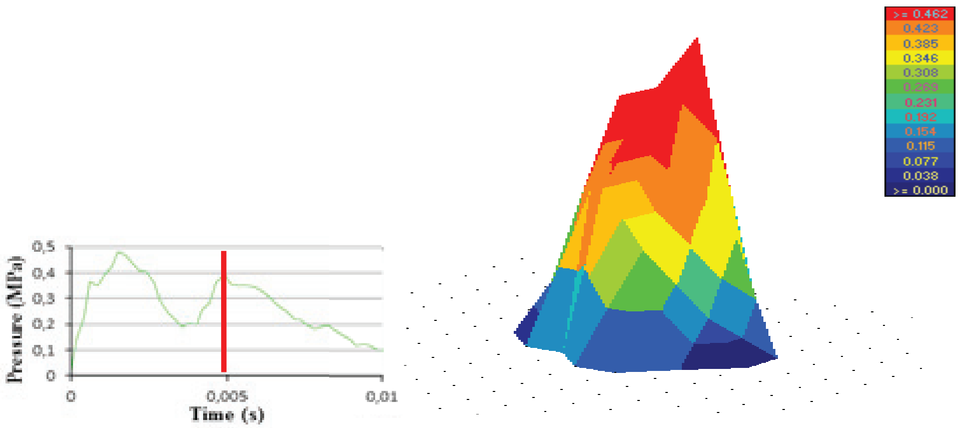


Figure 6. Contour layers of surface pressure – the first variant of load (Δt =6.41ms)

Such distribution of pressures may prove small values of plastic strains of the pulp tissue in the zone with the highest loads and prevailing elastic strains which cause avocado fruit bounce on a resistance surface. Majority of cells which are in the contact zone participate in returning elastic energy collected during a bump.

Table 5 presents mean values of parameters which are the object of measurements during tests which were performed along with the statistical analysis carried out for a test consisting in 10 repeats for the whole force impulse.

Table 4

Test results – first impulse (v=2 m·s^{-1}, E=1.0 J)

Factor	Value	
	stage 1	stage 2
Maximum pressure p_{max} (Mpa)	0.699	0.595
Mean pressure p_{max} (Mpa)	0.449	0.358
Force F (N)	139	131
Time of contact Δt (ms)	4.75	6.41
Impulse of force (N·*s*)	1.506	
Impulse of pressure (MPa·*s*)	0.004497	

Table 5

Test results statistical analysis – first impulse (v=2 m·s⁻¹, E=1,0 J)

Factor	N	Mean value	Standard deviation	95% confidence interval	
Maximum pressure p_{max} (Mpa)	10	0.403	0.0336	0.3884	0.4356
Force F (N)	10	135	6.50	128.97	144.03
Time of contact Δt (ms)	10	11.16	0.12	10.32	12.12

At higher values of speed and energy in the moment of impact planned during tests (2nd variant of load – table 3) the image of surface pressures in the contact zone does not significantly change. A single impulse for the 2nd variant of load in the initial phase of impact had a similar course for the 1st variant. Very quickly because in time approx. of 2 ms a maximum value of surface pressure was achieved (fig. 7). Two stages of force impulse are visible as in the 1st variant.

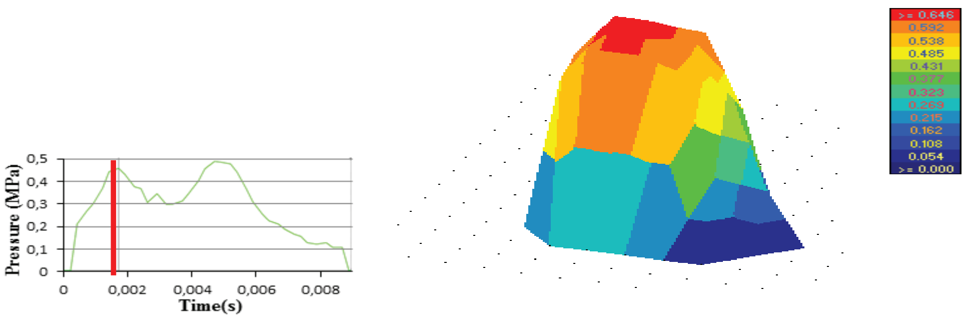


Figure 7. Contour layers of surface pressure – the second variant of load (Δt =1.77ms)

In the initial moment of impact (after 1.77 ms) a contact of avocado with the resistance surface had a point nature (fig. 7). At a small surface area of contact, the maximum values of surface pressure (p=0.612 MPa) were in the area of central zone but average value of pressure was p=0.462 MPa

As a result of fast operation of big pressure force on a small area an increase of pressure of cell liquids in the contact zone took place, which at lack of cell destruction led to elastic strains. Accumulated elastic strain resulted in bouncing avocado on a resistance surface (fig. 8), which was recorded as decrease of the values of maximum surface pressure to the level of p=0.385MPa.

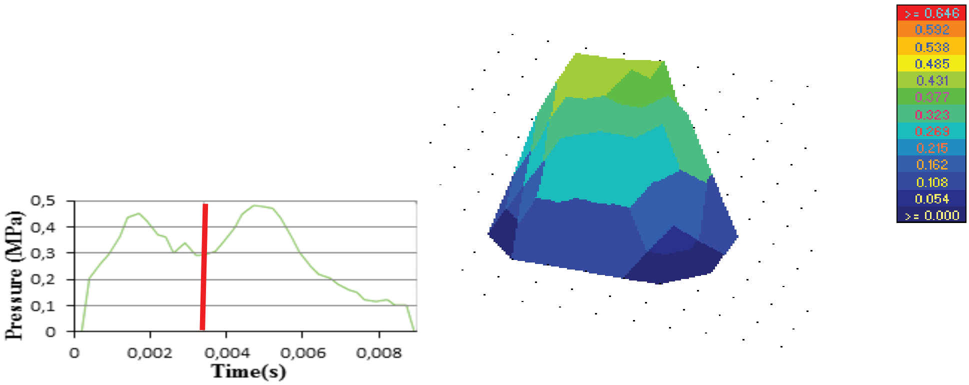


Figure 8. Contour layers of surface pressure – the second variant of load (Δt =3.34 ms)

Then, most probably as a result of inertial force of stiff stone the increase of surface pressures took place reaching the value of p=0.656MPa (fig. 11) and a gradual decrease to the moment avocado lost contact with the resistance surface.

The described mechanism of phenomena which take place during the impact of avocado fruit with the resistance surface did not lead to destruction of the pulp tissue and formation of elastic strains. The maximum values of surface pressure appeared always near the central contact point and disappeared at the border of the contact area in places, where new batches of cells entered the contact zone.

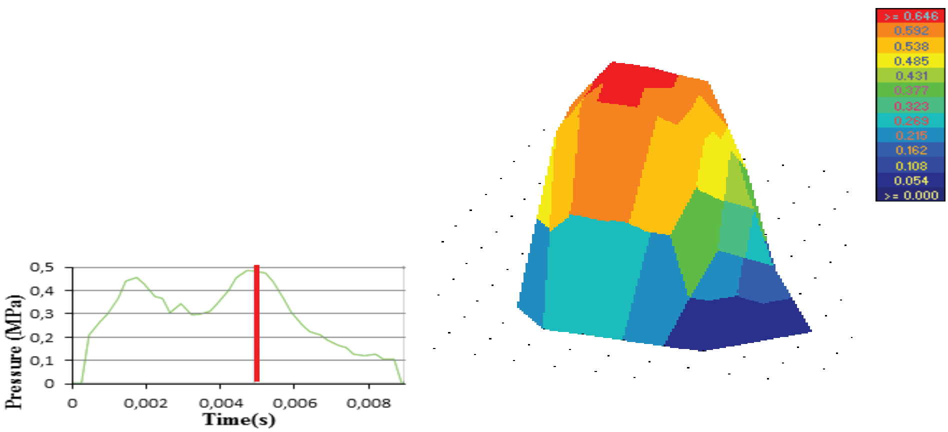


Figure 11. Contour layers of surface pressure – the second variant of load (Δt =4.99 ms)

Average values of parameters measured during the test at the 2nd variant of load (table 3) along with the statistical analysis carried out for 10 repeats was presented in table 7. The fact that along with the increase of force in the impact moment for the 2nd variant of load towards the 1st variant, surface thrusts were proportionally increased, should be mentioned. Contact time changed from 11.16 ms to 8.8 ms. It proves strain nature of the impact test which was carried out.

The impulse of force calculated as a quotient of average force and time of operation on avocado fruit and analogically the impulse of surface pressure calculated as a quotient of average pressure and time of its operation is an interesting parameter which describes the impact test. As long as the impulse of force for both variants of load increased almost by 19% the impulse of surface pressures increased only by over 7%.

Table 6
Test results – first impulse ($v=4\ m{\cdot}s^{-1}$, E=6.7 J)

Factor	Value	
	stage 1	stage 2
Maximum pressure p_{max} (Mpa)	0.612	0.656
Mean pressure p_{max} (Mpa)	0.462	0.490
Force F (N)	179	227
Time of contact Δt (ms)	1.77	4.99
Impulse of force (N·*s*)	1.786	
Impulse of pressures (MPa·*s*)	0.00418	

Table 7
Test results - first impulse ($v=4\ m{\cdot}s^{-1}$, E=6,7 J)

Factor	N	Mean value	Standard deviation	95% confidence interval	
Mean pressure p_{max} (Mpa)	10	0.476	0.0336	0.4584	0.4956
Force F (N)	10	203	4.50	192.97	214.03
Time of contact Δt (ms)	10	8.8	0.12	8.52	10.12

Conclusions

1. Contour layers of surface pressure slightly depend on the energy of avocado fruit impact. Mean values of maximum surface pressure increase from p=0.403 MPa at E=0.5J to p=0.476 MPa at E=1.0J.
2. Mass of a stone significantly influences distribution of surface pressure during a single impulse.
3. Maximum values of surface pressure are distributed close to the central point of contact of avocado fruit with impediment both in the phase of entering the contact as well as in the stage of bounce. It proves low loss of elastic properties by avocado pulp.

4. The increase of impact energy in the researched scope of loads causes shortening of the contact time of avocado with an impediment.
5. Research results may serve as verification of discreet models of processes related to harvesting, transport and storage of apples.

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Avocado, grupa Itum, pozyskano ze stronu:www.itum.com.pl

ROZKŁADY NACISKÓW POWIERZCHNIOWYCH OWOCÓW AVOCADO PRZY OBCIĄŻENIACH UDAROWYCH

Streszczenie. W pracy przedstawiono wyniki pomiarów nacisków powierzchniowych avocado odmiany *Fuerte* przy pomocy systemu Tekscan w warunkach obciążeń udarowych. Wyznaczono warstwice nacisków dla dwóch wariantów obciążenia różniących się prędkością i energią w momencie zderzenia. Wyznaczono średnie wartości wielkości mierzonych podczas testu i przeprowadzono dla nich analizę statystyczną. Ustalono, że wzrost prędkości i energii zderzenia powoduje zwiększenie wartości maksymalnych nacisków powierzchniowych, ale nie wpływa w istotny sposób na ich rozkład na powierzchni oporowej. Wykazano, że w centralnej strefie styku występowały głównie odkształcenie sprężyste przy braku odkształceń plastycznych tkanki.

Słowa kluczowe: naciski powierzchniowe, avocado, obciążanie udarowe

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ANALYSIS OF PHOTOVOLTAIC CELLS USAGE IN A HOUSEHOLD

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ABSTRACT

The issue of photovoltaic cells usage for hot tap water heating in a household has been presented. There has been built a research point, which was situated on a single-family house in the country. The aim of the research was obtaining maximum performance characteristics of the system for hot tap water heating based on photovoltaic cells. It was carried out during summer solstice because of the most favourable relationship of day versus night, from the point of view of efficiency. Results collected from the research enabled to obtain a lot of exploitation characteristics describing the system. There have been presented exemplary time courses of action of generated power and selected working parameters. Maximum energy performance of the system has been determined. Further research should enable to define minimum hot water tank capacity as a buffer of energy and minimum number of panels that constitute a heating water battery, in order to fulfil requirements included in the Ordinance of the Minister of Infrastructure dated 14th January 2002, related to defining average norms of water consumption (Journal of Law 8/02 item70).

Introduction

Development of renewable sources of energy in Poland is an activity, the aim of which is taking care of environment cleanness and improving energy stability of the state. Strategic document in the scope of energy development in the state is „The Energy Policy of Poland till 2030" adopted by the Government on 10th November, 2009. One of the priorities of the strategy is increasing by Poland till 2020 the share of energy obtained from renewable sources of energy to the level of at least 15%. The obligation to reach the aim mentioned above is the result of the regulation 2009/28/EC related to application of energy obtained from renewable sources of energy. It is a particularly significant problem, since 87% (53.8% hard coal, 33.2% brown coal) of electric energy in Poland is produced from coal (Grudziński, 2010). One of generally accessible, and still idle sources of renewable energy is the sun. Our planet receives 15 000 times of solar energy more than energy that we produce out of conventional sources. It is estimated that within the next 10 years, there will be a balance observed between the process of energy obtained in a conventional way and in the process of photovoltaic conversion (Jastrzębska, 2013). The Ministry of Economy has planned development of energy taking the advantage of photovoltaics till 2020 at the level of 2 MWp, but till 2030 at the level of 32 MWp (Hołub et al., 2010). It is worth emphasizing that renewable energy development will be mainly based on dispersed generation that allows reduction of losses resulting from energy transfer, which will significantly improve energy safety of the state and will reduce emission of greenhouse gases (Popczyk, 2011).

Generally, photovoltaic systems may be divided into (Jastrzębska, 2009; Jastrzębska, 2013; Forest and Simoes , 2006; Sarniak, 2009):

- autonomous (independent systems, comprising of a battery of photovoltaic panels, energy buffer – batteries, monitoring system and supervision of the system work, and DC/AC inverter – optionally);
- the ones cooperating with power network (system comprising a battery of photovoltaic panels and DC/AC inverter with capacity of direct cooperation with power network);
- hybrid (a combination of a photovoltaic generator with another system of energy production, e.g. wind power station).

A special type of autonomous system is a so called conjugated system. It comprises a battery of photovoltaic panels only, which is attached directly to a receiver (Jastrzębska, 2013). A photovoltaic hydrogen generator or installations for tap water heating may be included in this type of systems. This type of system is characterized by the simplicity of its construction, and much lower costs of production, when compared to systems with a buffer of electric energy. All types of the systems mentioned above can be used in households. It is estimated now that in Europe photovoltaic systems in households constitute 23% of photovoltaic systems in general, and their yearly increase is estimated at the level of 35% (Jastrzębska, 2013). Apart from being used to supply energy to typical household appliances, photovoltaic cells can also be used to supply energy to household means of transport (electric cars, single-track vehicles with electric drive) as well as vehicles used in a garden (battery-powered lawnmower, battery pump, etc.) (Carroll, 2003).

The advantage of photovoltaic systems used to supply energy to appliances in a household is that they are practically unattended contrary to biomass power generators, and they do not make noise, which is characteristic in case of wind power stations. Their disadvantage may be low efficiency (e.g. sillicon monocrystalline up to 24.7%, sillicon polycrystalline up to 20.3% (Panek, 2011), and instability of efficiency, for the perspective both of a day, and a year.

The aim of the paper is to evaluate exploitation characteristics of a system of tap water heating in a household supplied in energy from batteries of photovoltaic panels.

Characteristic of the research point and the course of measurements

In order to achieve exploitation characteristics there has been designed and made a prototype point of hot tap water heating, which was supplied by energy from photovoltaic cells (fig.1). The research point was installed in a household located in Zwierzewo (Ostróda province, Warmińsko- Mazurskie Voivodeship). The point is a classical conjugated system composed of 6 batteries of polycrystallic photovoltaic panels by DMEGC (DM235-P156-

60) and a heater installed in a hot water tank of 140 dm^3 capacity by Galmet. The tank was a part of the system exploited before.

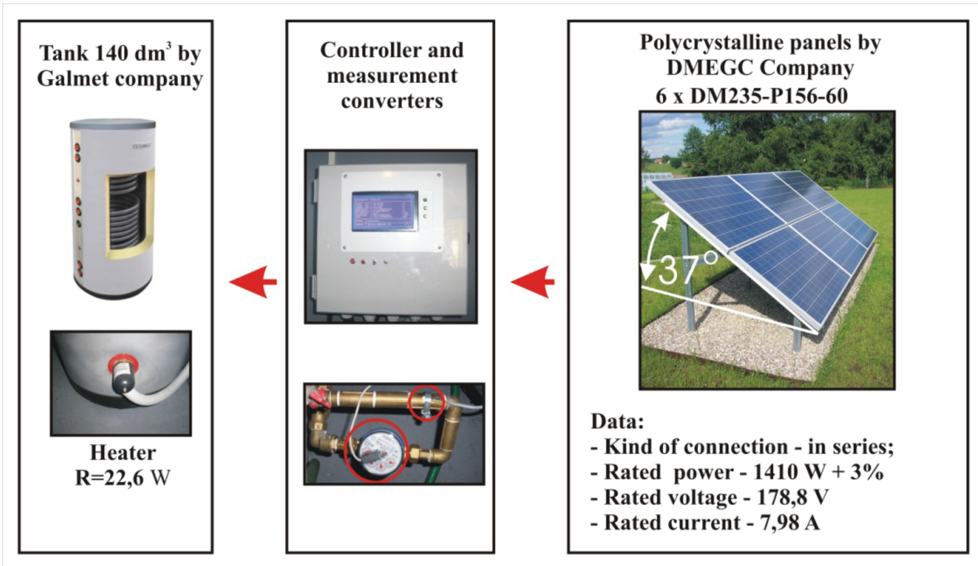

Figure 1. Picture of hot tap water system components in a household supplied by energy by means of photovoltaic panels

Resistance of the heater (22.6 Ω) was set in a way to obtain maximum energy efficiency of the batteries of photovoltaic panels. Panels were put in series connection and the following parameters were achieved: rated current of the value of 7.98 A, rated voltage of the value of 178.8 V, and rated power of the value of 1410 W. Battery efficiency was at the level of 14.5%. Panels were mounted on a static steel frame. They were directed to the south and the tilt angle value was 37º. It is the optimum position from the point of view of efficiency for the geographical location (53º42'25"N; 20º2'1"E). Panels tilt angle was calculated in „Photovoltaic Geographical Information System" calculator available at the website (http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php). Recording of time courses of action of selected working parameters, as well as monitoring of the research point functioning was made by means of a controller designed and produced for the requirements of the research, which remained in cooperation with measurement converters (Figure 2). For practical use, in systems that do not require monitoring of the value of selected working parameters, instead of a controller, it is sufficient to mount a thermostat that prevents from heating tap water to a too high temperature. It is a much cheaper and practical solution. The cost of mounting a point with a thermostat was estimated at PLN 5 660, in case of purchasing brand new panels, or PLN 3 980, in case of purchasing the panels from the secondary market.

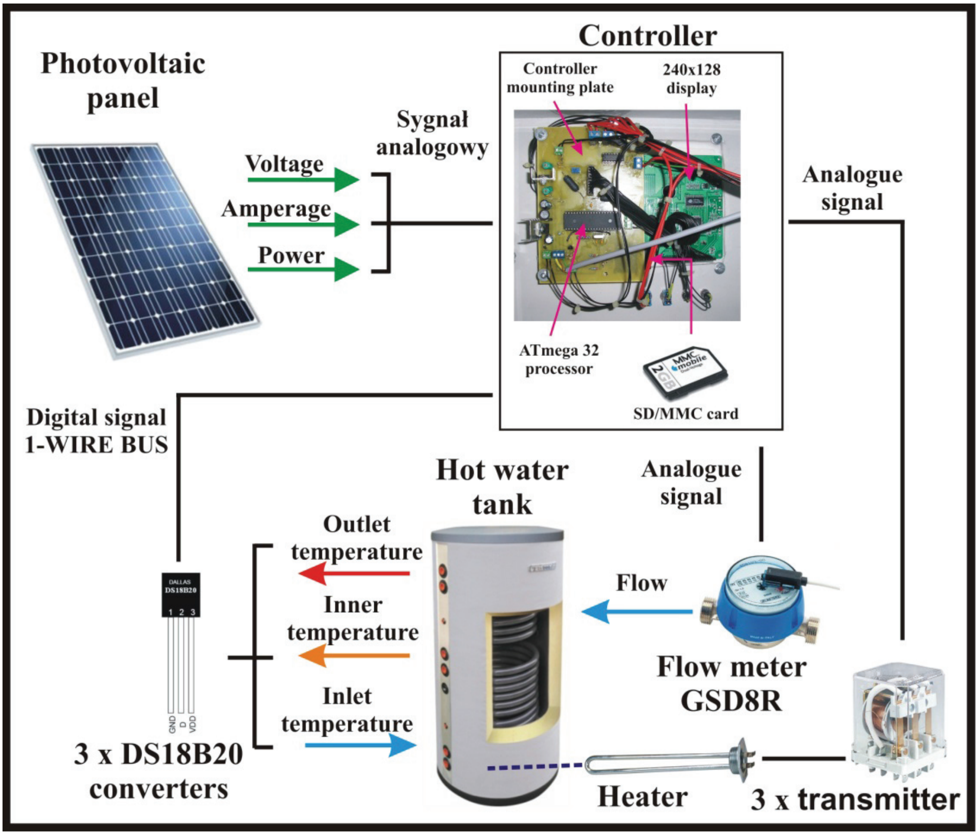

Figure 2. Scheme of monitoring system and supervision of tap water heating system

A designed controller was produced based on Atmega32 processor. It remained in co-operation with graphic display of 240x128 resolution. Memory card SD/MMC was used to record time courses of action of selected working parameters of the system. Data was recorded with 1 Hz frequency.

During the system functioning, the following working parameters were noted:
- voltage directly at the control clamp of photovoltaic panel of batteries;
- intensity directly at the control clamp of photovoltaic panel of batteries;
- power directly at the control clamp of photovoltaic panel of batteries;
- temperature at the intake pipe connector to the hot water tank (DS18B20 converter);
- temperature at the outlet pipe connector from the hot water tank (DS18B20 converter);
- temperature inside the tank of hot water (DS18B20 converter);
- flow of hot water (converter that cooperates with flow-meter GSD8R).

Applied converters cooperated with the processor using its analogue intakes data transfer buses 1-WIRE BUS. Through analogue intakes, the controller was able to operate three collectors of energy generated by a battery of photovoltaic panels. The presented system is an open one, and there is a possibility of its further development.

Observation of time course of action of selected functional parameters was carried out in the period preceding summer solstice (7:04 on 21st June 2013) and some days later, because of the most favourable relationship of the day versus the night. On these days it is possible to obtain highest capacity of the system because it is characterised by a possibility of generating energy, depending on the weather conditions and season of the year.

Analysis of the research results

In the given period, the lowest value of the working efficiency was observed on 14th June 2013 (during the day it was mostly cloudy), and the highest on 17th June 2013 (clear sky without clouds was observed from 10:00 a.m., and then after 5:00 p.m.). For those days, the observed results were in the extreme in the period that was object of the research, and the results relating to those days were subject of further analysis.

Figures 3 and 4 present time courses of action of generated power by the system in the period of two days that were characterised by different level of sunny weather.

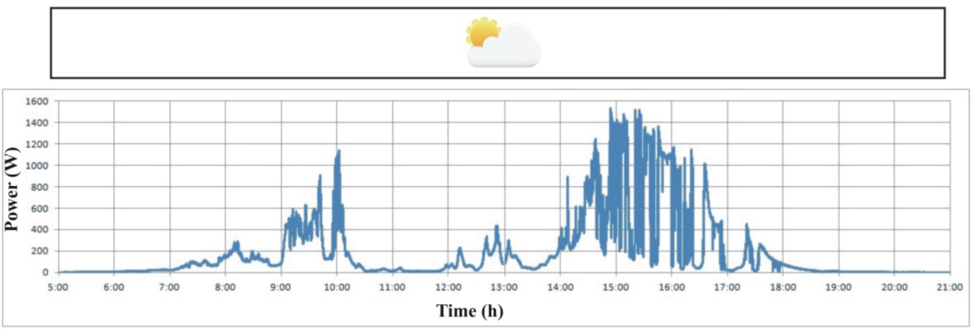

Figure 3. Time course of action of generated power by the system on 14th June 2013

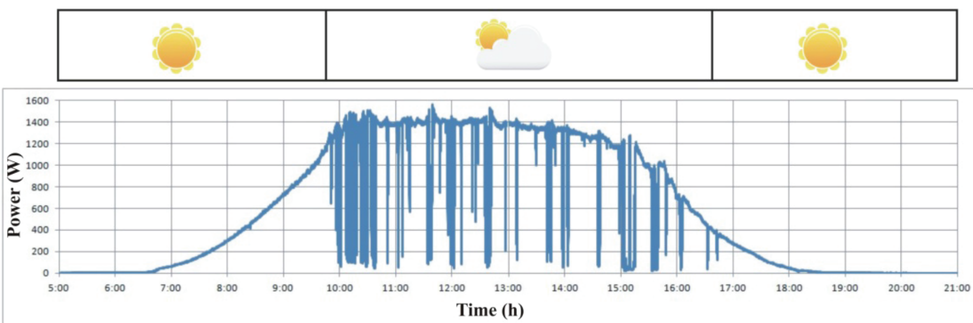

Figure 4. Time course of action of generated power by the system on 17th June 2013

Table 1 presents parameters that characterize work of tap water heating system on 14th and 17th June 2013.

Table 1
Parameters characterising work of tap water heating system

Characteristics of exploitation parameters	14th June 2013	17th June 2013
Average temperature of water at intake pipe connector to hot water tank (ºC)	14.85	14.82
Average temperature of water at outlet pipe connector from the hot water tank (ºC)	33.94	53.56
Minimum temperature of water in the tank (ºC)	31.8	42.19
Maximum temperature of water in the tank (ºC)	41.94	69.38
Water volume increase with temperature in the tank (ºC)	10.6	27.19
Consumption of hot water from the hot water tank (dm^3)	59	89
Average generated power (W)	180.59	565.22
Generated energy (kWh)	2.88	9.04
Usage indicator (%)*	12.76	40.07
Exploitation usage indicator (%)**	29.5	92.62

* – related to the energy that panels are able to produce in ideal conditions

** – related to the energy that panels are able to produce on a cloudless day for assumed tilt angle equal to 37° and given geographical location

Based on obtained results, it is possible to state that the battery of photovoltaic panels of total rated power 1,410W on a sunny day in June is able to produce a maximum 9.76 kWh of energy (amount assumed on the basis of analyzed power characteristics of 17th June 2013, with time of recording taken into account).

On 17th June 2013 the system generated 92.62% of energy that for a given configuration it was possible to obtain (this parameter defines also ratio of sunny weather during the day). On 14th June 2013, due to the fact it was cloudy, the amount of produced energy was three times lower than on 17th June. Such small amount of energy should be found insufficient in order to heat water (obtained energy was too low in order to heat realistic amount of water for a three-persons family to the temperature above 40ºC). Figures 3 and 4 allow observation of the dynamic decrease of power battery in photovoltaic panels, proportionally to the rate of cloudy weather. Within some seconds, generated power reaches the zero level, which makes it impossible to supply energy to majority of appliances in a household without the application of a system for buffering energy.

The presented system requires further research in order to define minimum capacity of hot water tank as an energy buffer and minimum number of panels comprising a battery, in order to secure required amount of hot tap water in summer season. In the present form, the system can be exploited as supplementary for tap water heating, in combination with conventional systems (e.g. provided in energy from power network).

Conclusions

1. The system of tap water heating presented in the paper is able to heat water itself on sunny summer days in order to heat water and fulfil realistic requirements of a three-persons family (on 17th June 2013 89 dm^3 were consumed from the tank, of the temperature from 42.19 to 69.38°C). On cloudy days, with applied solution, it can be used as a supplementary system of tap water heating when combined with conventional systems.
2. The presented system requires further research in order to define minimum capacity of hot water tank as energy buffer and minimum number of panels comprising a battery, in order to secure a required amount of hot tap water in summer season, according to requirements included in the Regulation by the Minister of Infrastructure of 14th June 2002, related to defining average norms of water consumption (Journals of Law 8/02 item70).
3. Direct energy supply of the heater in the hot water tank allows to reduce significantly the cost of materials necessary to make the system (configuration with a thermostat), the cost of which was estimated at PLN 5660, in case of purchasing brand new panels, or PLN 3980, in case of purchasing panels from the secondary market.
4. Systems of dispersed energy generation, based on photovoltaic cells are characterised by unattended exploitation and quiet functioning, they do not influence the environment in a negative way. However, defining the profitability of their application in the context of obtained efficiency requires further research in subsequent seasons of the year.

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Piotr Szczyglak, Jerzy Napiórkowski

ANALIZA WYKORZYSTANIA OGNIW FOTOWOLTAICZNYCH W GOSPODARSTWIE DOMOWYM

Streszczenie. Przedstawiono zagadnienie wykorzystania ogniw fotowoltaicznych do ogrzewania ciepłej wody użytkowej (CWU) w gospodarstwie domowym. Zbudowano stanowisko badawcze posadowione na domu jednorodzinnym usytuowanym w środowisku wiejskim. Celem badań było uzyskanie maksymalnych charakterystyk wydajnościowych układu do podgrzewania CWU opartego na ogniwach fotowoltaicznych. Przeprowadzono je w okresie przesilenia letniego, ze względu na najkorzystniejszy pod względem wydajności stosunek czasu dnia do nocy. Uzyskane z badań wyniki umożliwiły pozyskanie wielu charakterystyk eksploatacyjnych opisujących system. Zamieszczono przykładowe przebiegi czasowe generowanej mocy oraz wybrane parametry robocze. Wyznaczono maksymalną wydajność energetyczną układu. Dalsze badania powinny umożliwić ustalenie minimalnej pojemności zbiornika CWU jako bufora energii i minimalnej ilości paneli wchodzących w skład baterii do podgrzewania wody, by spełnić wymagania zawarte w Rozporządzeniu Ministra Infrastruktury z dnia 14.01.2002, w sprawie określenia przeciętnych norm zużycia wody (Dz. U. 8/02 poz. 70).

Słowa kluczowe: fotowoltaika, energia odnawialna, generacja rozproszona

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DYNAMICS OF ORGANIC FARMING DEVELOPMENT AND ITS SUBSIDIZING[1]

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ABSTRACT

Development of the Polish organic farming is characterized with great dynamics in the increase of the number of farms operating in this production system (number of farms increased by 10 times within 2003-2012). Moreover, area of agricultural land designated for such crops increases. Number of agricultural food-processing plants of raw materials, which come from organic farming, increases in a slower pace. Nevertheless, the trend is constantly rising. Results of field research on the example of 100 farms confirmed a national trend of organic farms development. The fact, that respondents from the researched facilities declared additional income sources, adding that incomes from organic production do not cover living demands for maintaining a family, was an essential information.

Introduction

Organic farming is a management system, which is an alternative to conventional farming, which tends to the improvement of quality and wholesomeness of food products and other agricultural products, organically balanced and limiting human interference in a farm eco-system. According to a definition of the Commission of Food and Agriculture Organization (FAO) and the World Health Organization, organic farming means the entire farming system, which supports biological variety, ecological cycles and soil biological activity (Codex Alimentarius Commission of FAO/WHO). The principles of organic agricultural production referred to plant production include inter alia: minimum 5-years rotation, the use of companion crops, intercrops, own organic fertilizers, mechanical weeding, whereas chemical plant protection is limited. In case of animal production there are limitations as to the size of livestock per one hectare of agricultural land, i.e.: 2 $LSU \cdot ha^{-1}$AL, thus it is assumed that it is equivalence of production up to 170 kg $N \cdot ha^{-1} \cdot year^{-1}$ (Cupiał and Szeląg-Sikora, 2014). The remaining rules which are binding in animal production include:

[1] *The paper was carried out as a part of a development grant no NR 12-0165-10 titled: "Innovative influence of technology and information management supporting system on the production efficiency in organic farms"*

a whole year access to yards, in summer – pasturage, a suitable size of stands, access to daily light in livestocks, rich fresh bedding and permanent access to water and fodder (Kowalski et al., 2012). The above features which are characteristic for organic farms prove that organic production is a farm management and food production system, which combines the most favourable practices for environment, high degree of biological variety, protection of natural resources, use of high standards concerning welfare of animals and the production method corresponding to the requirements of consumers who prefer products manufactured with the use of natural substances and natural processes (Tyburski and Żakowska-Biemans, 2007).

The objective of the paper was to analyse dynamics of organic farms development in Poland within 10 years, including the period of accession of our country in the European Union. The scope of work included source data obtained from the "Report on the condition of organic farming 2012" developed by the Inspection of Commercial Quality of Agri-Food Productsfrom Agency for Restructuring and Modernization of Agriculture, which determines the criteria of subsidizing organic farming. The study was carried out within the development subsidy no NR 12-0165-10 "Innovative impact of technology and IT support of management on efficiency of production in ecological farms".

Development of Polish organic farming

Literature states that the beginning of organic farming in Poland dates back to 1930, when the first biodynamic farm was established (Rolnictwo ekologiczne, on-line 2014). In 1972, International Federation of Organic Agriculture Movement (IFOAM) and in 1989 Association of Food Producers with Organic Methods EKOLAND were founded. Development of the first criteria and requirements for organic farming in Poland and granting first attestations to farms which meet the requirements is attributed to this association. Except for agricultural producers it associated also scientists and other representatives from the environment who act for the benefit of organic farming.

The newest data show that organic farming in Poland is still developing which may be proved by constantly increasing number of organic farms. According to data as on 31st December 2012 in Poland 26.5 thousand of organic producers, including 25.9 thousand of farms which operate on over 650 thousand of hectares were controlled by certifying units. It is approximately 10% increase of the area and number of farms in comparison to 2011. In 2012 the number of organic farms was 25 944, out of which the biggest number of organic farms was in the following voivodeships: Warmińsko-Mazurskie (3 793), Zachodniopomorskie (3 579) and Podlaskie (2,924). With regard to the number of food processing plants, Mazowieckie Voivodeship prevails (59), then Wielkopolskie Voivodeship (42) and Lubelskie Voivodeship (36). The biggest area organically used in 2012 was in Zachodniopomorskie Voivodeship (135 366.80 ha), Warmińsko-Mazurskie Voivodeship (112 945.30 ha) and Podlaskie (55 804.15 ha). The area of crops used pursuant to the provisions on organic agriculture in 2012 was in total over 661 687 ha. It is a 10% increase with reference to 2011. Within 2003-2012 the area of organic lands increased 11 times and presently constitutes approx. 3.4% of the total area used for agriculture in Poland. Average area of organic farms presently exceeds 26 ha at the national average which is approx. 10 ha for conventional farms (Raport o stanie rolnictwa ekologicznego, on-line, 2014).

Table 1
Area of agricultural crops, number of farms and organic food processing plants which are located within the system of organic agriculture as divided into voivodeships in 2012

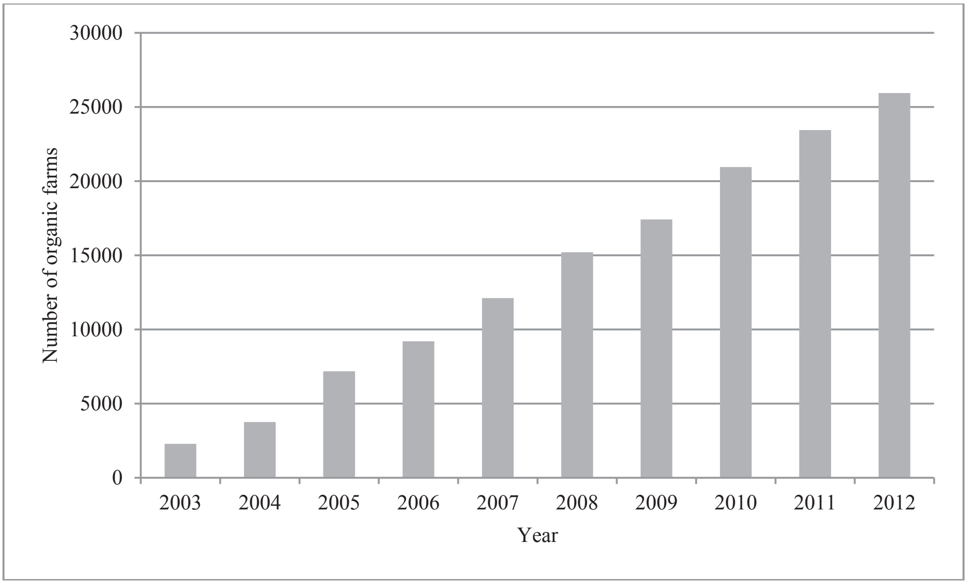
Voivodeship	Area of agricul-tural crops (ha)	Number of organic farms	Number of organic food-processing plants
Dolnośląskie Voivodeship	44 304.12	1 312	13
Kujawsko-pomorskie Voivodeship	8 812.35	390	15
Lubelskie Voivodeship	37 466.45	2 174	36
Lubuskie Voivodeship	52 580.52	1 356	6
Łódzkie Voivodeship	9 908.72	518	15
Małopolskie Voivodeship	21 049.73	2 103	24
Mazowieckie Voivodeship	55 804.15	2 373	59
Opolskie Voivodeship	2 930.26	90	2
Podkarpackie Voivodeship	30 381.46	1 940	18
Podlaskie Voicodeship	56 367.30	2 924	5
Pomorskie Voivodeship	30 615.70	894	17
Śląskie Voivodeship	7 124.97	236	16
Świętokrzyskie Voivodeship	14 550.84	1 288	10
Warmińsko-Mazurskie Voivodeship	112 945.30	3 793	10
Wielkopolskie Voivodeship	41 478.58	974	42
Zachodniopomorskie Voivo-deship	135 366.80	3 579	24
Total	661 687.30	25 944	312

Source: Raport o stanie rolnictwa ekologicznego, on-line, 2014

The recent years in the development of organic farming in Poland characterize with a constant dynamics of the increase in the number of organic farms (fig. 1) as well as the area of crops, which are within the organic farming system (fig.2). Development of organic farming sector is reflected in the number of food-processing plants (fig. 3).

Figure 1 presents dynamic of increase of the number of organic farms within 10 years. When comparing the increasing number of farms in the time system, one may notice that within 2003-2012 the number of facilities increased by 10 times. However, when referring the reported changes to the period for which our country has been a member of the European Union, we can see that both in the first as well as the second accession period the dynamics of increase of the number of organic food producers, was significant and linear. In the first period of 2004-2006 this increase was 5 434 farms in comparison to the base year of 2004. In the second accession period from 2007 to 2012 (i.e. one year before a planned end of this period i.e. 2013) the number of organic farms increased as much as by 308%. The reported high dynamics of the increase of the number of organic farms is difficult to see among other farming systems (e.g. conventional. integrated, etc.).

When analysing the pace of changes directed to intensive increase of the number of organic farms for comparative purposes, research results from the executed research project no 12 0165 10 "Innovative influence of technology and information management supporting system on production efficiency in organic farms" were taken into consideration. During field research responders (100 agricultural producers) were asked about further plans for future concerning operation of organic farms. The obtained results may be recognized as concurring with the national area of organic farming development. 37% of the responders declare their desire to maintain the present state of their farms (table 1).



Source: Raport o stanie rolnictwa ekologicznego, on-line, 2014

Figure 1. Number of farms within the system of organic farming in Poland in 2003-2012

Table 2
Future plans of organic farms

Farm groups (ha)	Plans of organic farms			
	maintenance of the present state	development and investments	reduction of production	liquidation
1	2	3	4	5
Up to 3	58.8	29.4	11.8	–
3.01 to 5	35.7	57.1	7.1	–
5.01 to 7	43.8	50.0	6.3	–
7.01 to 10	43.8	56.3	–	–
10.01 to 15	35.7	57.1	7.1	–
15.01 to 20	12.5	87.5	–	–
20.01 to 40	11.1	77.8	11.1	–
Above 40	16.7	83.3	–	–
Total	37.0	57.0	6.0	–

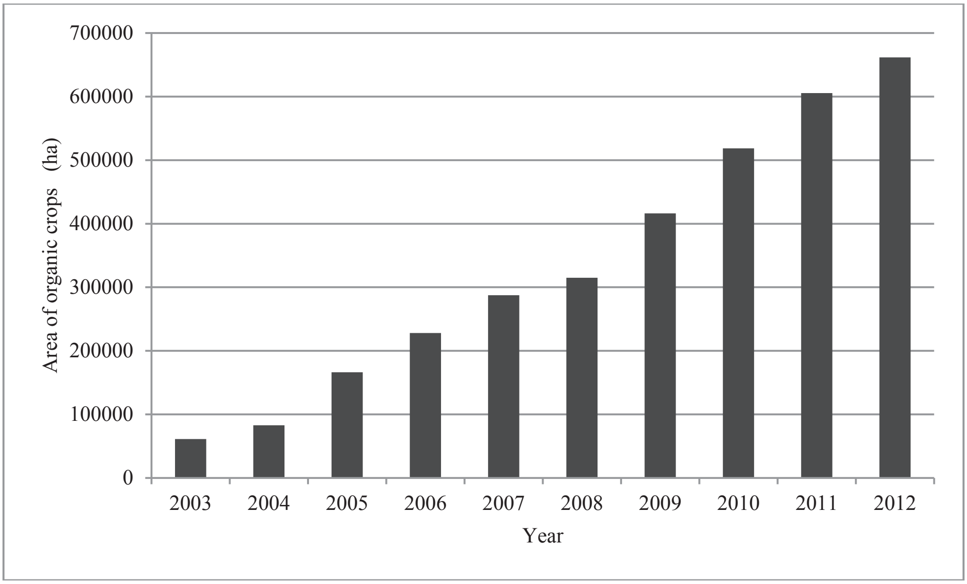
When assessing a population of farmers in the area groups system, their highest number was reported in the group of the smallest farms – as much as 58.8%. The biggest farms were characterised by low values of the assessed index. It is within 11.1% to 16.7%. As much as 57% of responders consider the perspective of development and new investments related therewith. It is particularly important, that from among the investigated groups in the biggest of them (above 15 ha) as much as approx. 87% and more plans development of a farm and investments. Only 6% of the investigated agricultural producers, who planned to decrease production, opposed. While, any of the investigated owners has not declared liquidation of his farm.

The professional activity of the questioned responders, which is not related to agriculture, is also noticeable. 2). From among the mentioned, also social benefits i.e. retirement pensions and pensions were reported. From among the mentioned additional sources of income, only a permanent job was reported in each of the listed area groups. In farms up to 5 ha (i.e. two first area groups) as much as over 50% responders declared simultaneous employment in a permanent job and in a farm. From among additional sources of income there were "Mechanization services" – 11% and "Agrotourism" – 8%. In both cases, the mentioned additional sources of income are related to the agricultural activity, which is carried out, the elements of which are used to render these services. According to data included in table 2, retirement pensions and pensions strengthen the budget of farms in 18%.

Table 3
Additional incomes in organic farms

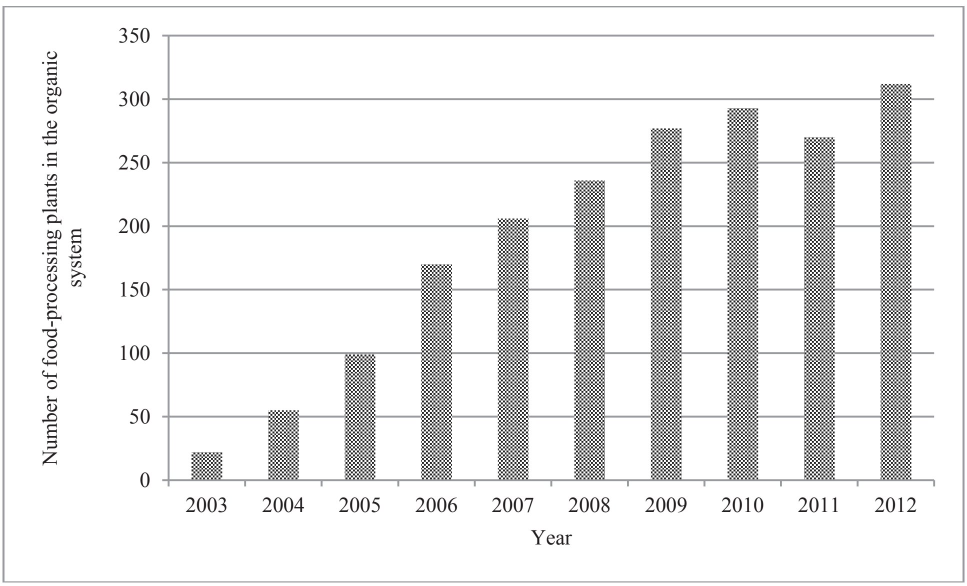
Farm groups (ha)	Type of income										
	Agritourism	Mechanization services	Trade	Permanent job	Retirement pension, pension	Horse riding	Trainings	Goat cheese production	Other services	Beekeeping	Lease of ponds
1	2	3	4	5	6	7	8	9	10	11	12
Up to 3	–	11.8	5.9	58.8	17.6	11.8	–	–	–	–	–
3.01 to 5	–	14.3	7.1	50.0	28.6	–	7.1	–	–	–	–
5.01 to 7	12.5	12.5	6.3	18.8	37.5	–	–	–	–	–	–
7.01 to 10	6.3	–	–	37.5	12.5	–	–	6.3	6.3	25.0	–
10.01 to 15	14.3	7.1	7.1	28.6	7.1	–	–	–	14.3	7.1	–
15.01 to 20	12.5	25.0	12.5	12.5	-	–	–	–	25.0	–	–
20.01 to 40	11.1	22.2	11.1	22.2	22.2	–	–	–	–	–	–
Above 40	16.7	-	-	33.3	-	–	–	–	16.7	–	16.7
Total	8.0	11.0	6.0	35.0	18.0	2.0	1.0	1.0	6.0	5.0	1.0

The increase in the number of organic farms was accompanied by the increase of the crop area designated for crops in the organic system. From 2004 (EU accession) to 2012 this area increased by 578 957 ha (fig. 3).



Source: Raport o stanie rolnictwa ekologicznego, on-line, 2014

Figure 2. The area of crops carried out according to the provisions on organic farming in Poland in 2003-2012



Source: Raport o stanie rolnictwa ekologicznego, on-line, 2014

Figure 3. Number of food-processing plants within the system of organic farming in Poland in 2003-2012

Along with the increase of the number of organic farms, production potential of food organic raw materials rises. Such action urges the changes in the food processing sector. Also, in this scope in Poland, within the last 10 years we report the increase in the number of food-processing plants which open in the organic agriculture system. Thus, it is one of examples which confirm improvement within the scope of technical infrastructure level, which accompany development of agricultural sector, which is emphasised by Sikora (2009) in one of papers. When comparing the changes, we see that from 22 food-processing plants, their number increased to 312 in 2012. When comparing the number of organic farms and the number of food-processing plants in 2012, one may notice that per one food-processing plant, there are approx. 83 organic farms (fig. 1 and 3).

Subventions to organic farming within the accession period 2007-2013

Organic agriculture is one of agricultural-environmental packets carried out as a part of RADP 2007-2013 during realization of which, financial aid was granted. It was at the average of PLN 996 (Euro 255.1) per one year for five years. An agricultural producer received support based on costs, which he really incurred. Environmental management payment presently is also paid out in the flat-rate form and constitutes a compensation of the lost income, additional costs incurred and incurred transaction costs.

Table 4
Possibility of realization of environmental managements variants within the organic agriculture package pursuant to RADP 2007-2013

Environmental management variants for the organic agriculture package	The amount of payment
Variant 2.1. Agricultural crops (for which the period of conversion was finalized)	790 $PLN·ha^{-1}$ (202.4 $EURO·ha^{-1}$)
Variant 2.2. Agricultural crops (in the conversion period)	840 $PLN·ha^{-1}$ (215.2 $EURO·ha^{-1}$)
Variant 2.3. Permanent grasslands (for which the period of conversion was finalized)	260 $PLN·ha^{-1}$ (66.6 $EURO·ha^{-1}$)
Variant 2.4. Permanent grasslands (in the conversion period)	330 $PLN·ha^{-1}$ (84.5 $EURO·ha^{-1}$)
Variant 2.5. Vegetable crops (for which the period of conversion was finalized)	1,300 $PLN·ha^{-1}$ (333 $EURO·ha^{-1}$)
Variant 2.6. Vegetable crops (in the conversion period)	1,550 $PLN·ha^{-1}$ (397 $EURO·ha^{-1}$)
Variant 2.7. Herb crops (for which the conversion period was finalized)	1,050 $PLN·ha^{-1}$ (269 $EURO·ha^{-1}$)
Variant 2.8. Herb crops (in the conversion period)	1,150 $PLN·ha^{-1}$ (294.6 $EURO·ha^{-1}$)
Variant 2.9. Fruit farming + berry farming (for which the conversion period was finalised)	1,540 $PLN·ha^{-1}$ (394.5 $EURO·ha^{-1}$)
Variant 2.10. Fruit crops + berry crops (in the conversion period)	1,800 $PLN·ha^{-1}$ (461.1 $EURO·ha^{-1}$)
Variant 2.11. Remaining fruit crops + berry farming (for which the conversion period was finalised)	650 $PLN·ha^{-1}$ (166.5 $EURO·ha^{-1}$)
Not fructifying walnut crops (for which the conversion period was finalised)	160 $PLN·ha^{-1}$ (41.0 $EURO·ha^{-1}$)
Fructifying walnut crop (for which the conversion period was finalised)	650 $PLN·ha^{-1}$ (166.5 $EURO·ha^{-1}$)

Environmental management variants for the organic agriculture package	The amount of payment
Variant 2.12. The remaining fruit crops + berry crops (in the conversion period)	800 PLN·ha^{-1} (204.9 EURO·ha^{-1})
Not fructifying walnut crop (in the conversion period)	160 PLN·ha^{-1} (41.0 EURO·ha^{-1})
Not fructifying walnut crop (in the conversion period)	800 PLN·ha^{-1} (204.9 EURO·ha^{-1})

Source: Rolnictwo ekologiczne, on-line, 2014

Simultaneously for subsidies to the organic agriculture package, degresiveness is binding – the amount of aid depends on the area of the agricul1.tural land covered by aid (Szeląg-Sikora, 2011). One should also remember that participating in the Organic farming package, may not be combined within one farm with an environmental management package Sustainable agriculture and Soils and water protection. Moreover, beneficiary of package 2. Organic farming may not combine this package within variants 2.3 and 2.4 (table 3) on the same area with:

– package 4. Protection of endangered birds species and natural habitats outside Natura 200 area
– package 5. Protection of endangered bird species and natural habitats on Natura 2000 areas.
– Requirements, which should have been met in order to receive subsidy in the accession period 2007-2013:
– to have a farm of the area min. 1 ha of agricultural land and identification number given by the Agency for Restructuring and Modernisation of Agriculture;
– to prepare an environmental management plan (with an environmental management advisor - a person, who is properly certified) which includes an organic farming packet and execute its assumptions for five years. The plan includes the list of tasks and recommendations, which should be executed by a farmer in his farm as a part of this packet. This document constitutes also essential source of information on the realization of the environmental management programme for control services;
– to have a certificate of conformity required by the provisions on organic farming or a document which certifies that a farm is in the conversion period into agricultural production with organic methods as of 1st March;
– to obey basic legal requirements, which refer to application of natural and mineral fertilizers, maintenance of cleanliness and order in a farm and protection of habitats;
– to maintain permanent agricultural lands and elements of landscape, not used for agricultural purposes at the moment realization of environmental management obligation begins at the territory of entire farm;
– to submit an application for granting payment for realization of environmental management undertakings and improvement of animals welfare in the Provincial Office of the Agency for Restructuring and Modernisation of Agriculture.

Conclusion

General economic state of the country and the number of consumers which are eager to pay more for better food products, related thereto is an essential limitation for development of organic farming. Interest in products from organic farms in our country may not achieve such a big scale as in the western Europe also on account of good values of traditional produce from conventional Polish farms. Conducting organic farms is for their owners an attractive form of economic activity. Thus, despite existing barriers, development of the Polish organic farming is characterized by great dynamics of the increase in the number of farms with this production system (number of this type of farms increased by 10 times) and thus the area of agricultural land designated for this type of crops, rises. Number of agricultural food-processing plants of raw materials, which come from organic farming increases slower. Nevertheless, the trend is constantly rising. Results of field research on the example of 100 farms confirmed a national trend in the development of farms. Available union funds, inter alia, determine the persisting developmental trend of organic farming. Financial aid for subsidizing organic farming within 2007-2013 was at the average of PLN 996 (EURO 255.1) per a year for five years.

However, the issue of not sufficient incomes from conducting only agricultural activity concerns also organic farms. The accepted strategy of the sustainable development of rural areas in its assumptions includes inter alia, diversification of agricultural producers' incomes. The observed agrarian overpopulation is a factor, which induces the rural society to increase its activity within the scope of conducting non-agricultural activity.

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DYNAMIKA ROZWOJU ROLNICTWA EKOLOGICZNEGO ORAZ JEGO SUBWENCJONOWANIE

Streszczenie. Rozwój polskiego rolnictwa ekologicznego cechuje duża dynamika wzrostu liczby gospodarstw o tym systemie produkcji (liczba gospodarstw zwiększyła się 10-okrotnie na przełomie 2003-2012 r). Rośnie również powierzchnia użytków rolnych przeznaczanych pod tego typu uprawy. W znacznie wolniejszym tempie wrasta liczba przetwórni rolniczych surowców pochodzących z ekologicznych upraw, niemniej jednak tendencja jest stale wzrostowa. Wyniki badań terenowych na próbie 100 gospodarstw rolnych potwierdziły ogólnokrajowy trend rozwoju gospodarstw ekologicznych. Istotną informacją jest również fakt, że respondenci z badanych obiektów deklarowali posiadanie dodatkowych źródeł dochodów, zaznaczając przy tym, iż dochody tylko z produkcji ekologicznej nie pokrywają potrzeb bytowych utrzymania rodziny.

Słowa kluczowe: gospodarstwo, ekologia, dopłaty, produkcja, źródło utrzymania

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PRECONDITIONS FOR MODELLING PLANT PRODUCTION TECHNOLOGY IN VEGETABLE ORGANIC FARMS[1]

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ABSTRACT

Preconditions for modelling technological processes in organic farms, which are oriented to vegetable field production, were presented. Based on empirical data, a rotation model and technical equipment models for farms of the agricultural land area of 10, 20 and 40 ha were developed. In relation to services, they enable full mechanization of production processes. Empirical data, which constitute batch data to models were collected in organic farms, which were included in the research as a part of the project NCBiR [National Centre for Research and Development] NR12-0165-10, titled "Innovative influence of technology and information management supporting system on production efficiency in organic farms." The project was carried out within 2011-2014.

Introduction

Selection of the production system in agriculture is preconditioned by restrictions of physical nature in the farm resources field. Financial means of a farmer play an important role in these resources, out of which a considerable part enables the use of farm mechanization means (Szeląg-Sikora and Kowalski, 2012). However, one should remember that only rational mechanization enables harmonization of production, social and ecological purposes, which are essential for sustained farming including organic farming (Muzalewski, 2008; Pawlak, 2008; Wójcicki, 2010; 2013). Economic work efficiency is a measurable effect of rational selection of mechanization means. It is usually measured as a ratio of the gross final production value per a unit of work inputs (Tabor, 2007). Thus, it reflects work productivity, which in small farms constitutes a basic production resource. However, due to the fact that mechanization on one side influences decrease of human work inputs and on the other hand generates costs related to its exploitation, assessment of efficiency as a part of agricultural incomes is significant. It is generated as a difference between final gross

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[1] *The paper was carried out as a part of the project of the National Centre for Research and Development NCBiR NR 12-0165-10, titled „Innovative influence of technology and information management supporting system on production efficiency in organic farms".*

production and incurred production costs, in the structure of which, all basic components of mechanization costs are included (beside contractual remuneration for own work)

Objective of the paper and method

The basic objective of the paper was development of models of technical equipment for organic farms oriented to vegetable field production. Organic production is defined as a system of farm and food production management, which combines the most favourable practices for the environment. It constitutes a collection of technological processes and auxiliary processes which are carried out according to soil, plants and animals requirements, which lead to production of food products of high quality. Thus, in an organic farm, production should be carried out pursuant to the rule of the sustained development, which favours development of agriculture (Krasowicz, 2009). Activation of environmental mechanisms of agricultural production takes place as a result of using natural production means, which ensure long-lasting soil fertility, high wholesomeness of plants and animals and high biological value of agricultural products (Kondratowicz-Pozorska, 2006). What is significant, organic farming is characterized with the rotation cycle of organic substance: soil - plant – animal. In this cycle, soil constitutes a base for cultivation of plants, indispensable for ensuring fodder for livestock. On the other hand, animals supply manure indispensable for renewal of organic substance in soil and supplementation of nutritious elements necessary for plants growth. Thus, the quality of soil and animal production trend determine a proper selection of plants and rotation and it enforces specific plant production technologies (Jończyk, 2005; Krysztoforski and Stachowicz 2008). Such conditions may be modified in case of vegetable field production, which usually is carried out with no animal production or at a very low livestock. Then, after-crops cultivated for green manure and even plants cultivated in the main crop are, except for straw, the source of organic substance – table 1.

Table 1
Characteristic of plant production

Plant or type of crop	Crop main ($t \cdot ha^{-1}$)	Crop side ($t \cdot ha^{-1}$)	Price of the main product, ($PLN \cdot t^{-1}$)	Coefficient of renewability of organic substance * ($t \cdot ha^{-1}$)	Coefficient of renewability of organic substance * ($1 \cdot t^{-1}$)	Balance of organic substance ($t \cdot ha^{-1}$)	Gross final production (thousand $PLN \cdot ha^{-1}$)
Edible potatoes	17.5	0.0	620.0	-1.40	-	-0.280	11.58
Winter wheat + after-crop	3.6	3.8	540.0	-0.53	0.18	0.031	3.54
Onion + after-crop	17.6	-	940.0	-1.40	-	-0.280	18.58
Spring barley + companion crop	3.1	2.7	510.0	-0.53	0.18	-0.009	3.23
White clover with grass	32.0	-	-	1.96	-	0.392	1.73
Companion crops	12.0	-	-	0.35	0.06	0.214	-
Fertilizing after-crop	16.5	-	-	0.35	0.06	0.536	-
Agricultural land	x	x	x	x	x	0.604	7.73

)* – Source: Kodeks Dobrej Praktyki Rolniczej. 2004. Fundacja Programów Pomocy dla Rolnictwa. Warszawa. ISBN 83-88010-58-1

In a classic five-field rotation, vegetables and edible potatoes are cultivated on two fields (40% of crops), grains on two fields (40% of crops) and forage crops on one field (20% of crops). Crops obtained from empirical research confirm that in ecological farms they are 20-30% lower in comparison to the crops obtained in conventional farms. Despite intensive use of land resources, the use of side products and after-crops and two windrows of white clover with grass for fertilization enables full reproduction of organic substance (0.6 $t \cdot ha^{-1}$).

Main crops of grains and vegetables and root crops mainly constitute commodity production. A small part of grain seeds (7%) and potatoes (12%) is left as sowing material and seed potatoes. Value of commodity production and the obtained funds (acc. to rates of 2013) constitute the gross final production value. For the example of the analysed rotation, the gross final production value of edible potatoes and vegetables constitutes 78% of total value.

Results of modelling

Farm tractors are the basic element of machinery park equipment of each agricultural farm. In the analysed models, three types of farm tractors of low and average classes of towing power of the respective rated power were selected: 34.6 kW; 52.2 and 68.0 kW. In models for 10 and 20 ha there are 2 items of tractors for each and in the model for 40 ha, beside 1 tractor of 68.0 kW power there are 2 items of tractors of power 52.2 kW – table 2. Consequently, indexes of power installed are respectively: 8.7 $kW \cdot ha^{-1}$; 6.0 $kW \cdot ha^{-1}$ and 4.3 $kW \cdot ha^{-1}$.

Table 2
Characteristic of equipment and use of farm tractors

Specification	Type	Parameter	Number (items)			Use (h)		
			10 ha	20 ha	40 ha	10 ha	20 ha	40 ha
URSUS tractor	U914	68.0 kW	-	1	1	-	243.5	430.0
URSUS tractor	U5312	52.2 kW	1	1	2	133.5	430.5	784.0
URSUS tractor	U3512	34.6 kW	1	-	-	312.0	430.5	784.0
Average use per 1 ha of agricultural land						44.6	33.7	30.3

The use of farm tractors increases along with the area of agricultural land. However, per 1 ha of these lands, tendency is decreasing and is respectively: 44.6 $cgh \cdot ha^{-1}$; 33.7 $cgh \cdot ha^{-1}$ and 30.3 $cgh \cdot ha^{-1}$. However, one should state that as long as in models of 20 and 40 ha, the use of tractors as a part of services was not predicted, in the model of 10 ha, each 1 ha of agricultural land is burdened with 4.2 cgh of hired labour.

Table 3
Characteristic of equipment and the use of basic agricultural tools and machines

Specification	Type	Parameter	Number (items)			Use (h)		
			10 ha	20 ha	40 ha	10 ha	20 ha	40 ha
Field plough	U151/1	3-furrow	1	-	-	38.0	49.0	-
Field plough	U151/2	4-furrow	-	1	-	-	49.0	-
Rotating plough	KM 180	3-furrow	-	-	1	-	-	79.5
Cultivator	U478/1	18 tines	1	-	-	18.0	-	-
Cultivating aggregate	Tiger 25	2.5 m	-	1	1	-	39.0	72.5
Grain seeder	S078u	3.0 m	-	1	1		12.0	22.0
Bucket seeder	S222	2-row	1	1	1	10.5	18.5	34.5
Spring onion seeder	SD 4u	4-row	-	1	1	-	14.0	26.0
Tractor chaff cutter	Z364	-	-	1	1	-	61.0	114.0
Elevator-digger	Bulwa 2	-	1	1	1	25.0	22.5	41.5
Potatoes combine	Pyra 1500	-	-	1	1	-	74.0	138.5

In the accepted models of equipment in the basic set of farm tools and machines, respectively small differences occur between objects of 20 and 40 ha. They concern only the type of a plough – a rotating plough occurs only in the model of the biggest facility. Whereas in the smallest facility, own machinery park is reduced to a field plough, cultivator, bucket seeder and an elevator-digger. Certainly, in all models equipment with the set of tools and machines for treatment and in trailers and sorting machines was accepted. In case of the biggest facility, a sorting machine was replaced with a sorting - cleaning machine. Whereas, an own combine harvester was not designed for any model. It was used only as a part of services.

Replacement value of the machinery park was respectively:

– model of 10 ha – 267.50 thousand PLN, i.e. 26.75 thousand PLN·ha^{-1};
– model of 20 ha – 473.63 thousand PLN, i.e. 23.68 thousand PLN·ha^{-1};
– model of 10 ha – 615.53 thousand PLN, i.e. 15.39 thousand PLN·ha^{-1};

Due to estimation of amortization, VAT tax was not included in the replacement value.

Total costs of mechanization show a clear decreasing tendency and they decrease from 2.64 thousand PLN·ha^{-1} in the model of the surface area of 10 ha to 1.65 thousand PLN·ha^{-1} in the model of 40 ha area – table 4. In the smallest facility, the participation of services costs in the structure of mechanization costs is 21.6%. While in the remaining facilities it is respectively: 20 ha – 7.6% and 40 ha – 9.1%. It should be mentioned that in these models, purchases of services concern only combine harvesting of grains. Their higher participation in the biggest facilities results from a considerable decrease of the costs of own machines exploitation including fixed costs.

Table 4
Mechanization costs (thousand PLN·ha^{-1})

Specification	Exploitation costs						Servi-ces	Total costs of mechanization
	Amortization	Charges	Garages and carports	Fuel and energy	Repairs and services	Total		
Model of 10 ha	1.05	0.12	0.23	0.49	0.18	2.07	0.57	2.64
Model of 20 ha	0.98	0.06	0.14	0.51	0.26	1.95	0.16	2.11
Model of 40 ha	0.68	0.03	0.08	0.46	0.25	1.50	0.15	1.65

Table 5
Production costs (thousand PLN·ha^{-1})

Item	Specification	Model		
		10 ha	20 ha	40 ha
1	Purchase of sowing material	0.64	0.64	0.64
2	Purchase of means for plant production	1.08	1.08	1.08
3	Purchase of other direct	0.01	0.01	0.01
I	Purchase of direct production means	1.73	1.73	1.73
1	Materials for repairs and renovations	0.21	0.28	0.27
2	Exploitation materials	1.67	1.68	1.68
3	Fuel and energy	0.50	0.54	0.55
II	Purchase of raw materials and exploitation materials	2.38	2.50	2.50
1	Amortization of buildings and infrastructure	0.51	0.41	0.36
2	Amortization of machines	1.05	0.98	0.68
III	Amortization of fixed assets	1.56	1.39	1.04
1	Veterinary and counselling services	0.02	0.02	0.01
2	Mechanization and craftsman ship services	0.57	0.16	0.15
IV	Services	0.59	0.18	0.16
1	Land tax	0.14	0.14	0.13
2	Property charges and insurance	0.02	0.01	0.01
3	Farmer's Social Security Fund	0.29	0.15	0.11
4	Other financial charges	0.06	0.06	0.06
V	Charges and other financial	0.51	0.36	0.31
VI	Total costs	6.77	6.16	5.74

Analogically to mechanization costs, also total production costs show a clear decreasing tendency – table 5. While in the 10 ha model they were 6.77 thousand PLN·ha^{-1} in the model, in the 40 ha model they were as much as 5.74 thousand PLN·ha^{-1}. In the type system, costs of raw material and exploitation materials have the highest participation. They constitute from 35.2% in the 10 ha facility to 43.6% in the 40 ha facility. The opposite relation of the participation concerns amortization of fixed assets. In this case its participation decreases from 23.0% in the 10 ha model to 18.1 % in 40 ha model. Whereas, mechanization costs in the structure of total production costs are from 28.7% in the biggest facility to 39.0% in the smallest facility. Thus, their participation has a clear increasing tendency and increases along with the surface area of agricultural lands.

In comparison to production and mechanization costs, also inputs of farmer's own and family work show clear decreasing tendency. They were respectively:
– 10 ha model – 1 195 man-hour, i.e. 119.5 man-hour·ha^{-1};
– 20 ha model – 1 195 man-hour, i.e. 89.0 man-hour·ha^{-1};
– 10 ha model – 3 010 man-hour, i.e. 75.2 man-hour·ha^{-1}.

Table 6
Production effectiveness

Specification	Model		
	10 ha	20 ha	40 ha
Agricultural income in thousand PLN per 1 ha of agricultural land	0.96	1.57	1.99
Agricultural income in PLN per 1 man-hour	8.00	17.70	26.50

Consequently, work efficiency which results from the generated agricultural income amounts to: in a 10 ha model – 8.00 PLN·man-hour^{-1}, in the 20 ha model – 17.70 PLN·man-hour^{-1}, whereas in the 40 ha model – 26.50 PLN·man-hour^{-1}. Thus, an increasing tendency is visible, which was significantly influenced by rationally selected machinery park.

Conslusion

In organic farms, at a respectively fixed level of purchases and considerably low participation of direct materials and raw materials, a rationally selected machinery park has a significant impact on the production efficiency. On one hand, it influences decrease of human work inputs and on the other hand it generates costs related to its exploitation. Thus, smaller farms usually have tractors of lower power and transport means and a basic set of machines indispensable to carry out technological processes in the determined agrotechnical time limits. Expensive machines and specialistic devices are used as a part of mechanization services. Along with the increase of the surface area of agricultural lands the power of the possessed farm tractors and technical and exploitation parameters cooperating machines increases. Consequently, the possessed machinery park is more numerous and more complex and in its structure there are more expensive specialistic machines. Also usually, tools and simple machines are replaced with multi-functional machines. As a result, purchase of mechanization services, the use of which is burdened with the risk of failure to keep agrotechnical time limits, is limited. The above preconditions constitute basic assumptions for designing mechanization of technological processes. It seems that the proper measure of assessing their efficiency is a ratio of economic efficiency of labour, which is a ratio of the farm income to inputs of farmer's work. In the model solutions it is respectively: 10 ha model – 8.00 PLN·man-hour^{-1}, 20 ha model – 17.70 PLN·man-hour^{-1} and 40 ha model – 26.50 PLN·man-hour^{-1}. An increasing tendency is visible, which was significantly influenced by rationally selected machinery park. A decreasing unit replacement value is inter alia a measure of this rationality of selection.

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UWARUNKOWANIA MODELOWANIA TECHNOLOGII PRODUKCJI ROŚLINNEJ W EKOLOGICZNYCH GOSPODARSTWACH WARZYWNICZYCH

Streszczenie. Przedstawiono uwarunkowania modelowania procesów technologicznych w gospodarstwach ekologicznych, ukierunkowanych na produkcję polową warzyw. W oparciu o dane empiryczne opracowano model zmianowania i modele wyposażenia technicznego dla gospodarstw o powierzchni użytków rolnych wynoszącej 10, 20 i 40 ha. W powiązaniu z usługami umożliwiają pełną mechanizację procesów produkcyjnych. Dane empiryczne, stanowiące dane wejściowe do modeli, zebrano w gospodarstwach ekologicznych objętych badaniami w ramach projektu NCBiR nr NR12-0165-10, pt. „Innowacyjne oddziaływanie techniki i technologii oraz informatycznego wspomagania zarządzania na efektywność produkcji w gospodarstwach ekologicznych". Projekt realizowano w latach 2011-2014.

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COMPARISON OF EXTERNAL FRICTION COEFFICIENTS FOR SINGLE SEEDS IN THE STABILISED SYSTEM

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ABSTRACT

The paper presents comparison of average static values of external friction coefficients of single caryopses of wheat of Naridana cultivar with caryopses in the-so called stabilised system at their various orientation towards the motion direction on a steel base. The research was carried out on the research position with an optielectronical system of lift angle of the plane arm. It was found out that average values of static friction coefficients of single wheat caryopses and caryopses in the stabilised system depend on the manner of their arrangement during measurements. For single caryopses, a significantly lower value of this parameter was reported in case of caryopses contact with a base with a back side up and their arrangement with longitudinal axis perpendicular towards the movement direction, whereas for caryopses in the stabilised system - at their arrangement with the back side on a steel plate and with a longitudinal axis in parallel to the motion direction. Moreover, it was determined that average values of static friction coefficients for single caryopses are considerably higher than for caryopses in the stabilised system at their identical arrangement during measurements.

Introduction

Friction is a set of phenomena, which occur in the area of contact of two bodies sliding against each other as a result of which resistance to motion take place. With regard to solid bodies (loose materials) two basic friction types can be distinguished: external (particle-working surface) and internal between neighbouring particles (Hebda and Wachal, 1980; http://pl.wikipedia.org/wiki/Tarcie).

In production and processing of agricultural produce external friction is of special significance. It mainly relates to technological operations related to soil cultivation, cutting off plant mass, threshing, transport, storing and processing (Gach et al., 1991; Molenda et al., 1995; Horabik, 2001).

This phenomenon also decides on the course of separation of seed mixtures. In practice, the value of external friction is expressed with the use of the so-called coefficient of friction: static (at the beginning of motion) and kinetic, which is determined during a relative motion of the considered objects. The most frequently, a plane of a variable inclination angle of an arm is used for measurement of this property and gluing seeds to a thin tape in order to ensure a sliding motion (the so-called stabilised system) is an additional treatment. Unfortunately, data available in literature, concerning coefficients of external friction indicate a high discrepancy of their values even for the same materials. The main reasons for this fact include: diversity of methods and measurement devices, variability of properties of particular mixture components and uniformity of conditions of measurements. Thus, works concerning research in coefficients of friction had a permanent nature and numerous researchers recommend determination of value of this property on current basis (Grochowicz, 1994; Horabik and Molenda, 2002; Konopka, 2000; Kram, 2006; Laskowski and Skonecki, 1999; McLean, 1989; Thompson et al., 1988; Zhang and Kushwaha, 1991).

Additionally, a question arises whether the measurement of friction coefficient in the stabilised system objectively reflects this property for single seeds. It should be emphasised that in real conditions of implementation of the separation process (cleaning, fractioning, sorting) seeds are connected and initiation of motion may take place through sliding or wheeling (Konopka, 2006).

The objective of the paper

The objective of the paper was to compare average static values of external friction coefficients of single wheat caryopses with caryopses in the so-called stabilised system at their various orientation towards the motion direction on a specific surface.

Methodology of research

Caryopses of winter wheat of Naridana cultivar purchased in Olsztyńska Hodowla Ziemniaka i Nasiennictwo OLZNAS-CN Sp. z o. o. were used for the research. The purchased batch of seeds of 1 kg mass was sieved with the use of a sifter with a flat sieve with rectangular meshes of side dimensions of 3.1 x 10.0 mm. The objective of this operation was removal of small seeds which characterize with significantly diverse (wrinkled) texture of external surface towards the correctly shaped seeds and the part of contamination. The sieved material was treated as a proper fraction of caryopses for preparation of samples.

Then, with an over-drying method (pursuant to PN-EN ISO 712:2012 P), moisture of selected seeds was determined. It was 11.3%. Caryopses for further stages of research were stored in exsiccator. It was assumed that moisture did not change significantly and has no significant impact on the measurements results.

From a separated fraction 90 single caryopses and caryopses for preparation of samples in the stabilised system were selected. Samples for research in the stabilised system were carried out in two variants. Caryopses were glued to a 1.5 cm thick piece (one-side adhesive) tape to avoid their contact with the use of tweezers. Seeds were identically oriented with a lengthwise axis and equally glued (for a given sample) – with a back side or the side with a fissure. 90 such samples were carried out for each variant.

Experiments including determination of external friction angles of single wheat caryopses and in the stabilised system at the moment of the beginning of motion were carried out on the research position (fig. 1) constructed acc. to the patented idea (no P.397572 as of 17th December 2011) and which is owned by Department of Mills and Methodology of Research, University of Warmia and Mazury in Olsztyn.

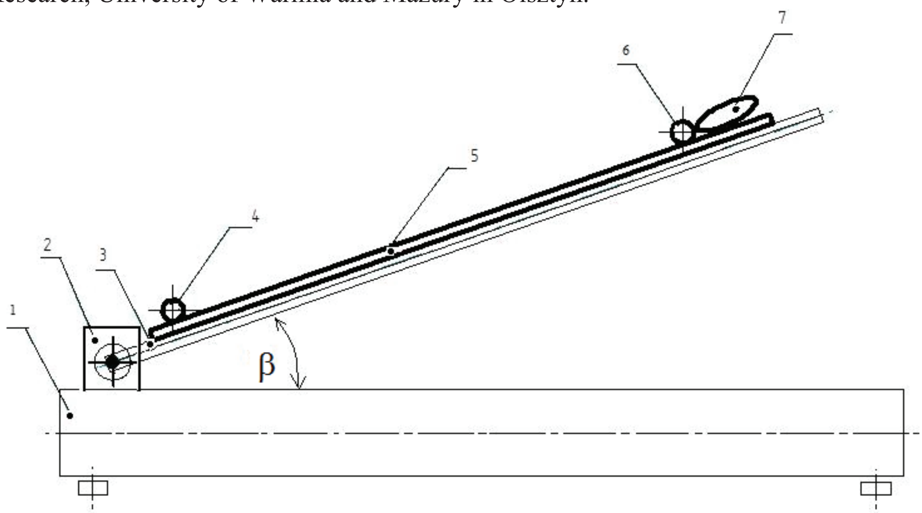

Figure 1. Schematic representation for external measurement of angle of friction of seeds: 1 – base, 2 – system for lifting the plane arm, 3 – the plane arm, 4 – lower optielectronical system, 5 – replaceable base (steel plate), 6 – upper optielectronical system, 7 – wheat caryopses (stabilised system of caryopses)

It is a measuring device with a lifted plane arm which enables determination of external friction angles for loose materials on bases made of various materials. After appropriate calculations of the recorder data, external friction coefficients may be determined.

In the research as a base a construction steel plate ST3 was used. Roughness of the working surface was determined with HOMMEL TESTER T1000 according to PN-EN ISO 4287:1999/A1:2010 P.

Experiments were commenced from arranging a sample (a single caryopses or a stabilised system). Samples were arranged manually with the use of tweezers on the horizontally located plane arm (3) along with a mounted based (5) just before a light ray of optielectronical system (6). Upon starting the mechanism of lifting (2), the plane arm (3) was lifted from the beginning of the single movement of caryopses or the stabilised system (7). In the moment of cutting the light ray of the system (6) the motion of an arm was stopped and the lifting angle of the plane arm was recorded. These data were transferred to the PC computer coupled with the measurement device and calculated according to a formula (1) into values of coefficients (μ) of external friction angles (Grochowicz, 1994):

$$\mu = tg\ \beta \quad (-) \tag{1}$$

where the symbol:

β – determined the lift angle of the plane arm in comparison to the level (^{o}).

Then, the plane arm was dropped and the following measurement (for a new sample) - was repeated.

Measurements were carried out for single caryopses and caryopses in the stabilized system in 4 variants:

– arranged on a steel plate with the furrow side up and a longitudinal axis perpendicular towards the motion direction (BD-H),
– arranged on a steel plate with the furrow side up and a longitudinal axis in parallel towards the motion direction (BD-V),
– arranged on a steel plate with the back side up and a longitudinal axis towards the motion direction (GD-H),
– arranged on a steel plate with the back side up and a longitudinal axis towards the motion direction (GD-V),

Results of measurements were developed statistically with the use of the following procedures (Greń, 1984; Rabiej, 2012):

– checking out, whether the assumed number of a sample for a given measurement variant is sufficient,
– checking out assumptions indispensable for carrying out analysis of variance, i.e. compatibility of distribution of external friction angles with a regular distribution for a given measurement variant (test χ^2) and equality of variance for comparable variants (Levene's test),
– carrying out comparative analysis of average values of static coefficient of external friction for particular measurement values in order to separate significant differences in this property. in case of determining significant differences, Duncan's "post-hoc" test was applied which enabled extinguishing of the-so called uniform groups.

For calculation, a package of statistical software „*Statistica*” v. 10 was used and testing hypotheses were carried out at the significance level of α=0.05.

Research results and their analysis

The calculations, which were carried out proved that the accepted number of samples for a given measurement variant was sufficient. The determined minimum number of trials did not exceed 90 measurements.

Moreover, it was determined that distribution of the measured static friction angles for particular measurement variants are in accordance with the regular distribution. An exemplary graphical illustration of a test for variant (BD-H) was presented in figure 2.

Results of Levene's tests also proved that there were no bases to reject hypotheses on uniformity of variation for the compared measurement variants.

Detailed results of statistical calculations for single caryopses were presented in table 1.

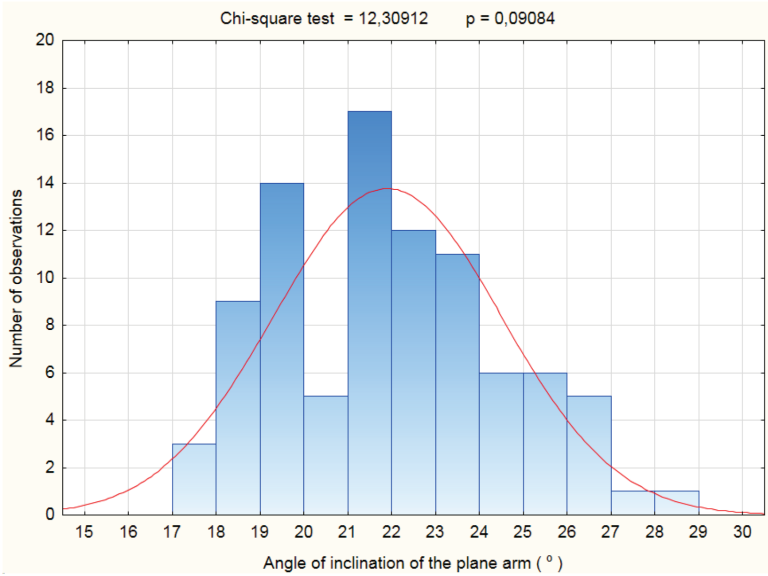

Figure 2. A histogram of the distribution of the value of external static friction angles for single wheat caryopses oriented during the measurement perpendicularly towards the motion direction and touching each other with the furrow side with and a steel plate

Table 1
The list of statistical parameters which characterize coefficients of static external friction of single wheat caryopses and results of analyses of variation for various measurement variants

Measurement variant	Minimum sample size	Average value of friction coefficient μ (-)*	Standard deviation (-)	Value of statistics of F-Snedecor's	Value of probability
BD-H	62	0.40[a]	0.053	71.88	0.000
BD-V	78	0.41[a]	0.063		
GD-H	50	0,31[b]	0.042		
GD-V	61	0.39[a]	0.051		

[*] - average values determined with the same letters do not differ statistically significantly (uniform groups)

The lowest average value of static friction coefficient for single caryopses on the steel base was reported for their arrangement with a back side up and with a longitudinal axis perpendicular to the motion direction. This value differed statistically significantly from the remaining (separated uniform group). The most probably it follows from the initiation of the seed motion by wheeling (turnover of the lifted caryopses on the contact side of a furrow with a base. For the remaining measurement variants statistically significant differences between average values of coefficients of static friction were not determined.

Results of statistical calculations for the stabilized system of caryopses were presented in table 2.

Table 2
The list of statistical parameters which characterize coefficients of static friction of the stabilised system of wheat caryopses and results of analyses of variation for various measurement variants

Measurement variant	Minimum sample size	Average value of friction coefficient μ (-)*	Standard deviation (-)	Value of statistics of F-Snedecor's	Value of probability
BD-H	49	0.29[a]	0.035	24.09	0.000
BD-V	50	0.28[a]	0.035		
GD-H	54	0.28[a]	0.043		
GD-V	51	0.5[b]	0.037		

* - average values determined with the same letters do not differ statistically significantly (uniform groups)

The lowest average value of static friction coefficient for caryopses in the stabilised system was reported for their arrangement with a back side up on a steel plate and with a longitudinal axis in parallel to the motion direction. This value differed statistically significantly from the remaining (separated uniform group). Probably, it follows from a relatively smaller contact surface of seeds with a surface (point contact) and more "favourable" conditions for motion initiation through sliding in case of measurement variants. For the remaining measurement variants statistically significant differences between average values of coefficients of static friction were not determined.

Additional comparison of average values of static friction coefficients between single caryopses and the stabilized system for a given measurement variant proved in all cases the occurrence of statistically significant differences. Considerably higher values of coefficients were reported for single wheat caryopses.

Conclusion

Based on the research results and their analysis one may state that average values of static friction coefficients of single wheat caryopses in the stabilized system on the steel base depend on the manner of arrangement during measurements. For single caryopses lower value of this parameter in case of caryopses contact with a back side and arranging them with a longitudinal axis perpendicular towards the motion direction. Identical relation for caryopses in the stabilized system was reported for their arrangement with a back side up on a steel plate and with a longitudinal axis in parallel to the motion direction.

Moreover, it was determined that average values of static friction coefficients for the tested wheat are considerably higher than for single caryopses (from 0.31 to 0.41) in the stabilised system at their identical arrangement during measurements. This fact requires further research because it is difficult to precisely define its reason.

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PORÓWNANIE WSPÓŁCZYNNIKÓW TARCIA ZEWNĘTRZNEGO DLA POJEDYNCZYCH NASION I W UKŁADZIE STABILIZOWANYM

Streszczenie. W pracy przedstawiono porównanie średnich wartości statycznych współczynników tarcia zewnętrznego pojedynczych ziarniaków pszenicy odm. Naridana z ziarniakami w tzw. układzie stabilizowanym, przy różnej ich orientacji w stosunku do kierunku ruchu po podłożu ze stali. Badania przeprowadzono na stanowisku z optoelektronicznym układem pomiaru kąta uniesienia ramienia równi. Stwierdzono, że średnie wartości współczynników tarcia statycznego pojedynczych ziarniaków pszenicy i ziarniaków w układzie stabilizowanym zależą od ich sposobu ułożenia w trakcie pomiarów. Dla pojedynczych ziarniaków istotnie niższą wartość tego parametru odnotowano w przypadku styku ziarniaków z podłożem stroną grzbietową i ułożeniu ich podłużną osią prostopadle w stosunku do kierunku ruchu, zaś dla ziarniaków w układzie stabilizowanym - przy ułożeniu ich stroną grzbietową na stalowej płytce i podłużną osią równolegle do kierunku ruchu. Stwierdzono również, że średnie wartości współczynników tarcia statycznego dla pojedynczych ziarniaków są znacznie wyższe niż dla ziarniaków w układzie stabilizowanym, przy identycznym ich ułożeniu podczas pomiarów.

Słowa kluczowe: współczynnik tarcia statycznego, nasiona pszenicy, podłoże ze stali

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DEPENDANCE OF ENERGY INPUTS ON AREA AND ECONOMIC SIZE OF FAMILY FARMS

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ABSTRACT

The objective of the paper is defining the influence of agricultural land area (AL) and economic size on energy inputs in family farms that are beneficiaries of European Union funding. 70 farms of Biłgoraj County that were beneficiaries of EU funding for technical modernization were researched within 2004-2009. In order to define energy inputs, the group of farms that were the object of the research were divided according to the amount of subsidy, area of agricultural land, economic size (ESU) and the income of an enterprise. In the process of characterizing the researched farms according to the level of possessed energy means, tractors, self-propelled combine harvesters and electric engines used in the process of farm production were taken into account, including also the ones mounted in the equipment operated in the farms. The level of energy inputs in the researched farms calculated into area unit was decreasing systematically, both when the amount of funding increased, as well as area, economic size and income of an enterprise. In the group of farms according to the economic size, when its size increased, energy inputs decreased, and the tendency remained the same in farms of the highest income of an enterprise. In farms of a small area (up to 10 ha) of agricultural land (AL), apart from high level of specific labour input, there were high inputs of manual labour.

Introduction

Agriculture technology implementation is connected with installing in the equipment or purchasing for a farm independent energy means, mainly combustion or electric ones. The main source of power in farms are tractors, and then self-propelled farm machines and engines working within the farm (Wasąg, 2011). Energy inputs are observable mainly in the form of manual labour and work of combustion or electric engines. Labour costs increase and decreasing relations between agricultural products and means of production make necessary changes in farms organization. In order to increase a family income, one should extensively organize and manage in an intense manner (Sawa, 1998). Technical condition and structure of possessed mechanization means in specific (organizational and economic) production conditions influence labour process and define effectiveness of managing in a farm, which plays a major role in the farmers' decision making process on investment purchase and their sources of financing (Sawa, 1994; Wójcicki and Pawlak, 1996; Kocira and Sawa, 2008). The process of improving technical modernization of farms requires increasing the level of labour process mechanization, with the assumption however, that it will have a positive influence on the whole farm production process, including the environment. Production factors are always combined with manual labour impact, they are defined as production means of production process, which are presented in relation of production means (capital) to labour force (labour). For this reason, it is necessary to „equip" labour (man-hour) and work-place (of a man), in order to achieve high effectiveness of farm production mechanization (Kocira and Sawa, 2008).

The objective of the paper is to define the influence of agricultural land area (AL) and economic size on energy inputs in family farms that are beneficiaries of European Union funding.

Material and methodology of the research

In the years 2004–2009 70 farms of Biłgoraj County that were beneficiaries of EU funding for technical modernization were researched. In order to define energy inputs, the group of farms under the research were divided according to the amount of subsidy, area of agricultural land, economic size (ESU) and the income of an enterprise. In the process of characterizing the researched farms according to the level of possessed energy means, tractors, self-propelled combine harvesters and electric engines used in the process of farm production were taken into account, including also the ones mounted in the equipment operated in the farms (e.g. machinery used for re-loading, for preparing pastures, milking machines and milk cooling machines).

Process mechanization level of work in the farms was assumed according to Zaremba (Pawlak and Wójcicki, 1993; Zaremba, 1985; 1986):

$$W = \frac{0{,}2\,L_m}{L_o + 0{,}2\,L_m} \cdot 100 \qquad (1)$$

where:

W – mechanization level (%),
L_m – total energy inputs of mechanical means (kWh),
L_o – total inputs of manual labour (man-hour),
0,2 – coefficient balancing specific labour (kWh) with manual labour (man-hour).

The increase of mechanization level coefficient in the period when the research was conducted, was recognized as an effectiveness proof for farmer's action. Apart from this, the coefficient characterises the labour process because it defines percentage share of specific labour in the process execution.

Energy share of specific labour that accompanies every man-hour may constitute the coefficient that defines the character of executed work (Sawa, 2009):

$$U_{ep} = \frac{L_m}{L_r} \tag{2}$$

where:
U_{ep} – work energetic equipment (kWh·man-hour^{-1}),
L_m – specific labour inputs (kWh),
L_r – manual labour inputs (man-hour).

Research results

The highest installed power (kW·100 ha^{-1} AL) was observed in the smallest farms in each researched group (table 1) and was decreasing along with their increase (e.g. of area: from 1241 up to 454 kW·100 ha^{-1} AL). The exception were farms of economic size of 8-16 ESU, where installed power in relation to the lower group (up to 8 ESU) increased from 968 to 1030 kW·100 ha^{-1} AL. However, specific labour inputs only in the group of farms placed according to their area were fluctuating, and they were higher in the group of farms of above 70 ha AL (1398 kWh·ha^{-1} AL) than 50-70 ha AL (999 kWh·ha^{-1} AL). Farms for which the subsidy amount was higher than PLN 150 thousand (table 1) had the highest average area (68.6 ha AL) and the lowest for this group coefficient of installed power (562 kW·100 ha^{-1} AL). Specific labour inputs in calculation to a working hour amounted to 42.41 kWh·man-hour^{-1} and they were only slightly lower than in farms of the area above 70 ha AL (51.48 kWh·man-hour^{-1}). It gets reflected in manual labour inputs that for a farm of the subsidy amount above PLN 150 thousand (80 man-hour·ha^{-1} AL) were higher from the inputs in farms of area above 70 ha AL (68 man-hour·ha^{-1} AL) and 50-70 ha AL (77 man-hour·ha^{-1} AL). Energy inputs for PLN one thousand of subsidy were relatively high in farms that were smaller from the point of view of area (82 man-hour·thousand PLN^{-1} and 524 kWh·thousand PLN^{-1}) and economy (73 man-hour·thousand PLN^{-1} and 814 kWh·thousand PLN^{-1}) , and of the lowest subsidy amount (111 man-hour·thousand PLN^{-1} and 1073 kWh·thousand PLN^{-1}) and the income of an enterprise (77 man-hour·thousand PLN^{-1} and 661 kWh·thousand PLN^{-1}).

Table 1
Energy inputs in the researched farms

Farm groups according to:	Number of farms	Area (ha AL)	Installed power (kW·100 ha^{-1} AL)	Inputs (kWh·ha^{-1} AL)	Energy share (kWh·man-hour^{-1})	Inputs man-hour·ha^{-1} AL (with others)	Energy inputs for a thousand PLN of subsidy amount (rbh·thousand PLN^{-1})	Energy inputs for a thousand PLN of subsidy amount (kWh·thousand PLN^{-1})
Subsidy amount (thousand of PLN): up to 50	20	13.9	949	2248	15.72	274	111	1073
50–100	26	17.9	995	2206	17.84	255	53	463
100–150	10	29.4	687	1795	21.51	192	30	327
above 150	14	68.6	562	1483	42.41	80	19	361
Area (ha AL): up to 10	11	7.1	1241	3197	12.30	477	82	524
10–30	41	16.1	912	2033	17.95	207	65	682
30–50	6	42.8	526	1151	25.67	95	39	377
50–70	3	65.0	424	999	32.77	77	18	224
above 70	9	89.5	454	1398	51.48	68	34	576
ESU: up to 8	19	13.0	968	2438	15.78	271	73	814
8–16	29	17.1	1030	2219	17.79	255	66	573
16–40	17	51.3	570	1608	36.07	121	38	476
above 40	5	74.7	479	942	31.30	110	35	315
IE (thousand of PLN): up to 10	19	10.1	1129	2720	14.28	370	77	661
10–20	18	17.1	983	2118	18.98	226	62	581
20–50	12	19.6	757	1705	19.12	157	74	813
above 50	21	60.1	541	1464	35.45	102	33	432
Average for the whole population		28.5	851	2014	22.67	216	59	598

ESU – European Size Unit, DP – income of an enterprise

Table 2
Energy inputs and coefficient of mechanization level according to Zaremba (W) taking into account the subsidy amount

Specification	Level of energy inputs (man-hour·ha^{-1} AL or kWh·ha^{-1} AL) in farms of subsidy amount (thousand PLN)				
	< 50	50-100	100-150	> 150	Average
Labour inputs (man-hour·ha^{-1} AL)					
Total in a farm,	274	255	192	80	200
including production:					
– crop	69	61	41	28	50
– animal	120	101	71	23	79
– other work plus outside workers	84	93	80	29	72
Inputs (kWh·ha^{-1} AL)					
Total labour of own means,	2248	2206	1795	1483	1933
including:					
– tractors	1868	1813	1445	1083	1552
– self-propelled combine harvesters	39	52	9	59	40
– pastures preparation	143	143	143	143	143
– milking and milk secure	27	27	27	27	27
– transportation of loading masses	51	51	51	51	51
– other	119	119	119	119	119
Mechanization coefficient according to Zaremba (*W*), (%)	64.8	64.0	67.4	76.0	67.1

In farms, taking into account the subsidy amount (table 2), labour inputs of outside workers were at the level of 72 man-hour·ha^{-1} AL, with general input for crop production 79 man-hour·ha^{-1} AL (2251 man-hour·farm^{-1}) and animal production 50 man-hour·ha^{-1} AL (1425 man-hour·farm^{-1}). In the researched farms there were higher labour inputs incurred for crop production than for animal production. The reason for this is a low number of heads of livestock and high inputs for crop production caused by hiring seasonal workers at large plantations of tobacco and fruit bushes. Wójcicki (2001) obtained in his researches production inputs of own labour (of a family) on an average 1171 man-hour·farm^{-1} with crop production and 2311 man-hour·farm^{-1} with animal production. Manual labour inputs replaced by specific labour were highest in farms with the subsidy amount up to PLN 50 thousand (2248 kWh·ha^{-1} AL), and they got reduced by almost 40% with the subsidy amount above PLN 150 thousand (1483 kWh·ha^{-1} AL). The inputs (table 3) were highest in farms up to 10 ha AL (3197 kWh·ha^{-1} AL) and got reduced significantly with the increase by 20 ha of AL area. In the group of farms according to the economic size it was also proved that together with its increase, energy inputs got reduced, and the tendency remained observable in farms of the highest income of an enterprise. Similar results were obtained by Kocira and others (2006), who stated that farms of the highest economic size incur unit energy inputs that are 3 times lower than in farms of lower economic value.

Table 3

Energy inputs and coefficient of mechanisation level according to Zaremba (W), taking into account the assumed grouping categories of farms

Specification	Level of energy inputs (man-hour·ha^{-1} AL or kWh·ha^{-1} AL) for farms grouped according to												
	farm area (ha AL)					ESU				income of a holding (PLN thousand)			
	< 10	10–30	30–50	50–70	> 70	< 8	8–16	16–40	> 40	< 10	10–20	20–50	> 50
	Labour inputs (rbh·ha^{-1} UR)												
Total in a farm, including:	477	207	95	77	68	271	255	121	110	370	226	157	102
– animal production	126	48	36	32	8	62	73	24	31	87	68	30	24
– crop production	176	90	26	14	26	140	88	43	21	148	78	82	41
– other work plus outside workers	174	68	32	31	34	69	93	54	58	134	80	45	37
	Inputs (kWh·ha^{-1} AL)												
Total labour of own means, including:	3197	2033	1151	999	1398	2438	2219	1608	942	2720	2118	1705	1464
– tractors	2838	1645	772	636	990	2062	1825	1225	553	2347	1730	1316	1075
– self-propelled combine harvesters	18	48	38	22	67	36	53	42	48	31	47	49	48
– motor engines in crop production and other within the farm	341	341	341	341	341	341	341	341	341	341	341	341	341
Mechanization coefficient according to Zaremba (*W*), (%)	57.7	66.8	71.2	73.2	75.3	66.8	65.1	72.6	63.0	61.0	65.8	69.2	72.5

Mechanization level of production according to Zaremba (table 2) increased with the increase of the subsidy amount, but only from 100-150 and area of PLN 150 thousand, and its average value amounted to 67.1%. A similar tendency was observed (table 3) together with the AL area increase and income of an enterprise increase. However, in the group arranged according to economic size, the highest mechanization level was proved by farms within the range of 16-40 ESU (up to 72.6%).

It has been stated (table 3), that in farms of small area (up to 10 ha) AL, apart from high inputs of specific labour (3,197 $kWh \cdot ha^{-1}$ AL), there were high inputs of manual labour reported (477 $man\text{-}hour \cdot ha^{-1}$ AL). Mechanization level (table 2) is only a coefficient of labour process organization, and it depends on the management process, which is represented amongst others by a rational way of equipping a farm with mechanization means, and on the production technology, which defines the usage of possessed technical means. For the whole group of researched farms, the coefficient of mechanization level (67.1% on an average) confirms the expected indicator (60-70%) for model farms (Pawlak and Wójcicki, 1993).

Work energetic equipment (fig. 1) increased proportionally to the area increase (ha AL) and assistance amount (PLN $thousand \cdot farm^{-1}$). Despite the fact that in farms of area above 70 ha AL the subsidy amount decreased in relation to the group from 50-70 ha AL, it did not influence the increase of the analyzed mechanization coefficient.

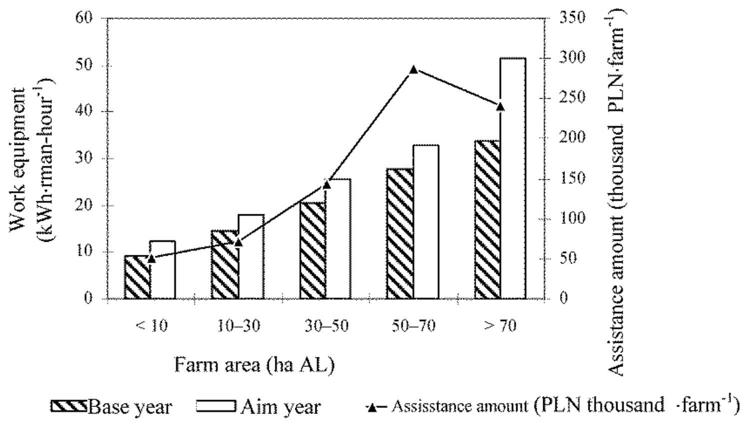

Figure 1. Work energetic equipment taking into account the area of researched farms and assistance amount

Conclusion

The highest installed power was observed in the smallest farms in each researched group, and it was decreasing along with their increase. Energy inputs in the researched farms are derivatives of manual labour and combustion and electric engines work. Their level calculated into to area unit was decreasing systematically, both with the increase of the subsidy amount, as well as area, economic size and income of an enterprise. In the researched farms higher labour inputs were incurred for crop production than for animal production. The reason for this is a low livestock and high inputs for crop production caused by hiring seasonal workers in big tobacco and fruit bushes farms.

Energy inputs for PLN thousand of the subsidy amount were relatively high in the smallest farms from the point of view of area and economy, and of the lowest subsidy amount level and income of an enterprise. Manual labour inputs replaced by specific labour were highest in farms of assistance amount level up to PLN 50 thousand, and decreased by almost 40% at the subsidy amount above PLN 150 thousand. The inputs were highest in farms up to 10 ha AL and decreased significantly with the increase of area of AL by 20 ha. In the group of farms according to the economic value, it was pointed out as well that with its increase, energy inputs got reduced, and the tendency remained valid for the farms of the highest income of a holding. In farms of small area (up to10 ha) AL, apart from high specific labour inputs, there were high inputs of manual labour observed.

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ZALEŻNOŚĆ NAKŁADÓW ENERGETYCZNYCH OD POWIERZCHNI I WIELKOŚCI EKONOMICZEJ GOSPODARSTW RODZINNYCH

Streszczenie. Celem pracy jest określenie wpływu powierzchni użytków rolnych (UR) i wielkości ekonomicznej na nakłady energetyczne w gospodarstwach rodzinnych korzystających z dofinansowania Unii Europejskiej. W latach 2004-2009 przebadano 70 gospodarstw rolnych z powiatu biłgorajskiego korzystających z dofinansowania UE na modernizację techniczną. Do określenia nakładów energetycznych badaną zbiorowość gospodarstw podzielono wg kryterium kwoty pomocy, powierzchni UR, wielkości ekonomicznej (ESU) i dochodu przedsiębiorstwa. Przy charakteryzowaniu stopnia wyposażenia badanych gospodarstw w środki energetyczne uwzględniono użytkowane w procesie produkcji rolniczej ciągniki, kombajny samobieżne i silniki elektryczne, w tym wmontowane w urządzenia pracujące w obrębie podwórza. Poziom nakładów energetycznych w badanych gospodarstwach w przeliczeniu na jednostkę powierzchni systematycznie spadał, zarówno przy wzroście kwoty pomocy, jak i powierzchni, wielkości ekonomicznej oraz dochodu przedsiębiorstwa. W grupie gospodarstw wg wielkości ekonomicznej wraz z jej wzrostem zmniejszały się nakłady energetyczne, a tendencja ta utrzymywała się w gospodarstwach o największych dochodach przedsiębiorstwa. W gospodarstwach o małej powierzchni (do 10 ha) UR, obok wysokich nakładów pracy uprzedmiotowionej, wystąpiły wysokie nakłady pracy ludzkiej.

Słowa kluczowe: nakłady energetyczne, powierzchnia UR, wielkość ekonomiczna, kwota pomocy, dochód przedsiębiorstwa

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IMPACT OF DRYING PARAMETERS AND METHODS ON THE VOLUME INCREASE OF DRIED APPLES DURING THEIR REHYDRATION[1]

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ABSTRACT

The objective of this paper was to analyse the impact of parameters and drying method on the increase of the volume of dried apple slices and cubes during their rehydration. Ligol apples (cut into 3 and 10 mm slices and 10 mm cubes) were dried with the following methods: natural convection (temperature of drying 60°C), forced convection (a tunnel drier, parameters of drying air: 50, 60, 70°C and 0,5, 2 m·s^{-1}), fluid drying (60°C and 6 m·s^{-1}). Dried fruit were rehydrated in the distilled water of 20°C temperature. Determination of volume was carried out with an uplift pressure method in petroleum ether. Tests proved the impact of ground dried particles and the impact of drying method on the increase of the volume of dried apples during their rehydration. The final volume of the rehydrated dried fruit increased along with the reduction of drying temperature, these differences in numerical values were low, but statistically significant.

Introduction

Drying is a frequent method of preserving food products. Its purpose is to remove water, which causes, inter alia, limitation of the growth and development of putrefactive micro-organisms and limits biochemical reactions, due to which the period of storing the product at the maintenance of proper storage conditions, may be considerably elongated (Jayaraman and Das Gupta, 1992). Simultaneously, however, in food products unfavourable quality changes take place during drying, which include both optical properties (colour), sensory (smell, taste), structural (volume, porosity, density), textural, rehydration properties and losses in nutritious elements, in particular vitamins, the intensity of which depends on the type of the dried product and the applied drying method (Krokida and Maroulis, 2001; Marabi et al., 2006).

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Reduction of volume is one of the most disadvantageous physical changes during the process of drying food. The loss of water and heating causes formation of stresses in the cell structure of food products which leads to drying shrinkage, the change of the product shape and the decrease of its dimensions (Mayor and Sereno, 2004). The phenomenon of shrinkage also negatively influences the process of rehydration of the dried product, decreasing ability of tissues of the dried material to absorb water (Krokida and Marinos-Kouris, 2003; Mayor and Sereno, 2004). At the same time, many dried products is consumed or industrially processed after previous hydration. Thus, it is important to obtain dried fruit in such conditions, which enable in the highest degree a later return of the rehydrated material to properties, which characterized the raw material.

Impact of drying parameters and methods on rehydration of fruit and vegetables was investigated and presented in literature. Rehydration of banana, carrot and potatoes dried by means of microwaves was faster and particles absorbed more water than samples dried by means of convection (Drouzas and Schubert, 1996; Prabhanjan et al., 1995). Witrowa-Rajchert and Radecka-Wierzbicka (2005) did not find any explicit impact of the drying technique (convection drying with the air flow along the material layer, convectional drying with a perpendicular air flow, fluid drying) on the ability of dried carrot and potatoes to rehydrate. The increase of the microwaves power caused deterioration of the rehydration of the dried beetroot pulp (Figiel et al. 2006). Stępień (2007) investigated rehydration of the dried celery, which was dehydrated by means of sublimation, microwave and vacuum and convection. Celery dried by means of sublimation was characterised with the highest kinetics of the increase of the sample mass and the increase of the water mass and the lowest loss of the dry substance mass. The increase of mass of the jujube fruit wholly dried (*Zizyphus jujuba* Miller) was higher if the temperature of drying air was higher (Fang et al., 2009). Investigating the impact of the drying method (convectional, sublimation, microwave-vacuum) Stępień (2009) proved that from the dried carrot obtained with convectional method from the material dehydrated by means of osmosis, during hydration, the biggest amount of dry substance diffuses to the solution, whereas Aversa et al. (2012) proved the impact of convectional drying parameters (temperature and the drying air velocity) on the increase of water mass during rehydration of dried carrot. If convectional drying will be preceded with microwave drying, then dried fruit and strawberries will absorb more water during rehydration. In such manner, dried mushrooms will absorb less water and in case of dried tomatoes, no impact of such drying on the course of rehydration was reported (Askari et al., 2009). Stępień et al. (2011) determined a significant impact of the drying method (convectional, sublimation, microwave-vacuum) on the ability to rehydrate dried parsley. Taking into consideration the results of the quality research of convectional dried fruit and freeze drying agent and in particular the course of rehydration Lis et al. (2011) reported their considerable variability, the bigger, the lower water content was in dried fruit (from a sublimation drier).

The impact of parameters and the drying methods on the increase of the volume of dried fruit and vegetable during their rehydration was researched less frequently and presented in literature. Bilbao-Sáinz et al. (2005) performed microwave drying of apples before convectional drying and determined that the increase of the volume of dried fruit during hydration is higher for a higher power of microwaves. The increase of volume during rehydration of apples dried by means of sublimation was higher than apples dried by means of convection (Lewicki and Wiczkowska, 2006). Markowski et al. (2009) proved the impact of the drying method of potatoes (microwave – vacuum, convectional) on the increase of the volume of dried fruit during rehydration. Górnicki et al. (2009) stated that temperature of drying influences the relative increase of the volume of dried parsley roots during rehydration.

The objective of this paper was to analyse the impact of parameters and drying method on the increase of the volume of dried apples during their rehydration.

Material and methods

Ligol apples were used for the research. Their initial temperature was approx. 85% (5.7 kg $H_2O \cdot kg^{-1}$ d.m.). The raw material was washed and sliced and cut into cubes. Slices were 3 and 10 mm and cubes 10 mm. The raw material was dried with the following methods:

- natural convection, temperature of drying air in a drier (KCW-100, PREMED, Marki) was 60ºC,
- forced convection, temperature of drying air in a tunnel drier was 50, 60 and 70ºC, whereas the velocity of drying air was 0.5 and 2 $m \cdot s^{-1}$, the air flow was horizontal, the initial load of meshes was 10 $kg \cdot m^{-2}$,
- fluidized drying, temperature of drying air was 60ºC and the drying air velocity was 6 $m \cdot s^{-1}$.

drying lasted to the moment a fixed value of the dried fruit mass was set. The final moisture of dried apples was approx. 9% (0.1 kg $H_2O \cdot kg^{-1}$ d.m.).

Dried fruit obtained in given conditions from three independent experiments were mixed and stored in a tightly closed container for approx. a week in temperature of 20ºC. Afterwards samples for further research were collected. A container, where dried fruit were stored was placed in a cardboard, so the dried apples were exposed to sun's rays effect. The process of rehydration was carried out for 6 hours in distilled water of a fixed temperature 20ºC. The relation of the dried fruit mass to water mass was 1:20. During the process of moistening water was not stirred. The initial mass of dried fruit subjected to rehydration was approx. 10 g. Determination of the volume was carried out with the uplift pressure method in petroleum ether (Kaleta (red.), 2013; Mazza, 1983). Measurements were carried out for dried fruit and during the process of rehydration. During rehydration volume was determined after 10, 20, 30, 50, 90, 180 and 360 min of the duration of moistening. Each sample was subjected to rehydration to a single measurement of volume. Designation was carried out in three repeats. The maximum relative error of designating the volume calculated with the total differential method was 5%.

Pelega model (1988) in the following form was applied for description of the volume of dried apples in the process of rehydration

$$\frac{V}{V_0} = 1 + \frac{\tau}{k_1 + k_2 \tau} \tag{1}$$

where:

k_1, k_2 – constant,
V – volume (ml),
V_0 – initial volume (volume of dried fruit) (ml),
τ – time (h).

This model was very frequently used for description of the rehydration process including inter alia for modelling the volume increase (Bilbao-Sáinz et al. 2005). For determination of the model parameters the method of non-linear estimation by Lavenberg-Marquardta was applied. Coefficients of correlation *r* were also calculated. Significance of the impact of methods and parameters of drying on the increase of the volume of dried apples during their rehydration was determined with the use of analysis of variance (ANOVA) after accepting the uniformity test of Levene's variance. Tukey's test HSD was applied for division into uniform groups (at the significance level of α=0.05). Calculations were carried out with the use of IBM® SPSS® Statistics 21 application.

Results and discussion

Results of experiments were presented in figures 1-5. Figure 1 presents an exemplary diagram of the increase of the volume of dried material (apple cubes of a 10 mm side, dried in a fluidized drier in temperature of 60ºC and the drying air velocity of 6 $m \cdot s^{-1}$) during rehydration in distilled water of temperature of 20ºC. This figure presents measurement points. It is visible, that the fastest increase of volume takes place in the initial period of rehydration, in the further stage of the process, water absorption slows down, because hydrated samples get close to the state of balance. A similar character of volume changes during rehydration was reported by Bilbao-Sáinz et al. (2005) for apples, Markowski et al. (2009) for potatoes and Witrowa-Rajchert (1999) for apples, carrot, parsley and potatoes. Fast initial water absorption is related the most probably with filling with water capillaries at the surface of a sample (Bilbao-Sáinz et al., 2005).

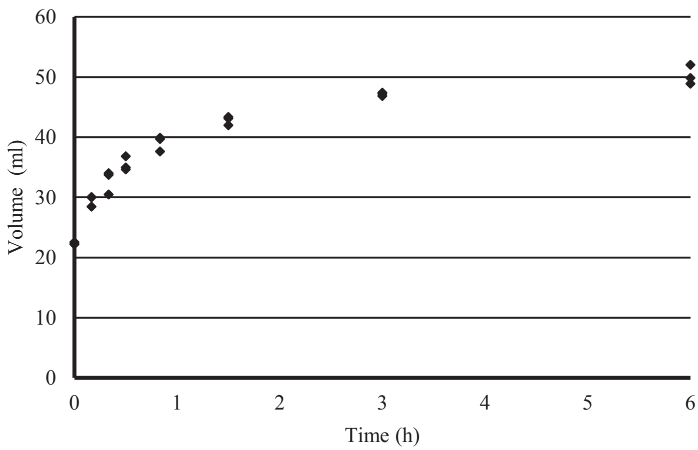

Figure 1. The increase of the volume of dried material (apple cubes of a 10 mm side, dried in a fluidized drier in temperature of 60ºC and the drying air velocity of 6 $m \cdot s^{-1}$) during rehydration in distilled water of temperature of 20ºC

Figures 2-5 present functions approximating the results of three repeats of measurements of volume changes during the process of rehydration (Pelega model). The calculations prove that Pelega model describes well the increase of volume of dried apples during their rehydration since the value of the coefficient of correlation r is within 0.956 to 0.996 (fig. 2-5).

Statistical analysis of the impact of drying methods and parameters on the increase of volume during rehydration of dried apples (division into uniform groups) was presented in table 1. In this table, numbers mean average values from three repeats of measurements of the relations of present volume of rehydrated dried fruit to the initial volume of dried fruit, whereas uniform groups for each time of rehydration were determined with the same letters. On account of transparency of diagrams in figures 2-5, measurement points and confidence regions were not marked.

Table 1
Average values of the relation of the volume of rehydrated dried fruit to the initial volume of dried fruit in the rehydration process

Form of raw material	Drying method and parameters	Time (min)						
		10	20	30	50	90	180	360
3 mm slice	tunnel drier 60ºC, 0.5 m·s^{-1}	1.98[a]	2.22[a]	2.41[a]	2.76[a]	2.89[a]	3.18a	3.12[a]
10 mm slice	tunnel drier 60ºC, 0.5 m·s^{-1}	1.19[b]	1.43[b]	1.36[b]	1.50[b]	1.60[b]	1.96b	2.22[b]
10 mm slice	natural convection, 60ºC	1.14[b]	1.31[c]	1.27[c]	1.53[b]	1.56[b]	1.83c	2.02[c]
cube 10 mm	fluidized drying, 60ºC, 6 m·s^{-1}	1.32[cdg]	1.47[bd]	1.59[dg]	1.75[cgh]	1.92[c]	2.11[dh]	2.25[b]
cube 10 mm	natural convection, 60ºC	1.37[cdegh]	1.50[bd]	1.62[dg]	1.85[defgh]	2.06[d]	2.43[e]	2.62[d]
cube 10 mm	tunnel drier 50ºC, 0.5 m·s^{-1}	1.42[defgh]	1.55[d]	1.71[eg]	1.90[defh]	2.15[e]	2.32[fg]	2.51[efh]
cube 10 mm	tunnel drier 60ºC, 0.5 m·s^{-1}	1.48[efh]	1.68[f]	1.80[f]	1.93[def]	2.16[e]	2.24[fg]	2.45[efgh]
cube 10 mm	tunnel drier 70ºC, 0.5 m·s^{-1}	1.39[cdegh]	1.46[bd]	1.64[deg]	1.79[cdgh]	1.92[c]	2.18[gh]	2.38[fg]
cube 10 mm	tunnel drier 60ºC, 2 m·s^{-1}	1.41[defgh]	1.52[bde]	1.65[deg]	1.83[cdegh]	2.02[d]	2.24[fgh]	2.48[fh]

a, b, c, d, e, f, g, h – the same letters in columns indicated uniform groups

Figure 2 presents the impact of slices thickness and in figure 3, the impact of the shape of a particle on the increase of the volume of rehydrated dried fruit. For the same time of process duration the increase of the volume of rehydrated dried fruit increased with the reduction of slices thickness and dependent on the shape of a particle (increase of volume for a cube is higher than for a slice with the same thickness). The higher degree of grinding of dried apples particles, the higher are the increases of volume in the rehydration process.

Such impact of grinding of particles on the increase of the volume of rehydrated dried fruit is statistically significant (table 1). A similar character of the impact of grinding was reported by Aversa et al. (2012) for carrot particles.

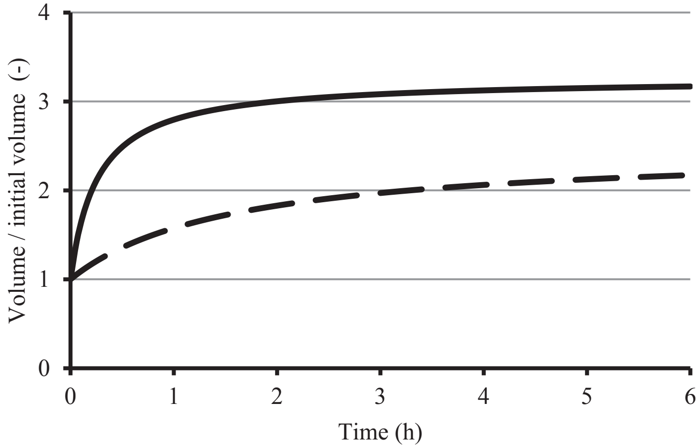

Figure 2. The increase of volume of dried apple slices (tunnel drier, drying air temperature 60ºC, drying air velocity 0.5 m·s^{-1}) of thickness: (——) 3 mm (r=0.986), (— —) 10 mm (r=0.956) during rehydration in distilled water

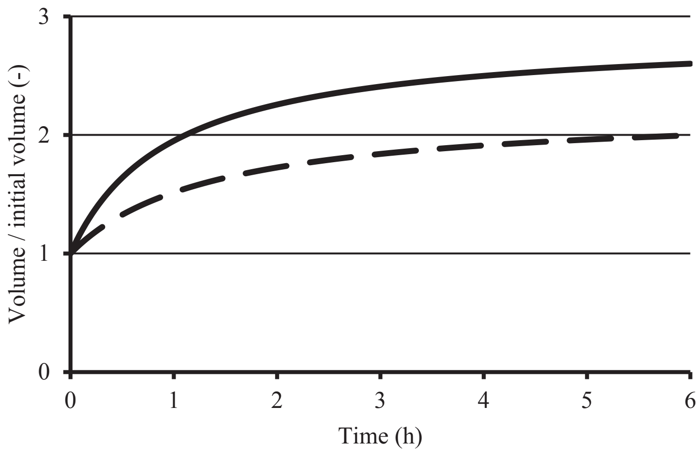

Figure 3. The increase of the volume of dried material (natural convection, drying air temperature 60ºC) during rehydration: (——) apple cubes of 10 mm side (r=0.992), (— —) apple slices of 10 mm thickness (r=0.956) in distilled water

The next figure presents the impact of convectional drying on the increase of volume of dried fruit during rehydration. The final volume of the rehydrated dried fruit increases along with the reduction of drying temperature, these differences for numerical values are low, but statistically significant (tab. 1). A similar character of the impact of drying temperature was reported for potatoes by Markowski et al. (2009).

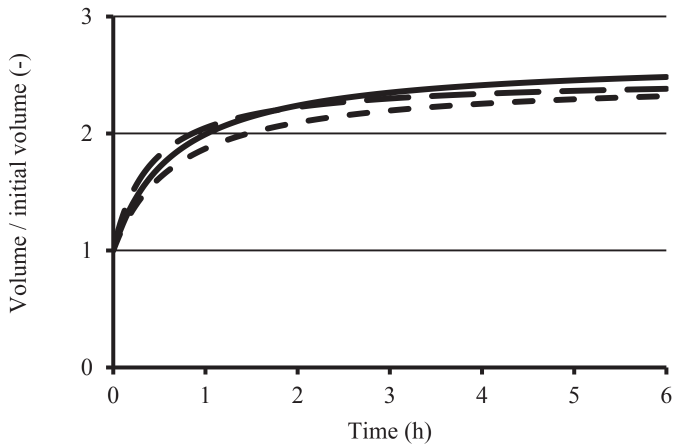

Figure 4. The increase of the volume of dried material (apple cubes of a 10 mm side, dried in a tunnel drier in temperature: (——) 50ºC (r=0.996), (— —) 60ºC (r=0.986), (- - -) 70ºC (r=0.990), drying air velocity 0.5 $m{\cdot}s^{-1}$) during rehydration in distilled water

Figure 5 presents the impact of convectional drying on the increase of volume of dried fruit during rehydration. The highest final volume have dried fruit obtained in natural convection conditions and the lowest the one obtained with fluidized drying method and the difference is statistically significant (tab. 1). Drying air velocity in a tunnel drier ceased to have a statistically significant impact on the increase of dried fruit volume as soon as after three hours of rehydration (table 1). Analysis of results of research presented in figure 5 gives basis to state that drying in natural convection conditions damages the plant tissue structure the least, and fluidized drying the most. The research carried out by Witrowa-Rajchert and Radecka-Wierzbicka (2005) on carrot and potatoes drying shows that although many advantages of fluidized drying, which characterizes with very good conditions of heat and mass exchange, this method negatively influences the structure of plant tissue.

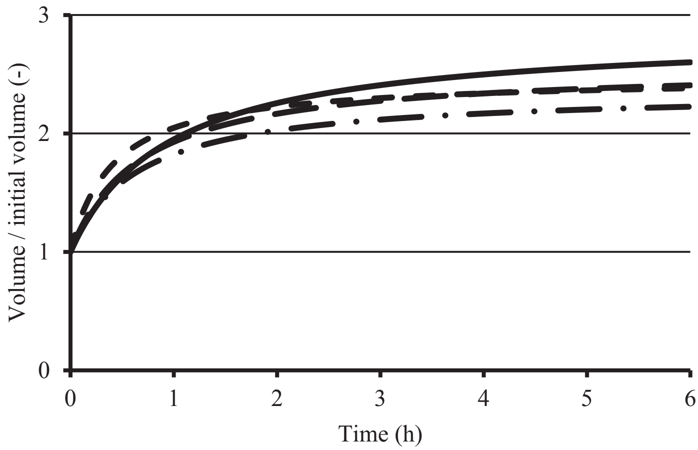

Figure 5. The increase of dried material (apple cubes of 10 mm side, dried in temperature 60ºC: (——) natural convection (r=0.992), (— —) tunnel drier, drying air velocity 0.5 m·s^{-1} (r=0.986), (– –) tunnel drier, drying air velocity 2 m·s^{-1} (r=0.986), (— · —) fluidized drying (r=0.993) during rehydration in distilled water

Conclusions

1. The higher degree of grinding of dried apples particles, the higher is the increase of their volume in the rehydration process.
2. The final volume of the rehydrated dried fruit increases along with the reduction of drying temperature, these differences for numerical values are low, but statistically significant.
3. Drying method affects the increase of the volume of dried fruit of apples particles during their rehydration. The highest final volume is assumed by dried fruit (cubes) obtained in natural convection conditions and the lowest the one obtained with fluidized drying method.

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WPŁYW PARAMETRÓW I METODY SUSZENIA NA WZROST OBJĘTOŚCI SUSZONYCH JABŁEK PODCZAS ICH REHYDRACJI

Streszczenie. Celem pracy była analiza wpływu parametrów i metody suszenia na wzrost objętości suszonych plastrów i kostek jabłek podczas ich rehydracji. Jabłka odmiany Ligol (plastry o grubości 3 i 10 mm, kostki sześcienne o boku 10 mm) suszono następującymi metodami: konwekcja naturalna (temperatura suszenia 60ºC); konwekcja wymuszona (suszarka tunelowa, parametry powietrza suszącego: 50, 60, 70ºC oraz 0,5, 2 $m \cdot s^{-1}$); suszenie fluidalne (60ºC i 6 $m \cdot s^{-1}$). Susz rehydrowano w wodzie destylowanej o temperaturze 20ºC. Oznaczenie objętości wykonano metodą wyporu w eterze naftowym. Badania wykazały wpływ rozdrobnienia suszonych cząstek i wpływ metody suszenia na wzrost objętości suszonych jabłek podczas ich rehydracji. Końcowa objętość rehydrowanego suszu rosła z obniżeniem temperatury suszenia, różnice te w wartościach liczbowych były niewielkie, ale statystycznie istotne.

Słowa kluczowe: sposób rozdrobnienia, temperatura, prędkość powietrza suszącego, suszenie, rehydracja, objętość, jabłko

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SOIL COMPACTION WITH WHEELS OF AGGREGATES FOR FERTILIZATION WITH LIQUID MANURE

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ABSTRACT

Te objective of the research was determination of the impact of loading capacity of fertilization sets on soil compaction. Degree of soil compaction was determined based on four indexes. Three fertilization sets were selected for research: set A – tractor Renault 95.14 plus a waste removal vehicle of cubic capacity of 6 m^3, set B – tractor John Deere 6420 plus a waste removal vehicle 12 m^3, and set C Valtra N121 plus a waste removal vehicle 8 m^3. Four indexes were determined: field area compaction, loading a field with sets crossings, degree of compaction in the trace of wheels and cubic capacity of ruts. It was determined that the biggest surface of the compacted field was for the set A (27%) and the smallest for the set B (16%). Loading of a field with the sets crossings was the highest also for the set A (212 kN·km·ha^{-1}) and the lowest for the set B (167 kN·km·ha^{-1}). Degree of compaction in the trace of wheels was the highest for the set B (105 kN·m^{-1}) and the lowest for the set A (77 kN·m^{-1}). The highest cubic capacity of ruts was determined on the field fertilized with the set A (99 m^3) and the lowest for the set B (61 m^3). From among the technical parameters of fertilization machines the following affect the soil compaction degree: tractor mass and a waste removal vehicle mass and its cubic capacity and the working width, which depends on the application unit which was used. The set B may be recognized as the the best selected fertilization set (a tractor and a waste removal vehicle) on account of soil compaction and the least favourable – the set A.

Introduction

A waste removal vehicle is a basic machine in liquid manure fertilization technology, which transports and applies fertilizer (Dreszer et al., 2008; Romaniuk et al., 1995; Śiłovoj, 2013). Producers of waste removal vehicles are inter alia Polish companies Meprozet Kościan, Pomot Chojna and foreign: Holmer, Exmoor, Zunhammer Gulltechnik, Venhuis, Kyndestoft Maskinfabrik ApS, Freiberger, Oldenburger, Toric (Zbytek, et al., 2008). Waste removal vehicles are both agricultural machines as well as transport means. They move on various bases, both on public roads, hardened roads, and field roads as well as on fields, meadows and pastures. Thus, their equipment in appropriate driving systems, which meet the requirements regarding axis loads and unit loads are very important (Powałka, 2008). Tendencies concerning construction of even higher cubic capacities of waste removal vehicles and their equipment in additional devices, such as: spreading beams, cultivation tools cause that their mass in the recent years has increased a lot (it reaches several tonnes) (Rjazanov, 2009; Zbytek and Talarczyk, 2011; Zbytek, et al., 2013). Such big masses of machines cause high demand for power of cooperating tractors, which also are of big mass. The mass of an aggregate with fertilizers reaches up to 45 tonnes, which causes a threat of excessive soil compaction with tractor wheels and a waste removal vehicle wheels. This compaction, as numerous authors state (Buliński i Marczuk, 2007; Jakliński, 2006; Marczuk, 2006; Marczuk and Skwarcz, 2006; Koniuszy, 2010) may be minimized with the use of fertilization aggregates with properly selected mass, power of the tractor engine, number of wheels, size and pressure in tyres, wheel track (tractor wheels track compatible with the waste removal vehicle wheels track). Various indexes are used for assessment of the degree of soil compaction, including: the area of the compacted field, pressures on the axis of the driving system, unit pressures in a rut, depth of a rut, cubic capacity of the formed ruts (Marczuk and Kamiński, 2012). Each index describes only a part of soil compaction phenomenon. It is also significant, in what soil-climate conditions fertilization treatment is carried out (Pilarski, et al., 2008; Wesołowski, 2008; Iwaszkiewicz, 2013; Marczuk, 2013; Lorencowicz, 2013).

Objective, scope and the methodology of research

The objective of the research was to determine the loading capacity of waste removal vehicles (6, 8 and 12 m^3) used in farms of a varied acreage, various livestock, on soil compaction, determined with four indexes which characterize the degree of soil compaction. The scope of research included three fertilization sets (a tractor and a waste removal vehicle) which differ with tractor power, cubic capacity of vehicles, number of wheels and the size of the set tyres.

Exploitation research of machines took place on the territory of Podlaskie voivodeship in farms with agricultural land acreage 28, 60 and 90 ha with cowsheds with respective livestock: farm I 25 dairy cows and 15 cattle, farm II 40 cows, 10 heifers and 10 cattle, 25 bulls, farm III 55 dairy cows, 25 heifers and 25 cattle. In farms there were tanks for natural liquid manure of cubic capacity 200, 850 and 250 m^3, which ensure collection of 6-month liquid manure production.

Fertilized cultivation fields were located in the following distance from farms (tanks for natural liquid manure): 400, 350 and 200 m. Liquid manure was spread on the surface of a field with sod podzod soil with stubble after winter wheat and skimming carried out with a disc harrow. Relative moisture of fertilized soils was 10-12%.

Three fertilization sets were accepted for research: set A – tractor Renault 95.14 and a waste removal vehicle of cubic capacity 6 m^3 Strautman&Sohne 580, set B – tractor John Deere 6420 and a waste removal vehicle of cubic capacity 12 m^3 Fliegl Fass 12000 and set C – tractor Valtra N121 and a waste removal vehicle of cubic capacity 8 m^3 Siegfried Marchner 8000 (fig. 1).

a) Set A b) Set B c) Set C

Figure 1. Fertilization aggregates during work on field; a setA, b. set B, c. set C

An abridged technical description of the used tractors and waste removal vehicles was presented in table 1 and 2.

Table 1
*Technical description of agricultural tractors**

Tractor type	Total mass (kg)	Engine power (kW/KM)	Tyre size (front/back)	Fuel consumption ($dm^3 \cdot h^{-1}$)	Tractor price (PLN)
Renault 95.14	4740	62.5/85	360/70R28 480/70R34	9.38	200.000
John Deere 6420	4.800	88/120	420/70R24 520/70R34	13.20	300.000
Valtra N121	4.950	101/137	480/65R28 600/65R38	15.15	389.610

* Acc. to producer's data and authors' own measurement

Table 2
Abridged technical description of waste removal vehicles (water carts)*

Type of water cart	Total mass (kg)	Tyre size	Cubic capacity of a tank (m^3)	Manner of filling	Manner of emptying	Performance W_{07} ($ha \cdot h^{-1}$)	Price of a water cart (PLN)
Strautman &Sochne 580	1000	550/60-22,5 (air)	5.8	compressor	compressor	0.88	61.500
Fiegl Fass 12.000	2000	600/55-22,5	12.0	compressor	compressor	2.06	123.000
Siegfried Marchner 8000	1300	550/60-22,5 (air)	8.0	compressor	compressor	2.86	55.000

* Acc. to producer's data and authors' own measurement

Methodology of research

For assessment of soil compaction degree, four following indexes were accepted citing Marczuk and Kamiński (2012): compacted field surface (k_s), field load (k_{ob}), degree of soil compaction in the trace of wheels (k_{ug}), cubic capacity of ruts (V_k).

Compacted field area. The field area compacted with tractor wheels and waste removal vehicles was determined with participation of trace area (ruts) of tractor wheels and waste removal carts in the total area. It is equal to the relation of the ruts width to the working width of a waste removal vehicle:

$$k_s = \frac{S_1}{S_2} \cdot 100 \quad (\%) \tag{1}$$

where:
k_s – participation of the compacted field area (%),
S_1 – width of left and right wheel tracks (m),
S_2 – working width of a machine (m).

Field load. Index of field load with working crossings of an aggregate were calculated according to the following formula:

$$k_{ob} = \frac{(G_c + G_w + 0.5G_ł) \cdot L_B}{P_p} \quad (\text{kN}\cdot\text{km}\cdot\text{ha}^{-1}) \tag{2}$$

where:
k_{ob} – field load ($\text{kN}\cdot\text{km}\cdot\text{ha}^{-1}$),
G_c – tractor weight (kN),
G_w – waste removal weight (kN),
$G_ł$ – load weight in the waste removal vehicle (kN),
L_B – route of an aggregate of the working width B on the area P_p (km),
P_p – area of 1 ha.

Degree of soil compaction in the track of wheels. These are average axis pressures resulting from the tractor mass, waste removal vehicle mass with the content during the crossing of an aggregate on a field. Total pressure (k_{ug}), it is a sum of axis pressures of the set (tractor, waste removal vehicle with the tank half-filled):

$$k_{ug} = N_{opc} + N_{otc} + N_{opw} + N_{otw} \quad (\text{kN}) \tag{3}$$

where:
k_{ug} – total pressure of the fertilization set (kN),
N_{opc} – pressure of front axis of a tractor (kN),
N_{otc} – pressure of the back axis of a tractor (kN),
N_{opw} – pressure of the back axis of a waste removal vehicle (kN),
N_{otw} – pressure of the back axis of a waste removal vehicle (kN).

Unit pressure of the set on the unit of compacted area is a ratio of the total pressure and the rut width made by right and left wheels of the set.

$$Nj = \frac{k_{ug}}{S_{sl}} \tag{4}$$

where:
N_j – unit pressure ($kN \cdot m^{-1}$),
$S_{śl}$ – width of left and right wheels track (m).

Cubic capacity of ruts. It was determined as the cubic capacity of the tractor and waste removal vehicle wheels track made on the area of 1 ha, which was determined in the following manner:

$$V_k = S_k \cdot G_k \cdot D_a \quad (m^3) \tag{5}$$

where:
V_k – cubic capacity of ruts on the area of 1 ha (m^3),
S_k – the rut width of left and right wheels (m),
G_k – the rut depth at 1/2 content of a tank (m);
D_a – route of an aggregate on the area of 1 ha (km).

Measurements of width and depth of a rut was carried out with the use of a batten and measure with precision to 1 mm following crossing of front and back wheels of a tractor and front and back wheels of a waste removal vehicle.

Results of the research

Compacted field surface. Working width of a machine and the width of wheel tracks (right and left) of the machine set has a main impact on the compacted field surface. Working width of the waste removal vehicle depends on the type of and performance of a compressor used in the vehicle. In the researched waste removal vehicles the working width was respectively: 4,7.5 and 5 m. Te same wheel track of tractors and waste removal vehicles caused that ruts had a width equal to the size of the widest wheel. For sets A and B these were rut widths made by waste removal vehicles (tyres 550/60-22.5 and 600/55-22.5), in the set C it was the rut width made by tractor wheels (600/65 R38).

Width of tracks of left and right wheels, working width of machines and percentage participation of the compacted field area for three fertilization sets were presented in table 3.

Table 3
Percentage participation of the compacted field area during fertilization with liquid manure

Symbol of the fertilization set	Width of left and right wheels (m)	Working width of machines (m)	Compacted field area k_s (%)
A	1.10	4.0	27.50
B	1.20	7.5	16.00
C	1.20	5.0	24.00

The research and calculations show that the highest percentage participation of the compacted field area (27.5%) was reported for the fertilization set A (vehicle with cubic capacity of 6 m^3) the lowest for the set B, comprising a waste removal vehicle of cubic capacity of 12 m^3 – 16 %.

Loading a field with working crossings

Loading a field with working crossing was determined based on measurements and calcualtions including: the weight of the set comprising a tractor plus a waste removal vehicle with 0.5 loading capacity of a tank, widths of waste removal vehicle, travelled distance by the fertilization sets on 1 ha area. Table 4 presents values of the index of loading a field with working crossings for the testes three fertilization sets. It was determined that loading a field on the 1 ha area with fertilization sets crossings at the assumption that the half of total mass of the load is placed at the average in a tank, it was the highest for the set A (211.90 $kN·km·ha^{-1}$), average for the set C (201.11 $kN·km·ha^{-1}$) and the lowest for the set B (167.01 $kN·km·ha^{-1}$). Such values of the index mainly result from the fertilization sets masses and the working width of waste removal vehicles, which in case of lower values (load mass and working width of a vehicle) travelled a longer distance.

Table 4
Loading a field with working crossings of fertilization sets

Symbol of the fertilization set	Weight of the set: tractor+waste removal vehicle + 1/2 of load (kN)	Working width of waste removal vehicles (m)	Width of ruts (m)	Distance travelled by the sets (km)	Field load k_{ob} ($kN·km·ha^{-1}$)
A	84.76	4.00	1.10	2.50	211.90
B	125.57	7.50	1.20	1.33	167.01
C	100.55	5.00	1.20	2.00	201.11

Unit pressure in the wheels track

Calculated average unit pressures of wheels on soil of the researched fertilization sets were presented in table 5. The highest values of this index characterize the B set, average values – the C set and the lowest – A set. They directly related to masses of tractors and waste removal vehicles with load rolled over on a field.

Table 5
Unit pressure in the wheels track of fertilization sets

Symbol of the fertilization set	Weight (kN)				Width of a rut (m)	Unit pressure N_j ($kN·m^{-1}$)
	Tractor	Waste removal vehicle	1/2 of the load of a vehicle	Total		
A	46.50	9.81	28.45	84.76	1.10	77.05
B	47.09	19.62	58.86	125.57	1.20	104.64
C	48.56	12.75	39.24	100.55	1.20	83.79

Cubic capacity of ruts

Analysis of depth and width of ruts was carried out based on the measurements of cross section of wheels tracks of a tractor and a waste removal vehicle. At the same time, degree of fill-up in the tank – a full tank, 0.5 of cubic capacity of a tank and an empty tank were included. Depth and width of ruts made by front and back wheels of a tractor and waste removal vehicles were measured taking into account left and right side of an aggregate. Measurements were taken three times and then average values were calculated. Results of measurements and calculations were presented in table 6.

Table 6
Average values of measurements of wheel tracks of a tractor and a waste removal vehicle and cubic capacity of ruts V_k

Axes of wheels	The state of fill-up of a waste removal vehicle tank						Index of cubic capacity of a rut V_k ($m^3 \cdot ha^{-1}$)
	Full tank		1/2 of a tank		Empty tank		
	Left side depth/width (mm)	Right side depth/width (mm)	Left side depth/width (mm)	Right side depth/width (mm)	Left side depth/width (mm)	Right side depth/width (mm)	
Fertilization set A							
1 axis of a tractor	30.3/383	30.3/380	31.8/382	31.8/388	32.0/383	33.0/387	93.5
2 axis of a tractor	33.5/480	34.6/475	36.0/487	36.5/483	35.5/550	35.1/480	
Axis of a waste removal vehicle	32.3/553	33.6/550	34.0/553	34.3/550	34.6/550	35.3/550	
Fertilization set B							
1st axis of a tractor	34.0/430	34.6/425	32.0/420	32.3/420	30.3/420	31.0/420	62.2
2nd axis of a tractor	40.6/550	38.6/540	38.0/520	39.0/522	39.3/520	38.6/520	
1st axis of a waste removal vehicle	40.3/600	39.6/600	38.3/600	38.0/600	38.0/600	38.3/600	
2 axis of a waste removal vehicle	38.3/600	39.3/600	38.0/600	38.0/600	37.3/600	37.3/600	

Fertilization set C							
1st axis of a tractor	16.3/450	17.3/450	19.3/450	19.6/450	20.6/450	21.3/450	67.2
2nd axis of a tractor	25.0/593	26.6/593	29.0/593	30.0/573	30.3/593	32.0/593	
1st axis of a waste removal vehicle	27.3/600	28.0/600	28.0/600	30.0/600	30.3/600	31.3/600	
2nd axis of a waste removal vehicle	27.6/600	28.3/600	28.3/600	30.3/600	30.3/600	30.3/600	

Research and calculations prove that in caseof fertilization sets A and C, the ruts depth made by the front axis of a tractor increased along with emptying the waste removal vehicle tank. It means that a full tank of a vehicle considerably loads the back axis of a tractor which results in relieving the front axis. In case of the fertilization set B the ruts depth made by the front axis of a tractor decreases along with emptying the tank. It was calculated based on average values of depth and width of ruts which were formed during filling the tank of a waste removal vehicle to 0.5 maximum cubic capacity and were for the set A, B and C respectively 93.5 m^3, 62.2 m^3 and 67.2 m^3. High value of ruts cubic capacity in case of the A set at the lowest cubic capacity of the tank of a waste removal vehicle and at its lowest mass results from small working width (4.0 m).

Summary

Research proved that the used fertilization sets in farms cause considerable soil compaction in wheels tracks. The list of numerical values of soil compaction degree indexes for the analysed fertilization sets presented in fig. 2.

Cubic capacity of a rut, made on the area of 1 hectare of the fertilized field is a significant index which presents the soil compaction degree. Calculated cubic capacity of ruts based on average values of depth value and width of wheels track made at filling the tank of a waste removal vehicle which is 0.5 of maximum cubic capacity, was the maximum for the fertilization set of A – 93.5 m^3. For the remaining two sets it was on the similar level (B – 62.2 m^3, C – 67.2 m^3). From among four indexes of assessment of the soil compaction degree with wheels of fertilization aggregates for the A set the lowest unit pressures in wheels track were reported and for the b set the lowest field compaction, the lowest load of a field with working crossings and lowest cubic capacity of ruts. The C set featured average values of all four indexes.

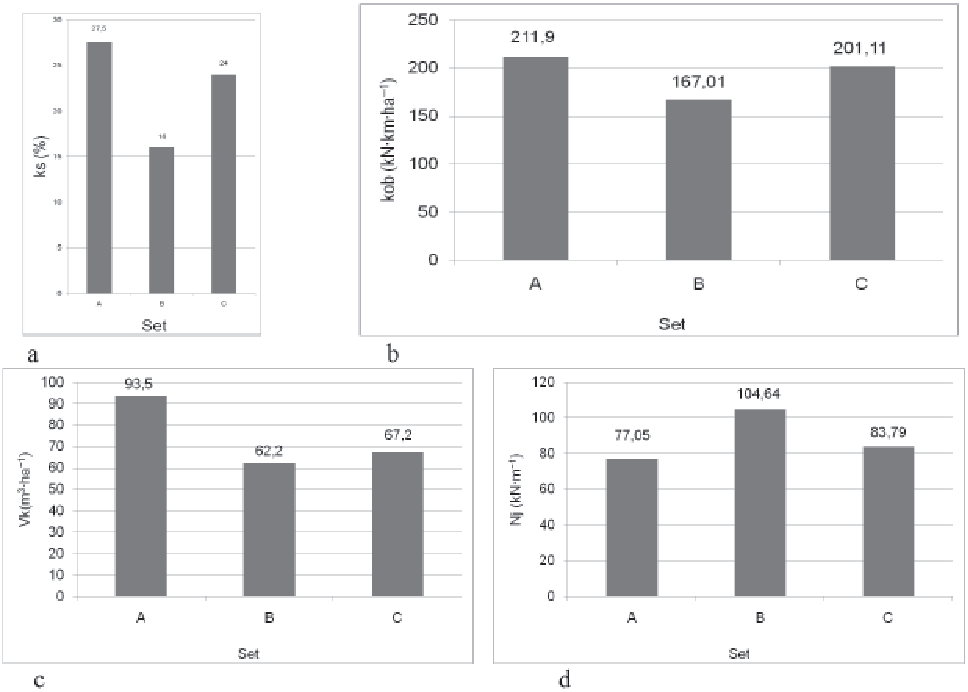

Figure 2. Numerical values of soil compaction degree indexes: (a) compacted field surface k_s, (b) field load k_{ob}, (c) rut cubic capacityV_k, (d) rut load N_j

Conclusions

1. Technology of fertilization with liquid manure should include besides agricultural requirements also ecological requirements related to soil compaction and pollution of natural environment. Numerous factors affect the degree of coil compaction, inter alia: technical parameters of a machine, exploitation parameters and weather conditions (soil moisture).
2. The smallest area of the compacted field (16%) was reported in the B set. It is related to the working width of a set which translates into the distance travelled on the area of 1 ha.
3. Along with increase of the cubic capacity of waste removal vehicles also cubic capacity of ruts made on the field surface decreased from 93 m^3 to 62 m^3.
4. Tests on the fertilization sets proved that the B set (with a vehicle 12 m^3) obtained most favourable indexes and the least favourable the A set (with a vehicle 6 m^3).

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UGNIATANIE GLEBY KOŁAMI AGREGATÓW DO NAWOŻENIA GNOJOWICĄ

Streszczenie. Celem badań było określenie wpływu ładowności zestawów nawozowych na ugniecenie gleby. Stopień ugniecenia gleby określono na podstawie czterech wskaźników. Do badań wytypowano trzy zestawy nawozowe: zestaw A – ciągnik Renault 95.14 plus wóz asenizacyjny o pojemności 6 m^3, zestaw B – ciągnik John Deere 6420 plus wóz asenizacyjny 12 m^3, i zestaw C – ciągnik Valtra N 121 plus wóz asenizacyjny 8 m^3. Określono cztery wskaźniki: ugniecenie powierzchni pola, obciążenie pola przejazdami zestawów, stopień ugniecenia w śladzie kół jezdnych i objętość kolein. Stwierdzono, że największa powierzchnia ugniecionego pola wystąpiła dla zestawu A (27%) a najmniejsza dla zestawu B (16%). Obciążenie pola przejazdami zestawów było największe również dla zestawu A (212 $kN \cdot km \cdot ha^{-1}$) a najmniejsze dla zestawu B (167 $kN \cdot km \cdot ha^{-1}$). Stopień ugniecenia w śladzie kół jezdnych był natomiast największy dla zestawu B (105 $kN \cdot m^{-1}$), a najmniejszy dla zestawu A (77 $kN \cdot m^{-1}$). Największą objętość kolein stwierdzono na polu nawożonym zestawem A (99 m^3) a najmniejszą dla zestawu B (61 m^3). Z parametrów technicznych maszyn nawozowych na stopień ugniecenia gleby wpływ mają: masa ciągnika oraz wozu asenizacyjnego a także jego pojemność i szerokość robocza, która zależy od zastosowanego zespołu aplikacyjnego. Za najlepiej dobrany zestaw nawozowy (ciągnik i wóz asenizacyjny), z punktu widzenia ugniatania gleby, należy uznać zestaw B, a za najmniej korzystny zestaw A.

Słowa kluczowe: gleba, ugniatanie gleby, zestaw nawozowy, ciągnik rolniczy

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IDENTIFICATION OF EXTRUSION PROCESS PARAMETERS BASED ON ITS RESPONSE TO THE STEP FUNCTION

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ABSTRACT

The paper presents results of the research on the single-screw extruder strength on sudden changes of dosing raw material during the extrusion process. The tests were carried out in a short single-screw extruder KZM-2 whose relation of length to diameter of a screw was 6:1 and rotational speed was 200 rpm. Grits moistened up to 15% moisture and five disturbing samples of mass 0.2-1.2 kg prepared from the same raw material constituted a research material. Particular samples were used for disturbing a stable course of the extrusion process. Disturbance of the process consisted in fast introduction of the whole disturbing dose to the extruder input and measurement of the value of intensity change of current consumed by the extruder engine, time of return to stable conditions and changes in the image of obtained samples of extruder. Measurements of the impact of disturbance on the measured amounts were carried out for three settings of extruder performance. It was found out that a single-screw extruder at all set performances reacted with fast increase of electric current consumption; moreover, time of process stabilization changed each time. Moreover, it was reported that particular disturbing doses affected significantly the changes of quality parameters of extrudates.

Introduction

Extrusion is a food production technology, which may be presently recognized as a standard method of production of many cereal products e.g. breakfast products, small breads, snacks, pasta or even highly processed meat analogues of plant protein (Wianecki, 1999; Pęksa, 2007; Mitrus, 2010; Wójtowicz, 2011). Possibility of creating the raw material composition, specific for this technology, enables such great diversity. Majority of extrudated products, known on the market, is thus mainly produced of mixtures of few raw materials, which additionally are enriched with such additives as: dyes, seasonings, fats, starches, which are directly applied into the extruder's chamber during the process (Mościcki et al., 2007). Appropriate setting of initial parameters of the process and proper control of an extruder enable formation of the wide array of various products during even one stabilized process (Mościcki, 2002). Undoubtedly, it is an advantage of the extrusion process, however, maintaining a stable course of the process, frequently proves then to be difficult and usually is related to the change of energy consumption of the process, considerable losses of raw material and may also even lead to blocking of an extruder (Ekielski et al., 2007; Wójtowicz and Mościcki, 2008). The reason for destabilization of the process may be a sudden change of a dose, moisture, degree of raw material crushing or the operator's fault, etc. Present systems which control the extruder's operation include a wide range of disturbances (Hamrol, 2005) which result from the character of work of a given type of an extruder through the use of modern systems and algorithms of control e.g. a diffuse control (Erikainen and Linko, 1987; Ekielski, 2006). However, one should emphasise that border conditions in which a specific device may work and the time of the process stabilization after its disturbance are described in literature rather scarcely. Thus, it seems purposeful to recognize the possibility of getting out the extruder from transient state.

The objective and the scope of research

The objective of this work was to identify resistance of the single-screw extruder on sudden changes of dosing raw material during the extrusion process.

The scope of work covered:

1. Carrying out the process of extrusion at variable provision of raw material.
2. Purposeful disruption of the stabilized extrusion process.
3. Assessment of the quality of extrudates obtained during the research.

Methodology of research

The research material consisted in grits purchased in Silesian Grain Sp. z o.o. of moisture 13.1%, starch content 70% and granulation 0.25-0.75 mm. Initial preparation of raw material for extrusion consisted in previous moistening of grits with water to moisture of 15% and mixing it in a continuous mixing machine. Then, a raw material was set aside for approx. 1 hour. Then, four samples of the following mass were weighed out: 0.2 kg, 0.5 kg, 0.8 kg and 1.2 kg. Samples prepared in such a manner as doses which disturb the process, were added directly to the extruder's dose during a stabilized extruder's operation. On account of a constant transport ability of the extruder's screw for the researched material, introduction of a disturbing dose may be treated as introduction of step disturbance of variable duration of operation depending on the present load of an extruder. Thus, function (1) may describe the duration of step disturbance:

$$t = f(Q_i, Q_e) \tag{1}$$

where:

Q_i – is a mass of a disturbing dose (kg),
Q_e – extruder's load (kg·hour^{-1}).

A single-screw extruder KZM-2 of motive power of an electric engine 22 kW in length L to diameter D ratio which is L/D – 6:1 and rotational speed of a screw 200 rpm. The applied extruder's matrix was equipped with two round exhaust nozzles of 6 mm diameter each.

Temperature of the extrusion process measured in the plastification section of an extruder was approx. 130ºC. During the research, an extruder worked in three sets of the speed of the raw material feeder, which corresponded to three various performances of an extruder.

At the setting of the feeder performance:

1. in the 1st position - performance of the process was 80 ($kg \cdot h^{-1}$),
2. in the 2nd position - performance of the process was 110 ($kg \cdot h^{-1}$),
3. in the 3rd position - performance of the process was 160 ($kg \cdot h^{-1}$).

During the process of extrusion, current intensity consumed by the engine of the extruder (A) was registered every second. LabView 7.1. software was applied for data acquisition. A current clamp Z202A by METRAWAT was used for measurement. It was connected to the set for data acquisition by National Instrument, composed of: measurement card - PCI-6024E, module NI SCXI-100 and NI SCXI-1302.

For determination of basic quality parameters of the obtained extrudated products, the following were used: index of radial and volumetric expansion, index of water absorption WAI and water solubility index WSI.

Density of an extrudate was calculated by division of the extrudate mass by its volume. A cylinder with a measure and rapeseeds were used for measurement. Previously weighed amount of extrudate was poured into a cylinder and then precisely mixed with prepared 250 cm^3 of rapeseed. From the read out result previously set value of rapeseed was deducted and volume of the tested extrudate was obtained, from which density in $g \cdot cm^{-3}$ was determined.

Index of volumetric and radial expansion (2,3) was determined with Alvarez-Martinez et al. (1988):

$$SEI = \frac{S_e}{S_d} \tag{2}$$

$$VEI = \frac{\rho_m}{\rho_e} \frac{(1 - MC_m)}{(1 - MC_e)} \tag{3}$$

where:

SEI – degree of radial expansion (-),
VEI – degree of volumetric expansion (-),
S – diameter (mm),
e – extrudate,
d – nozzle,
m – material,
ρ – density ($g \cdot cm^{-3}$),
MC – raw material moisture (%).

Values of water absorption **WAI** and solubility in water **WSI** indexes were determined according to Anderson/s method (1969) from the following relations (4,5):

$$WAI = \frac{\text{weight of sediment}}{\text{weight of dry solids}} \tag{4}$$

$$WSI\ (\%) = \frac{\text{weight of dissolved solids}}{\text{weight of dry solids}} \cdot 100\,\% \tag{5}$$

Statistical analysis

Statistica 10 software was used for statistical analysis. In order to plan an experiment Central Composition Plan (CPK) was generated 2**(2), of 2 input numbers, 2 blocks and 10 systems with iteration, which will later serve for obtaining the area of response. Particular levels of variables were coded to numerical values as values: -1,0,1.

For statistical analysis of the selected parameters additional Taguchi method was used, thus an orthogonal table L9 with the number of input sizes 4 and value 3 was generated (Taguchi, 1993; Statsoft; Kiełbas, 2006). Experience allowed determination of ETA average value calculated as a relation of S signal (English signal factors) to noise N (English: noise factors). ANOVA analysis of variance was used for analysis of variables significance.

For statistical asessment of the quality of adjustment of responses area equations, coefficient of determination R^2, $R^2_{popr.}$ and Mean Square Error were used.

Research results

Diagram 1 presents measurement results of the maximum strength of electric current charged by the engine of the extruder and the time, which the extruder needs to stabilize the course of the extrusion process subjected to disturbances. Diagram shows that both strength of current as well as time of stabilization of the extruder increase along with the increase of a disturbing dose at all set performances of the extruder. It was also found out that the consumption of electric current during extrusion increased along with the increase of efficiencies and reached the highest values of 42.92 A at the performance of 160 ($kg \cdot h^{-1}$) and a disturbing dose of 0.8 kg. In the same conditions a dose of 1.8 kg caused that a nozzle of the extruder got stuck and ceased the extrusion process. It was also reported that at the performance of the extruder 80 ($kg \cdot h^{-1}$) and 110 ($kg \cdot h^{-1}$) differences of the changes in the current charge were the highest, but at the performance of 160 ($kg \cdot h^{-1}$) differences in the current charge were lower, time of extruder stabilization got longer and it was even as much as 260s. In case of the remaining measurements of times necessary for stabilization of the extrusion process, it was determined that they were within 20s for the lowest disturbing dose at performance of 80 ($kg \cdot h^{-1}$) and 125 s at a disturbing dose of 0.5 kg and performance 160 ($kg \cdot h^{-1}$).

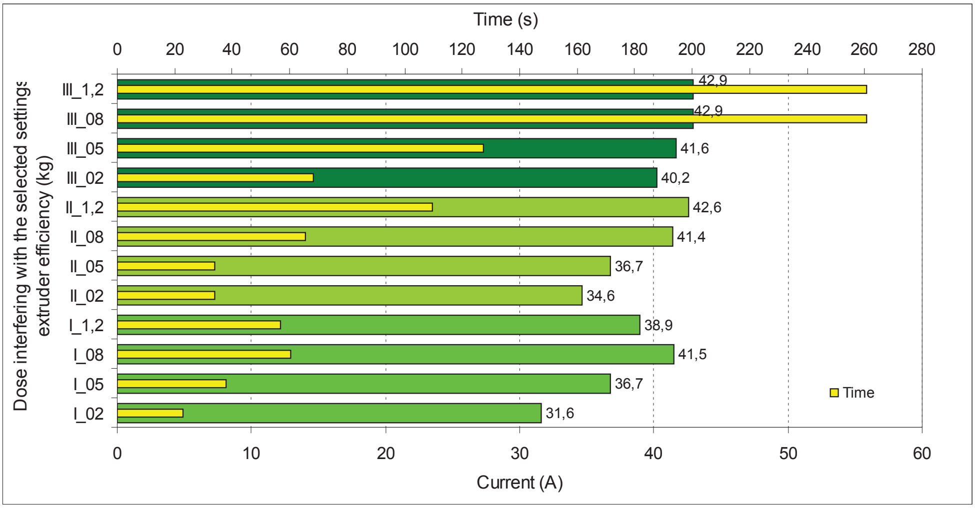

Figure 1. Impact of the amount of a disturbing dose and extruder performance on the changes of current intensity consumed by the extruder engine.

It was found out that the change of proportion of a disturbing dose caused also explicit changes of the index of extrudate expansion, which may be observed even visually. Each time after application of a disturbing dose the obtained extrudate was characterized explicitly by a higher volume.

In order to carefully analyse the assessment of the impact of changes in a disturbing dose on the quality of the obtained extrudates during destabilization of the process of extrusion statistical analysis was carried out by subjecting results of empirical research to ANOVA analysis of variance (table 1). Considering the index of volumetric expansion it was found out that all analysed factors were significant except for the parameter · of extruder performance (the effect of the second row). Similarly in case of the radial expansion index, majority of factors proved to be significant except for the impact of the disturbing dose (the effect of the first row). When analysing WSI index, it was found out that only effects of the second row for a disturbing dose had an insignificant impact. In case of WAI index, it was found out that only change in performance of the extruder was a significant factor.

In further analysis after elimination of insignificant variables from the obtained result coefficients of regression were calculated, from which regression equation was developed and response areas were determined (tab. 2). Omitting insignificant factors resulted in added to the error increasing thus its mean square MSE and contributed to the decrease of probability *p*.

Table 1
Analysis of variance

Parameter	SS	df	MS	F	p
Volumetric expansion (–)					
(1) Disturbing dose (kg)	75.1825	1	75.1825	70.2352*	0.0000
Disturbing dose ^{2} (kg)	25.3032	1	25.3032	23.6382*	0.0003
(2) Performance of extruder ($kg \cdot h^{-1}$)	75.3793	1	75.3793	70.4192*	0.0000
Performance of extruder ^{2} ($kg \cdot h^{-1}$)	0.1090	1	0.1090	0.1018	0.7544
1 wz. 2	9.8410	1	9.841	9.1934*	0.009
Error	14.9861	14	1.0704		
Radial expansion (–)					
(1) Disturbing dose (kg)	0.1324	1	0.1324	1.0424	0.3246
Disturbing dose ^{2} (kg)	1.7081	1	1.7081	13.4481*	0.0025
(2) Performance of extruder ($kg \cdot h^{-1}$)	1.9644	1	1.9644	15.4664*	0.0015
Performance of extruder ^{2} ($kg \cdot h^{-1}$)	6.7511	1	6.7515	53.1534*	0.0000
1 wz. 2	0.7328	1	0.7328	5.7696*	0.0308
Error	1.7782	14	0.1270		
WSI (%)					
(1) Disturbing dose (kg)	259.0240	1	259.0240	40.6377*	0.0000
Disturbing dose ^{2} (kg)	16.6230	1	16.6230	2.6079	0.1286
(2) Performance of extruder ($kg \cdot h^{-1}$)	1256.507	1	1256.507 0	197.1302 *	0.0000
Performance of extruder ^{2} ($kg \cdot h^{-1}$)	95.2250	1	95.2250	14.9396*	0.0017
1 wz. 2	31.7030	1	31.7030	4.9739*	0.0426
Error	89.2360	14	6.3740		
WAI (–)					
(1) Disturbing dose (kg)	0.2133	1	0.2133	3.0039	0.1050
Disturbing dose ^{2} (kg)	0.0001	1	0.0001	0.0008	0.9780
(2) Performance of extruder ($kg \cdot h^{-1}$)	3.6633	1	3.6633	51.5806*	0.0000
Performance of extruder ^{2} ($kg \cdot h^{-1}$)	0.0516	1	0.0516	0.7267	0.4083
1 wz. 2	0.0875	1	0.0875	1.2327	0.2855
Error	0.9943	14	0.0710		

* Significant difference at the level of significance $p \leq 0.05$

Table 2
Regression equations of the area of response and values of the coefficient of determination and the mean square error MSE

$R^2 = 0.921$	$R^2_{popr} = 0.901$	MSE = 1.0063
$EO = -262 + 28.47 \cdot x - 10.24 \cdot x^2 + 0.102 \cdot y - 0.091 \cdot x \cdot y$		
$R^2 = 0.8578$	$R^2_{popr} = 0.8199$	MSE = 0.1274
$ER = 11.297 + 20.918 \cdot x - 0.115 \cdot x^2 + 0.0005 \cdot y - 0.007 \cdot x \cdot y$		
$R^2 = 0.9229$	$R^2_{popr} = 0.9085$	MSE = 8.3950
$WSI = 27.576 + 12.584 \cdot x - 0.337 \cdot y + 0.003 \cdot y^2$		
$R^2 = 0.7314$	$R^2_{popr} = 0.7165$	MSE = 8.3950
$WAI = 5.928 - 0.013 \cdot y$		

Diagram (fig. 2) presents changes of the volumetric expansion index as the function of performance and a disturbing dose of the extruder. Diagram shows that the values presenting the volumetric expansion index increased along with introduction of the increased disturbing dose at all performances of the extruder. At performance of 80 ($kg \cdot h^{-1}$), values of this index reached the lowest values but at setting the performance of 160 ($kg \cdot h^{-1}$) the highest. One may notice a slow inclination of the surface downwards on the diagram, which suggests that a dose of raw material 1,2 in the conditions of the highest performance of the extruder may cause sudden decrease of the degree of expansion resulting for example from the local increase of temperature and blocking of the nozzle of the extruder. In case of the index of radial expansion (fig. 3) it was determined that the change of the extruders performance clearly affected changes of the extruder's performance. Despite determined small increase of the parameter along with the change of a disturbing dose, differences between particular samples were slight.

When analysing the course of diagram (fig. 4) one should pay attention that values of solubility index for extrudate in water, change both along with changes of disturbing doses as well as with changes of setting a feeder of the extruder . Linear course of diagram and high value of coefficient of determination R^2=0.94 may suggest very clear changes of this index and good adjustment of empirical data to calculated area of response. The highest values of WSI index achieved at setting the performance at the level of 160 ($kg \cdot h^{-1}$) and simultaneously very low values of WAI index (fig. 5) particularly in case of destabilising doses of raw material 0.8 kg and 1.2 kg indicated highly progressed starch degradation in extrudates produced in these conditions. In case of extrudates it may not be a desirable feature and such products the most probably may have unsatisfactory sensory values e.g. perceptible taste of burning as a result of local change of temperature of raw material. High values of WSI may also affect reduction of density and the volumetric expansion index (Ekielski et al., 2007).

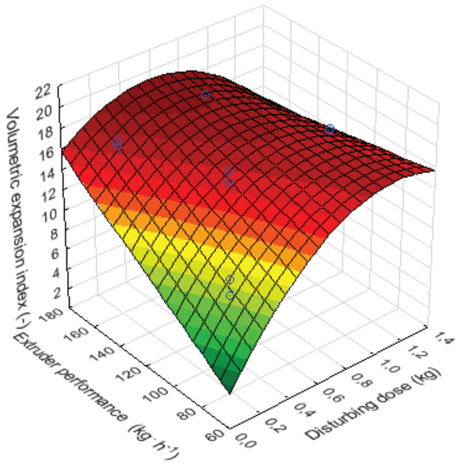

Figure 2. Impact of a disturbing dose and the extruder performance and on the volumetric expansion index

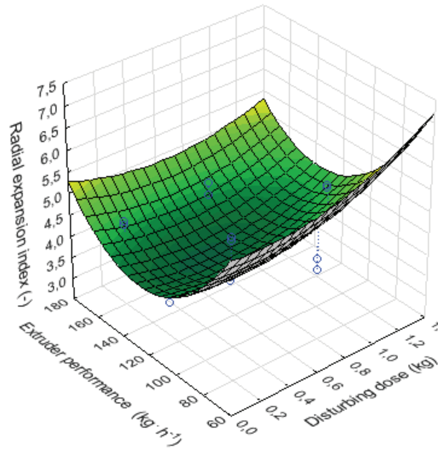

Figure 3. Impact of a disturbing dose and the extruder performance and on the radial expansion index

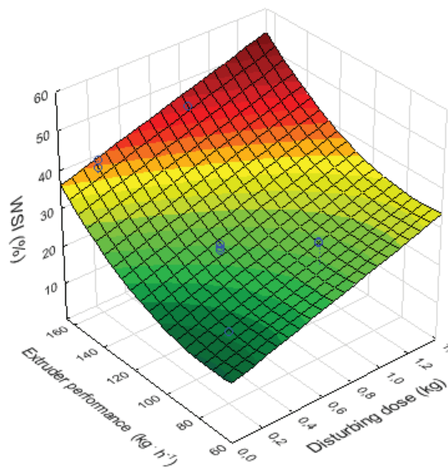

Figure 4. Impact of the disturbing dose and extruder performance on WSI index

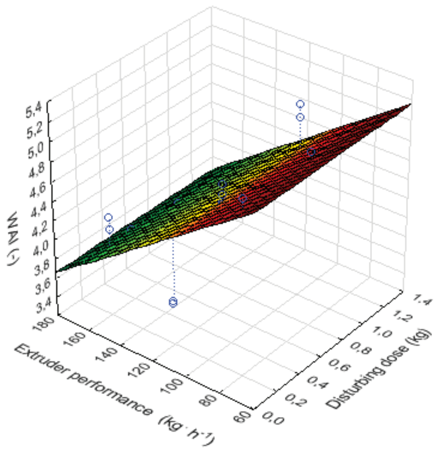

Figure 5. Impact of the disturbing dose and extruder performance on WAI index

Volumetric expansion index and WSI, significance of which was confirmed in the analysis of variance ANOVA was additionally analysed with the use of experience with Taguchi method.

As additional variables in Taguchi orthogonal table, the maximum values of temperature changes and raw material moisture were applied, which slightly changed as a result of applied doses, that disturb the process of extrusion or minimum regulation of water additive in order to maintain continuity of the extrusion process.

The objective of this analysis was to minimize the product variability as a response to *disturbing* factors that is *noise* (N) at simultaneous maximization of variability in response to factors of *signal* (S). The result of the analysis was obtaining average value of coefficient S/N Eta towards input sizes followed from the analysis which was carried out. In the experiment, which analyses the impact of disturbing doses on the value of volumetric expansion index and water solubility index WSI a type of the research problem in the Taguchi method know as: "nominal – the best" where values of dependent variables (y) are higher or equal to), were used. Ideal values > 0. Below a formula (6) for calculation of the constant value of signal was presented (nominal values), where variability around this value may be treated as a result of noise operation:

$$ETA = 10 \cdot \log 10\left(\frac{m^2}{s^2}\right) \tag{6}$$

where:

m – mean,

s^2 – variance.

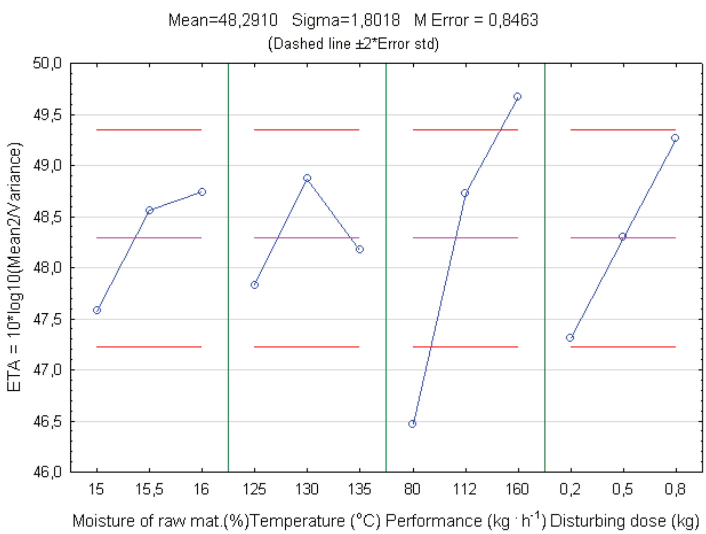

Figure 6. Diagram of average values of ETA (coefficient S/N) of the volumetric expansion index towards values of the analysed factors

On diagram (fig. 6) where mean values of ETA (index S/N) towards the value of analysed factors for volumetric expansion index, settings of each input value may be recognized, which means settings maximizing the value of coefficient S/N to which changes of extruder performance are included and a disturbing dose, were presented. The remaining variables of raw material moisture and temperature were fluctuating around the mean value of ETA and did not significantly influence the course of experiment.

Diagram (fig. 3) which presents mean ETA values of WSI index one may observe that the border of double standard deviation was exceeded by temperature within (130-135ºC) and performance (160 kg·h^{-1}).

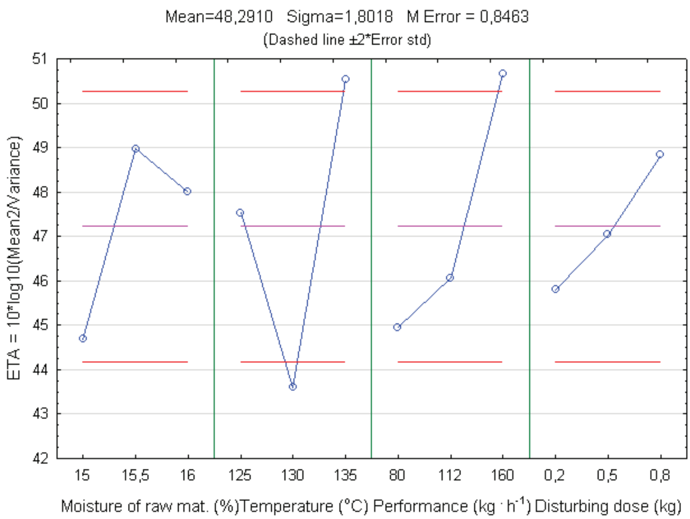

Figure 7. Diagram of mean values of ETA (coefficient S/N) towards values of the analysed factors

Observed explicit impact of the process temperature operation, which, despite the fact that it was determined in a constant scope, could follow from a short-term local increase as a result of sudden changes in the raw material dose. In short time on account of high temperature inertia of the extruder, such changes could not be recorded by the measurement system. In case of the remaining parameters i.e. a disturbing dose and moisture of raw material were around average value of ETA and their variability was low.

Conclusions

1. Measurements of the strength of electric current during disturbance of the extruder's operation proved that the consumption of energy clearly increased as a result of disturbance of the extruder's operation. It was found out that differences between the values were the highest in case of the set lowest performance of the extruder and the lowest in

case of the highest performance. Such behaviour may be a positive feature of single-screw extruders because the excess of raw material in conditions of the highest load of the extruder is withdrawn from the section of plastification in the back flow not causing each time the extruder's lock.
2. Disturbance of operation of the analysed extruder resulted in the explicit change of the quality of extrudated products. However, it should be emphasised that the quality of products was satisfactory in case of the dose 0.2; 0.5 and 0.8 kg and explicit deterioration of the quality was noticeable at the disturbing dose the highest of which was equal to 1.2 kg irrespective of the set performance of the extruder.
3. High values of WSI index achieved at the highest performance of the extruder may follow from the high sensitivity of the extrusion process to the changes in the temperature of the process even within the scope up to 5ºC.

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IDENTYFIKACJA PARAMETRÓW PROCESU EKSTRUZJI NA PODSTAWIE JEGO ODPOWIEDZI NA WYMUSZENIE SKOKOWE

Streszczenie. W pracy przedstawiono wyniki badań odporności ekstrudera jednoślimakowego na nagłe zmiany dawki podawania surowca w trakcie procesu ekstruzji. Badania przeprowadzono w krótkim ekstruderze jednoślimakowym KZM-2 o stosunku długości do średnicy ślimaka 6:1 i prędkości obrotowej 200 obr·min^{-1} (rpm). Materiałem badawczym była kaszka kukurydziana nawilżana do wilgotności 15% oraz pięć próbek zakłócających o masie 0,2-1,2 kg przygotowanych z tego samego surowca. Poszczególne próbki posłużyły do zakłócenia ustabilizowanego przebiegu procesu ekstruzji. Zakłócenie procesu polegało na szybkim wprowadzeniu do wejścia ekstrudera całej dawki zakłócającej i pomiarach wartości zmiany natężenia prądu pobieranego przez silnik ekstrudera, czasu powrotu do warunków stabilnych oraz zmian w obrazie otrzymanych próbek ekstrudatu. Pomiary wpływu zakłócenia na mierzone wielkości przeprowadzano dla trzech ustawień wydajności ekstrudera. Stwierdzono, że ekstruder jednoślimakowy przy wszystkich ustawionych wydajności reagował szybkim zwiększeniem poboru prądu elektrycznego, każdorazowo zmieniał się także czas ustabilizowania procesu. Zaobserwowano również, że poszczególne dawki zakłócające wpływały istotnie na zmiany parametrów jakościowych ekstrudatów.

Słowa kluczowe: ekstruzja, ekstruder, ekspansja, Taguchi, zakłócenia