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ANALYSIS OF THE LYING AREA IN A BARN WITH THE USE OF A VIDEO RECORDING TECHNOLOGY

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ABSTRACT

The paper aimed at investigating influence of the period when cows were kept in a sand filled lying area onto the lying time and the animals's other behaviours if the bedding material was not supplemented in the lying stalls during the investigation period. Registration of the cows' behaviour in the investigated area was conducted continuously over 10 days, using the video recording technology. The investigation included two technological groups of dairy cows kept in a barn with a freestall maintenance system. A trend for reduced lying time of the cows over the investigated period was observed. The paper proposes an approach to analysis of the investigation results, which involved distinguishing blocked investigation days. Blocking the days within the continuous measurement of the cows' lying time allowed description of the dependent variable (cows' lying time over the investigated period) with a linear model characterised with a considerably higher value of the coefficient of determination in comparison to the option considering single days.

Introduction

Continuous improvement in cattle maintenance conditions is a common characteristic of contemporary dairy cattle production. Maintenance conditions determine the cattle's comfort in particular barn areas and in the cattle-run, which translates into the achieved production efficiency.

The importance associated with improvement of dairy cattle maintenance conditions, particularly in the lying area, is confirmed in numerous investigations which put significant emphasis on recognition of the influence of the selected structural characteristics of the lying stalls on the animals' behaviour and preferences.

Among the structural characteristics of lying stalls, analysed within the investigations, the quality and condition of bedding material is of key importance. The main reason underlying the undertaken investigations is the search for bedding materials ensuring the highest possible level of comfort to animals, decisive for the lying time length (Haley et al., 2000).

The detailed evaluation comprises various types of bedding materials, from concrete, matts and mattresses (Haley et al., 2001) to consumable materials such as hay, sawdust and sand (Tucker et al., 2003). An important criterion considered in the investigations is the condition of the bedding material, including humidity (Fregonesi et al., 2007b) and quantity of the bedding material (Drissler et al., 2005) in the area designated for the cows' rest.

Next to bedding materials, the investigations cover elements of the lying stall construction (in particular, in the freestall dairy cattle maintenance system), including above-neck railings (Tucker et al., 2005), stall divisions (Ruud and Bøe, 2011), as well as front limiting thresholds (Tucker et al., 2006), analysed in the context of dairy cattle comfort improvement.

A common denominator of numerous investigations concerning technical equipment of the dairy cattle lying area is assumption concerning the animals' preferences and behaviour as the evaluation criterion. Measurements of the time spent by animals in the lying position, number of entries into lying stalls, frequency of cows lying down and standing up as well as other forms of behaviour in the lying area characterised with certain structural and functional features give ground for drawing conclusions concerning the animals' reaction to particular tested technical solutions in the lying area.

Cows' preferences in the lying area and the analysis thereof provide a set of important information contributed to the know-how related to dairy cattle in connection with environmental factors (Nawrocki, 2009). The results of investigations covering cows' preferences in combination with specific technical and technological solutions in the barn can, therefore, be practically utilised for improving the animals' comfort and maintenance in livestock buildings.

Collecting detailed information connected with cows' behaviours and preferences in the lying area as well as in other barn areas encourages the use of properly selected investigation methods and apparatus. Both the methods and the apparatus used for monitoring of animals undergo continuous enhancement and evaluation (O'Driscoll et al., 2008; Ledgerwood et al., 2010), thus letting resolve scientific and research problems connected with the analysis of dairy cattle production in livestock buildings.

Investigation objective, scope and methodology

Keeping a herd of dairy cows in a barn with a freestall maintenance system may involve change in the condition of lying stall bedding material. While leaving the lying stalls, cows remove bedding material with their hoofs into a manure alley. Moreover, excrements remaining on the lying area surface frequently need to be removed by the staff, which involves removal of some of the bedding material into the manure alley. In consequence, as days pass by, the quantity of bedding material decreases which – if the material is added at longer intervals – may cause deteriorated rest conditions for animals in the lying area (Gaworski et al., 2003).

In the context of the problem related to the use of bedding materials in a barn, as mentioned above, the objective of the investigation was to determine influence of the time spent by cows in the sand-filled lying area on animals' lying time and other forms of behaviour when the bedding material was not supplemented in the lying stalls during the investigation period. Formulated as above, the investigation objective was related to raising a thesis that the level of sand covering the lying stalls reduces as days pass by and, therefore, animals' rest conditions in the lying area deteriorate. This was the underlying objective of the investigation, i.e. identification whether or not – over the days passing by and with a lowered level of sand – the cows' lying time during the day decreased, which may have unfavourable influence on their production indices.

The scope of investigation covered two selected pens in a freestall maintenance system barn, containing 12 lying stalls covered with sand as the bedding material. Each of the pens contained three rows of lying stalls (fig. 1). A single pen was occupied by the process group of 12 dairy cows.

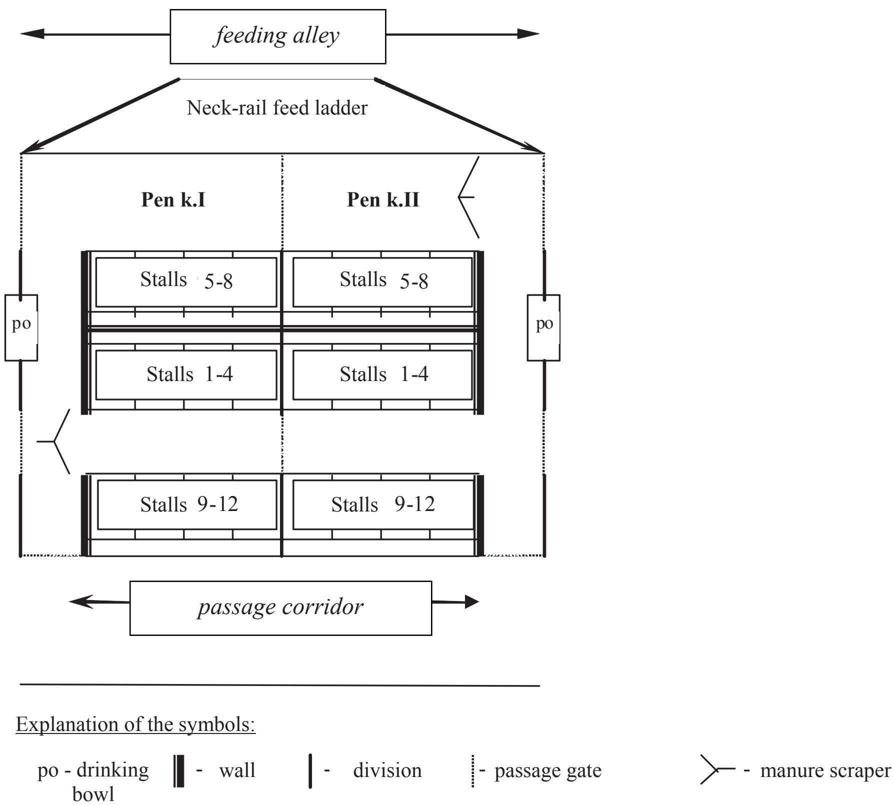

Figure 1. Schematic representation of rows with numbered lying stalls for dairy cows

In the first stage, the investigation methodology involved identification of cows included in the project. This was done using paint for writing subsequent letters of the alphabet on the cows' sides, which facilitated identification of particular animals during the recording thereof and, subsequently, playback of the video material. A set consisting of cameras (one for each pen), Panasonic AG-6540 single-picture video, Panasonic WJ-FS 216 multiplexer and a monitor used in the project for ongoing viewing of recorded cows as well as playback of the video material to be used in detailed analyses. Recording of the cows' behaviour in the lying area was being conducted continuously for 10 days.

Before commencement of recording, bedding material in the lying stalls was prepared so that the level of the sand was equal with the level of the rear curb separating the stall from the manure alley, which corresponded to the industrial practice related to filling the pan constituting the lying stall bottom with sand.

The following dairy cows' behaviours were considered during detailed observations of the recorded video material:

– lying in the lying stalls,
– standing with front legs on the bedding material and with rear legs in the manure alley,
– standing with four legs on the bedding material.

Throughout the investigation period, the same technological groups of dairy cows were kept in particular pens. The cows were not removed from the pens for veterinary or other procedures, but they only left their place twice a day for the time needed for miliking in the milking hall.

During playback, the recorded video material was divided into 10-minute sections used for reading the analysed cows' behaviours, including lying as well as standing with two and four legs on the bedding material of particular lying stalls. Cows' behaviours identified based on the recorded video material were recorded in an Excel form. Identification of cows which were lying, standing with two or four legs during subsequent periods of time was entered into particular fields of the form identifying the lying stalls. If a lying stall was not occupied by a cow during the given period, the field was left blank.

The investigation was conducted in a barn with a freestall dairy cow maintenance system, in a farm located on the western coast of Canada.

Investigation results and discussion

From among observation results collected in Excel spreadsheet, data concerning the cows' lying time were selected for detailed analysis of the cows' behaviours and preferences. For each day of analysis, the time during which particular stalls in a given pen were occupied by cows in the lying position was summed up. Results concerning the total time of lying in the stalls, concerning particular days (from day 1 to day 10) are presented in tables 1 and 2 for pens k.I and k.II, respectively. This form of results presentation is referred to in tables 1 and 2 as "Analysis option 1". Moreover, an extension in "Analysis option 2" and "Analysis option 3" is proposed based on the collected research results, as presented in tables 1 and 2.

Table 1
Lying time of 12 dairy cows in the investigated pen k.I including combined periods

Analysis option 1		Analysis option 2		Analysis option 3	
Day	Lying time (min·24h^{-1})	Combined periods (A)	Lying time (min·48h^{-1})	Combined periods (B)	Lying time (min·24h^{-1})
1	8,620	1. (days 1-2)	18,250	I (days 1-5)	8,984
2	9,630				
3	8,710	2. (days 3-4)	17,850		
4	9,140				
5	8,820	3. (days 5-6)	18,050		
6	9,230			II (days 6-10)	8,744
7	8,810	4. (days 7-8)	17,120		
8	8,310				
9	8,590	5. (days 9-10)	17,370		
10	8,780				

Table 2
Lying time of 12 dairy cows in the investigated pen k.II including combined periods

Analysis option 1		Analysis option 2		Analysis option 3	
Day	Lying time (min·24h^{-1})	Combined periods (A)	Lying time (min·48h^{-1})	Combined periods (B)	Lying time (min·24h^{-1})
1	9,270	1. (days 1-2)	18,700	I (days 1-5)	9,052
2	9,430				
3	9,480	2. (days 3-4)	18,440		
4	8,960				
5	8,120	3. (days 5-6)	17,270		
6	9,150			II (days 6-10)	8,906
7	9,280	4. (periods 7-8)	17,680		
8	8,400				
9	9,080	5. (days 9-10)	17,700		
10	8,620				

Within "Analysis option 2", the investigation time was divided into five time intervals, each including two days. The lying time covered by combined investigation periods (A) was determined based on the sum of the following periods during the investigation: 1-2, 3-4, 5-6, 7-8 and 9-10.

The distinctive characteristic of "Analysis option 3" was the division of the investigation period into two parts, considering – respectively – the first five and the last five days, during which observation of the animals was conducted in the lying areas of pens k.I and k.II. In the case of distinguished five-day periods, referred to as combined periods (B), the average lying time was determined for one day, both in pen k.I (tab. 1) and in pen k.II (tab. 2).

Based on the figures for the two investigated pens, analysis of variance for the cumulative lying time of 12 dairy cows in relation to s pen was conducted using Statistica v.10 software. Analysis reults are presented in table 3.

Moreover, analysis of variance for the cumulative lying time of 12 dairy cows in relation to pen, including data for combined periods (A) for the two investigated pens was conducted. Analysis results are presented in table 4.

Table 3

Analysis of variance for cumulative lying time of 12 dairy cows in relation to pen

	Sum of quadrants	Degrees of liberty	Average quadrants	Fisher-Snedecor F statistics	Critical significance level p
Absolute term	1.591863E+09	1	1.591863E+09	9109.29	0.0000
Pen	6.612500E+04	1	6.612500E+04	0.38	0.5462
Error	3.145530E+06	18	1.747517E+05		

Table 4

Analysis of variance for cumulative lying time of 12 dairy cows in relation to pen, including data for combined periods

	Sum of quadrants	Degrees of freedom	Average quadrants	Fisher-Snedecor F statistics	Critical significance level p
Absolute term	3.183726E+09	1	3.183726E+09	11127.24	0.0000
Pen	1.322500E+05	1	1.322500E+05	0.46	0.5158
Error	2.288960E+06	8	2.861200E+05		

One of the factors inspiring the proposition of "Analysis option 2" and "Analysis option 3" was the course of changes in the total lying time of cows in the investigated pens over the 10 subsequent days (fig. 2). A comparison of data from particular days and pens allows determination of a random character of the investigated value (lying time), analysed over particular days. Therefore, to expand the analysis, figure 3 presents changes in the total lying time of cows in pens k.I and k.II over 5 combined investigation periods.

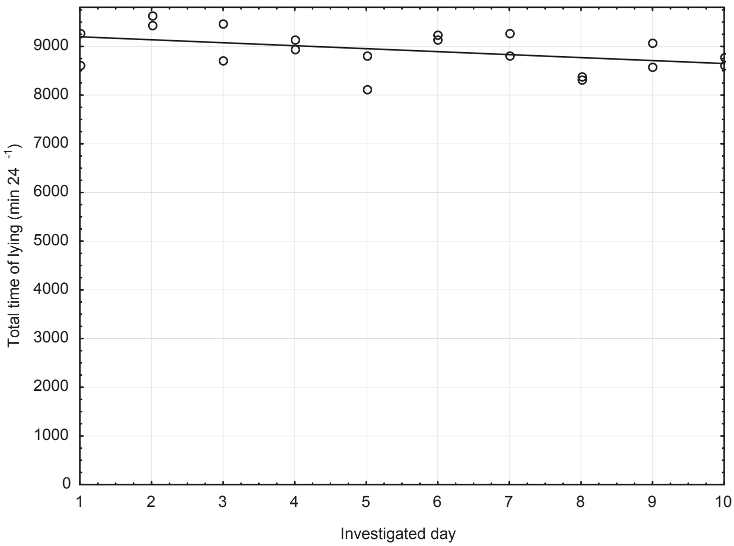

Figure 2. Changes of total lying time of dairy cows in k.I and k.II pens for 10 following days

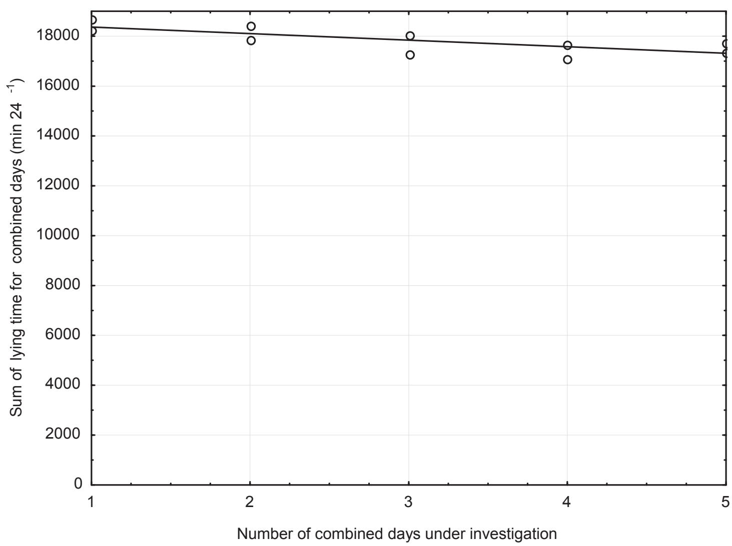

Figure 3. Changes of total lying time of dairy cows in k.I and k.II pens for 5 combined periods

Analysis of regression of the dependent variable, i.e. total lying time of dairy cows depending on a day was performed for data from investigated pens k.I and k.II. Summary of the analysis is presented in table 5.

Table 5
Analysis of regression of dependent variable, i.e. total lying time of dairy cows depending on day

Source of variability	Regression coefficient	Standard error of regression coefficient	t-Student test	Critical significance level p
Absolute term	9,257.0	183.5	50.45	0.0000
Day	-61.0	29.6	-2.06	0.0539

Analysis of regression of the dependent variable, i.e. total lying time of dairy cows depending on combined periods was also conducted considering data for pens k.I and k.II. Summary of the analysis is presented in table 6.

Table 6
Analysis of regression of dependent variable, i.e. total lying time of dairy cows depending on combined periods

Source of variability	Regression coefficient	Standard error of regression coefficient	t-Student test	Critical significance level p
Absolute term	18,630.5	267.8	69.57	0.0000
Combined periods	-262.5	80.7	-3.25	0.0117

A relation between combined investigation days may be presented using a linear function with the critical significance level of p = 0.0117 (tab. 6). Combining of the days during the continuous time of measurement of the cows' lying time allowed determination of the dependent variable (cows' lying time during the investigated period) with a linear model characterised with a significantly higher value of the determination coefficient (R^2=0.569) as compared with the option considering individual days (R^2=0.191).

The trend related to decreasing lying time of cows in the pen during the investigation period was confirmed by "Analysis option 3" (tables 1 and 2), considering two time periods, i.e. days 1-5 and days 6-10. The comparison of the average daily lying time in pen k.I allows statement that the lying time during the second period (days 6-10) was shorter as compared with the corresponding time determined during the first period (days 1-5) by 240 min·day^{-1}, i.e. app. 2.67%. On the other hand, in the case of pen k.II, the lying time during the second period (days 6-10) was shorter as compared to the corresponding time determined during the first period (days 1-5) by 146 min·day^{-1}, i.e. app. 1.61%.

In reference to the assumption made in the paper, one may state that results of the conducted investigations suggested the possibile problem of reduced cows' lying time over subsequent days spent by the animals in the pen with the freestall lying area. Reduction of the lying time over the investigated period of 10 days may result from the lowering level of sand in the lying stalls, as indicated by the investigations conducted by Drissler et al. (2005). The lowering sand level in the pan constituting the lying stall causes that the inner surface of the rear stall curb is uncovered. As the inner surface of the rear stall threshold is sloped, along with the lowering level of sand, the active length of the stall where a cow may lie is reduced. This involves numerous kinds of discomfort experienced by animals, i.e. both as the reduced comfort of lying and a growing risk of abrasion of hair on the rear legs of an animal as a result of contact with the side surface of the curb (Mowbray et al., 2003).

A condition of the bedding material in the stall, including that resulting from the quantity of sand, is one of but not the only determinant of the cows' lying time. The results of detailed investigations cited in the literature indicate the possibility of seasonal differences within the lying time (Uzal Seyfi, 2013), as well as the influence of such factors as location of lying stalls within the pen (Gaworski et al., 2003; Wagner-Storch et al., 2003), number of animals in the group (Fregonesi et al., 2007a), environmental and other conditions on the lying time. The multitude of factors determines the complexity of undertaken investigations and the need for further development of knowledge related to factors influencing behaviour of cows in the barn lying area, including selection of investigation methods including the use of video recording.

Conclusions

The conducted investigation demonstrated a trend for reduction in the cows' lying time over the investigated period of 10 days during which sand was not added to the lying stalls. Possible extension of the investigation period to more than ten days might justify a claim on the impact of keeping cows in the pen without supplementing the bedding material (sand) onto the lying time.

The proposed method of investigation of the results of the analysis, which involved distinguishing of the blocked investigation days, allowed logical shaping of the interrelation between the lying time and subsequent periods of time and its presentation with the use of linear regression.

Investigations related to changes in cows' lying time constitute a premise for undertaking reasonable decisions on supplementing the bedding material, including sand, which needs to be extended in further detailed analyses.

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WYKORZYSTANIE TECHNIKI FILMOWEJ W BADANIACH STREFY LEGOWISKOWEJ W OBORZE

Streszczenie. Celem pracy były badania wpływu okresu przebywania krów w strefie legowiskowej z piaskiem na czas leżenia i inne formy zachowań zwierząt w sytuacji, gdy materiał podłoża nie był w boksach legowiskowych uzupełniany w okresie badań. Rejestrację zachowania krów w badanej strefie prowadzono w sposób ciągły w okresie 10 dni z wykorzystaniem techniki filmowej. Zakresem badań objęto dwie grupy technologiczne krów mlecznych w oborze z wolnostanowiskowym systemem utrzymania. Wskazano na tendencję zmniejszania czasu leżenia krów w badanym okresie. Zaproponowano metodę podejścia do analizy wyników badań, uwzględniającą wyodrębnienie zblokowanych dób badań. Zblokowanie dób w pomiarze ciągłym czasu leżenia krów przełożyło się na możliwość opisania zmiennej zależnej (czasu leżenia krów w rozpatrywanym okresie) modelem liniowym wyróżniającym się znacznie wyższą wartością współczynnika determinacji w porównaniu z opcją uwzględniającą pojedyncze doby.

Słowa kluczowe: krowa, boks legowiskowy, czas leżenia, rejestracja filmowa

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CRITICAL REVERSE FLUIDIZATION VELOCITY OF THE SELECTED VEGETABLES

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ABSTRACT

The objective of this paper was to study a possibility to use existing models for determination of the minimum fluidization velocity during freezing fruits and vegetables by reverse fluidization. French fries, Brussels sprouts, broccoli florets, carrot in the form of a cube with sides of 1 cm and slices with dimensions of 3x3x0.5 cm were used to form frozen material. Values of the minimum fluidization velocity were measured by means of an anemometer. The results of calculation from four calculation models of the minimum fluidization velocity were compared to the values obtained experimentally. The calculated values were affected by average errors from 24% in case of a carrot cube to 224% in case of broccoli florets. There was no statistical difference between the results obtained between the tested models.

The list of symbols:

A – surface area, (m^2)
d – diameter of a particle, characteristic dimension of a product, (m)
F – fluid pressure force, (N)
g – gravitational acceleration, ($m \cdot s^{-2}$)
G – gravity, (N)
L – length, (m)
m – mass, (kg, g)
P, ΔP – pressure, difference in pressure, (Pa)
S, S_1, S_2 – distance between nozzles, (mm)
V – volume, (m^3)

w – velocity, ($m\cdot s^{-1}$)
ε – porosity of a bed
μ – dynamic viscosity of air, (Pa·s)
ν – kinematic viscosity of air, ($m^2\cdot s^{-1}$)
ρ – density, ($kg\cdot m^{-3}$).

Indexes:

f – fluid
mf – minimum fluidization
p – initial
rz – actual
s – solid body
z – substituting

Similarity numbers:

Ar – Archimedes number, $Ar = \dfrac{g \cdot d^3 \cdot \rho_f (\rho_s - \rho_f)}{\mu_f^2}$

Re – Reynolds number, $Re = \dfrac{w \cdot d}{\nu}$

Introduction

Fluidization is one of the most important unit operations used currently in agricultural engineering. Advantages of this process caused that it is widely used in such sectors of industry as: power industry, dehydration industry and from the beginning of the 60's also in refrigeration.

Generally, the fluidization phenomenon requires fluid pressure on the surface of a bed to be equal to the resultant of gravity and buoyant forces (Kawamura and Suezawa, 1961). Gravity of a bed equals to:

$$G = (\rho_s - \rho_f) \cdot g \cdot V \cdot (1 - \varepsilon) \tag{1}$$

The fluid pressure force may be calculated from the modified Darcy-Wesibach equation (Niven, 2002):

$$F_w = f \cdot \frac{V}{d_z} \cdot \frac{1 - \varepsilon}{\varepsilon^3} \cdot w_{mf}^2 \cdot \rho_f \tag{2}$$

In this equation *f* stands for a flow resistance coefficient. This coefficient, independently from the fluid flow type, was determined by Ergun (1952) as:

$$f = \frac{150 \cdot (\rho_s - \rho_f) \cdot \mu}{d_z \cdot \rho_f \cdot w} + 1{,}75 \qquad (3)$$

If the fluid pressure force is lower than the gravity of a bed then the fluid flows through channels between immovable particles. The fluid pressure decrease is proportional to its velocity (fragment 0-A) (fig.1). When the fluid pressure on the bed surface is equal to the static pressure (point A), an immovable bed turns into a fluidized state. The fluid velocity in this point marked with w_{mf} is called the minimum fluidization velocity. During further increase of velocity the fluid pressure on the bed surface is higher than its static pressure. The layer expansion and the increase of the bed porosity takes place (fragment B-C). Decrease of pressure is constant within the entire fluidization. It is related to balancing the increase in the bed porosity with its increased turbulence (Yang, 1998; Gruda and Postolski, 1999; Kmieć et al., 2007).

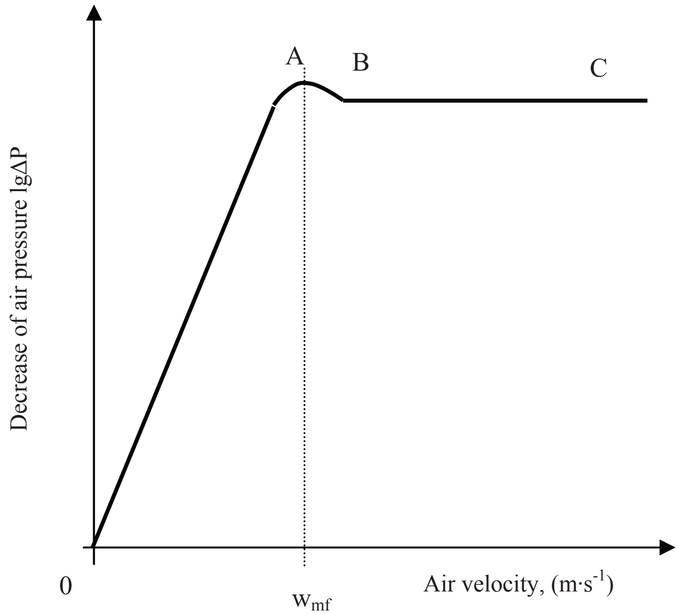

Figure 1. Dependence of pressure drop on velocity of gas stream flowing through the bed

A necessary condition of the product bed fluidization is that the bed velocity is equal to or higher than the velocity of the minimum fluidization. This velocity depends on, inter alia, a particle diameter and porosity of a bed (Gruda and Postolski, 1999).

A reversed fluidization is a specific variety of fluidization. In this method, an impingement phenomenon is used for causing fluidized boiling of the product bed. In this method, with the moment of achieving the minimum velocity of fluidization, the air buoyant force is higher than the product gravity and the product is floated towards the fountain top. Then, as a result of mutual influence of the neighbouring particles of a product, single particles are placed on the edge of the fountain top and get to the zone of lower air pressure or under the stream of air flowing out of a nozzle. It causes their dropping to the bottom of a working chamber of a device and a new process cycle begins (fig. 2).

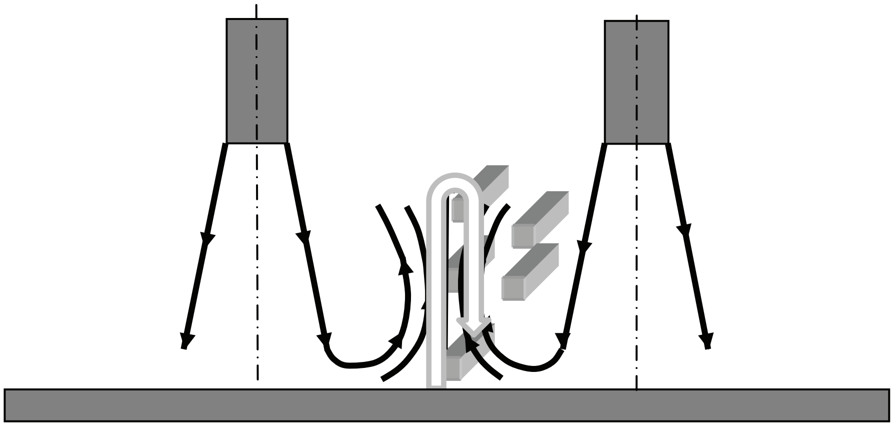

Figure 2. Motion of bed particle under reverse fluidization

There are many formulas for determination of the minimum velocity of fluidization. However, they are developed for other sectors of industry than the food industry and they do not include such properties of agricultural and food products as e.g. irregularity of the shape or adhesion forces. In practice, majority of solutions to this problem origins in Ergun's equation (3) (Ergun, 1952):

$$\frac{\Delta P}{L} = 150 \frac{(1-\varepsilon)^2}{\varepsilon^3} \frac{w \cdot \mu}{\phi^2 d^2} + 1{,}75 \frac{(1-\varepsilon)}{\varepsilon^3} \frac{w^2 \rho}{\phi^2 d} \tag{4}$$

Where ϕ is a coefficient of the bed particle shape and decrease of pressure on the length L ($\frac{\Delta P}{L}$) may be determined as:

$$\frac{\Delta P}{L} = (1-\varepsilon)(\rho_s - \rho_f) g \tag{5}$$

In order to simplify the equation (4) in many studies, Wen's and Yu's approximations are used (Niven, 2002):

$$\frac{1-\varepsilon}{\phi^2 \cdot \varepsilon^3} \approx 11 \text{ and } \frac{1}{\phi \cdot \varepsilon^3} \approx 14 \tag{6}$$

The use of these constants leads to simplification of Ergun's equation (4) to the following form (Dechsiri, 2004):

$$Re_{mf} = \frac{d \cdot w \cdot \rho_f}{\mu} = \sqrt{33{,}7^2 + 0{,}0408 \frac{d^3 \cdot \rho_f \cdot (\rho_s - \rho_f) \cdot g}{\mu^2}} - 33{,}7 \tag{7}$$

The above formula is used in cases of powder beds fluidization. With reference to the fluidizing bed of carbon in high air pressures, Chitester et al. (1984) suggested modification of Ergun's equation through the use of constants 28.7 and 0.494:

$$Re_{mf} = \sqrt{28{,}7^2 + 0{,}494 \frac{d^3 \cdot \rho_f \cdot (\rho_s - \rho_f) \cdot g}{\mu^2}} - 28{,}7 \tag{8}$$

In calculations related to the minimum velocity of fluidization in cooling or freezzing conditions of food, many authors recommend the use of Todes's formula (Todes and Tsitovich, 1981):

$$Re_{mf} = \frac{Ar}{1400 + 5{,}22\sqrt{Ar}} \tag{9}$$

or Kuni's and Levenspiel's formula (Gruda and Postolski 1999):

$$w_{mf} = \sqrt{\frac{d \cdot (\rho_s - \rho_f) \cdot g}{24{,}5 \cdot \rho}} \tag{10}$$

Selection of an appropriate equation for determination of the minimum velocity of fluidization of food products even in case of a classic fluidization is not easy on account of a varied shape and size of products. Theoretical determination of the velocity of the minimum fluidization in the reverse fluidization method has not been investigated so far. Thus, the objective of the paper is to find a solution, which would enable determination of the minimum velocity of fluidization of vegetables during their freezing by means of the reverse fluidization method.

Methodology

The research was carried out on a prototype laboratory device which allowed realization of cooling processes with the reverse fluidization method. A working chamber of the device was equipped with a replaceable head consisting of a tube sheet with nozzles located in it with 370 mm length and the internal diameter of 18 mm (fig. 3). There were 20 nozzles in the head and their distribution was respectively S1 = 50 mm and S2 = 47 mm. This head was selected as a result of optimization research, which was previously carried out (Góral and Kluza, 2012).

Measurements were carried out in the environmental temperature of –22ºC at the scope of the reflected air velocity from 2 $m \cdot s^{-1}$ to 12 $m \cdot s^{-1}$. Distance from the working chamber bottom to the nozzles was fixed and it was 120 mm. The raw material used in the research consisted of French fries of a cross section of 1 cm x 1 cm and a varied length, carrot cut in cubes of a 1 cm side and slices of 3 cm x 3 cm and thickness of 0.5 cm, Brussels sprouts of a diameter from 2 cm to 3.5 cm and broccoli florets.

Products were fresh, no traces of mechanical damages or infection were reported.

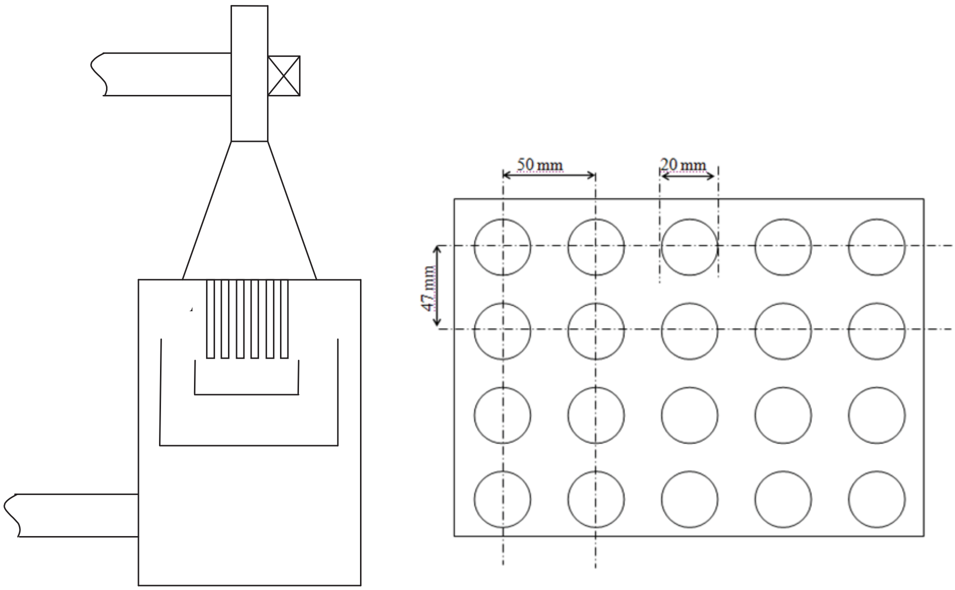

Figure 3. Scheme of test rigs with cross section of operating head

Since, the investigated products came from various classification groups, the course of their preparation was varied. The test was prepated generally by removing an external cover, washing in water in order to remove peeling remains and then cutting into cubes, columns or slices. Before fluidization, raw materials were weighed on an electronic scale and raw material volume was measured. On this basis, the raw material density was determined. A balanced diameter of raw material was calculated from the formula $d_e = 1{,}24\sqrt[3]{V}$ (Gruda and Postolski, 1999; Jaros and Pabis, 2006). Samples, prepared this way, of the mass of approx. 0.5 kg each were subjected to fluidization. Experiments were carried out in three repeats. In conditions of fluidization in a bed, velocities of air reflected from the working chamber bottom, its temperature and moisture were measured. Measurements were carried out with the use of KIMO Anemo-Manometer MP 120 with a Pilot tube L type with the outside diameter of 6 mm. The remaining air parameters required for calculations were accepted from moist air tables (Pawiłojć et al., 1998). The theoretical minimum velocity of fluidization was calculated from formulas (7), (8), (9) and (10) and the obtained values were compared to the results obtained from experiments with the use of Statistica 10.0 statistical packet.

Research results and discussion

The experimental test allowed determination of the critical velocity of the early stage of fluidization of the selected vegetables (fig. 4). The highest minimum fluidization velocity during freezing with the reversed fluidization method was with regard to broccoli florets (11 m·s^{-1}). The lowest velocity of the minimum fluidization was measured during carrot cube treatment (2,5 m·s^{-1}). According to predictions, this velocity depended mainly on the diameter of the bed element.

Figure 4. View of the bed of carrots cubes under fluidization

Values of the minimum fluidization velocity of French fries, Brussels sprouts and broccoli florets obtained through calculations with the use of formula (7-10) considerably differed from experimental results (figure 5). Average values calculated for those raw materials were within 161% and 224% from the measured values. However, while comapring the minimum velocity of fluidization of carrot cubes and slices obtained by experiments and calculated values, deviation did not exceed 30%.

Then, a statistical significance of differences of values obtained acc. to particular calculations models, was investigated. Firstly, Fischer's test was carried out in order to investigate variability of variance. Results of this test were presented in table 1.In each analysed case the value p was higher than α=0.05, thus variability of variance was not statistically significant. Therefore, the t-Student test, which assumed equal variances in order to investigate the significance of differences between the particular values obtained from calculations, could be carried out. Values obtained acc. to this test were presented in table 2.

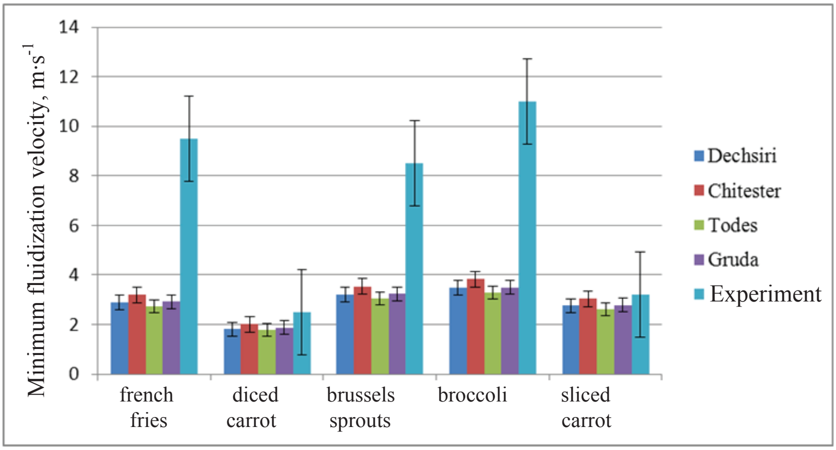

Figure 5. Minimum fluidization velocity of selected vegetables which were determined using four models in comparison with experimental data

Table 1
The p values which were obtained in Fischer's test

	Dechsiri	Chitester	Todes	Gruda
Dechsiri		0.44191	0.41279	0.34568
Chitester	0.44191		0.35739	0.29447
Todes	0.41279	0.35739		0.42936
Gruda	0.34568	0.29447	0.42936	

Table 2
The p values which were obtained in t-Student's test

	Dechsiri	Chitester	Todes	Gruda
Dechsiri		0.70272	0.867159	0.710021
Chitester	0.70272		0.576874	0.943268
Todes	0.867159	0.576874		0.557300
Gruda	0.710021	0.943268	0.557300	

When analysing the t-Student's test results it was found out that the value p for each method was higher than the assumed $\alpha=0.05$ which proves that there were no significant differences between the values calculated according to each method.

To conclude, the value of the minimum fluidization velocity calculated and determined by means of experiments was the most similar to the beds comprising of cubed and sliced carrot. With respect to the treatment of French fries, broccoli florets and Brussels sprouts, measurements of the value of this velocity may be burdened with a significant error. It is related to the specificity of this raw material. The shape of French fries considerably differs from the ball shape accepted for the research. Thus, French fries require considerably higher air velocity to initialize fluidization. Whereas, the Brussels sprouts bed consisted of single elements with the varied size. In calculations of the minimum velocity of fluidization, an average diameter of Brussels sprouts was assumed as a diameter of the bed element. This, certainly influenced divergence between calculations results and the measured values. Similarly, a considerable divergence between the calculated results and experimentally determined of the minimum fluidization velocity of broccoli florets, was reported. It was caused by not only high variability of the size and shape but also by significant difference of the mass of particular florets.

Conclusions and statements

Values of the minimum velocity of fluidization determined experimentally ranged from 2.5 m·s-1 for the bed of cubed carrots to 11 m·s-1 for the bed of broccoli florets.

The calculations of the minimum velocity of fluidization carried out by means of four methods (Dechsiri, Chitester, Todes and Gruda) were burdened with average deviations from the value of the ones obtained by means of experiments from 24% in case of cubed carrot to 224% with regard to the beds of broccoli florets. Such significant deviations were the most probably caused by approximation of the French fry and broccoli shape to a ball shape and in case of Brussels sprouts - assuming for calculations an average diameter of a product. The statistical analysis carried out by the t-Student's test, which assumed equality of variance, confirmed that there were no significant differences between the values of the minimum velocity of fluidization calculated with particular methods in each investigated case of fluidization.

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PRĘDKOŚĆ KRYTYCZNA ODWRÓCONEJ FLUIDYZACJI WYBRANYCH WARZYW

Streszczenie. W pracy analizowano możliwość wykorzystania istniejących modeli wyznaczania minimalnej prędkości fluidyzacji podczas zamrażania owoców i warzyw metodą odwróconej fluidyzacji. Złoża poddawane zamrażaniu formowano z frytek ziemniaczanych, brukselki, różyczek brokułu, marchwi w postaci kostki o boku 1 cm i plastrów o wymiarach 3x3x0,5 cm. Wartości minimalnej prędkości fluidyzacji wyznaczano przy pomocy anemo-manometru. Wyniki z badań eksperymentalnych porównywano z wartościami uzyskanymi z 4 modeli obliczeń minimalnej prędkości fluidyzacji. Obliczone wartości obarczone były średnimi odchyleniami od wartości uzyskanych eksperymentalnie, od 24% w przypadku marchwi w kostce do 224% w przypadku złóż różyczek brokułu. Jednocześnie stwierdzono brak statystycznych różnic pomiędzy wynikami uzyskanymi wg badanych modeli.

Słowa kluczowe: minimalna prędkość fluidyzacji, odwrócona fluidyzacja, zamrażanie, warzywa

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FUNCTIONAL PROPERTIES OF THE COMPUTER SYSTEM FOR TEMPERATURE DIAGNOSIS OF COWS[1]

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ABSTRACT

The objective of the paper was to analyse thermographs of the milk flow from quarters of cows' udders on account of initial separation of disturbing factors which influence the conditions of milk temperature measurement during a machine cow milking. Research was carried out in cowshed conditions with the use of a special milking device, equipped with thermistor temperature sensors mounted in teat cups and microprocessor recorder of measurement signals. Based on the analysis of thermographs obtained during the cowshed tests, the impact of the health conditions of cows' udder quarters, individual physiology of milking in cows, milking phase, correctness of the sensor operation on the shaping of temperature in teat cups of milking machines were reported.

Introduction

In the Institute of Biosystem Engineering at Poznan University of Life Sciences and the Department of Cattle Breeding at the University of Agriculture in Kracow research and construction works were carried out. Some of them constituted a part of the governmental project funded by the Polish Ministry of Science "Diagnostics of physiological states and health of cows with the usage of intelligent milk temperature sensors" (No N N313 787040). The research has led to construction of a modern milking system with diagnostic functions. To construct the device four temperature sensors mounted in teat cups were used. Owing to the values of milk temperature recorded automatically during quarter milk flow and the use of diagnostic algorithm it is possible to detect heat, early pregnancy and udder quarters condition in cows (Jędruś and Gil, 2011). A detailed structure as well as selected technical and metrological parameters of the computer system components for cows' temperature diagnostics were described in literature (Beba, 2013; Jędruś, 2013a,b).

[1]This work has been funded by the Polish Ministry of Science. This study presents initial work started within the framework of governmental projects "Diagnostics of physiological states and health of cows with the usage of intelligent milk temperature sensors" (No N N313 787040)

As already indicated by Jędruś (2013c), the issue of temperature measurement during cow machine milking remains an insufficiently analysed problem in literature. The impact of disturbances occurring during machine milking on the shaping of temperature in teat cups has not been analysed so far. It is only Gil (1988) who reported that milk temperature fluctuation appearing during cow milking process is a direct result of anomalies taking place in the quarter milk flow.

The aim of the research was to analyse the thermographs of quarter milk flow in order to single out disturbing factors which influence the conditions of milk temperature measurement during cow machine milking.

Materials and methods

The study done with the use of a computer system for cow temperature diagnostics was carried out in a cowshed in Wławie near Kościan in Wielkopolskie Voivodship. The cowshed was equipped with a conventional pipeline milking machine that was a hybrid between constructional solutions of DeLaval and Polanes companies. Dairy cattle consisted of twenty Holstein-Friesian high-yield cows, normally milked with four milking apparatuses. In the cowshed alternating pulsation system was used. The pulsation rate and ratio were 60 cycles·min^{-1} and 60:40%, respectively. The system working vacuum level was adjusted to 50 kPa. The new milking system used during the study consisted of following elements and components (fig. 1):

– conventional milking cluster (Classic Vestfalia 300) manufactured by GEA Farm Technologies equipped with four thermistor temperature sensors type TT4-5KC3-25-3500-UPP. The sensors are additionally covered with stainless steel where walls are 0.2 mm thick. Thermistors accuracy in shields equals ±0.1ºC in the temperature range of 30-45ºC. Temperature sensors mounted in transparent inspection glasses for two-piece liners;
– stainless-steel hanger with integrated connector Trico II and electronic pulsator Duo (all the devices manufactured by Polanes company in Bydgoszcz) where pulsation parameters are the same as those normally applied in a cowshed, microprocessor recorder of measurement signals and accumulator;
– other milking equipment: milk tube, long pulse tube, conductors placed in a second long pulse tube that connect temperature sensors with a measurement signals recorder, and others.

This milking device was used in summer 2013 to milk twenty high-yield Holstein-Friesian cows. In order to evaluate the health condition of udder quarters in cows, quarter milk samples were taken for microbiological analyses. The analyses, carried out in a laboratory in Krotoszyn, allowed it to define somatic cell count (SCC) in milk.

The recorded temperature values were the source for creating a few hundred thermographs of quarter milk flow. The thermographs, created with the use of Microsoft Office Excel, became a subject of further analyses.

Figure 1. Milking device used in cowshed tests: 1 – milking apparatus with embodied thermistors 2 – microprocessor recorder of measurement signals

Results

Figures 2-6 present exemplary thermographs of quarter milk flow obtained during cowshed tests. On their basis, it was possible to single out a group of disturbances that influence conditions for milk temperature measurement in teat cups while machine milking is in progress.

The first factor that might contribute to the disturbances of temperature shaping in teat cups is mastitis. It is a problem thoroughly analysed in literature (Gil, 1988). According to Gil (1988), inappropriate milk flow may be also a result of disturbances occurring during milking, caused by illnesses of quarters of subclinical character.

Figure 2 presents an exemplary thermograph of milk flow for ill quarter characterised by high somatic cell count in quarter milk.

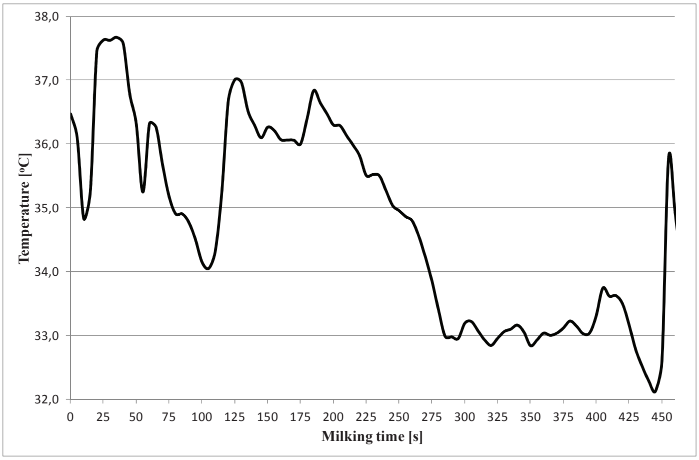

Figure 2. Thermograph of milk flow in back right quarter for cow with cowshed number 7595 and number of somatic cells equal to 5035 thousand in 1 ml of quarter milk

The analysis of quarter milk flow thermographs made it possible to single out a group of fluctuation courses for which somatic cell count in quarter milk was less than 400 thousand, and frequently even below 100 thousand in 1 ml of quarter milk, which is characteristic of a healthy udder quarter (Jarmuż and Skrzypek, 2006). An exemplary thermograph has been presented in figure 3.

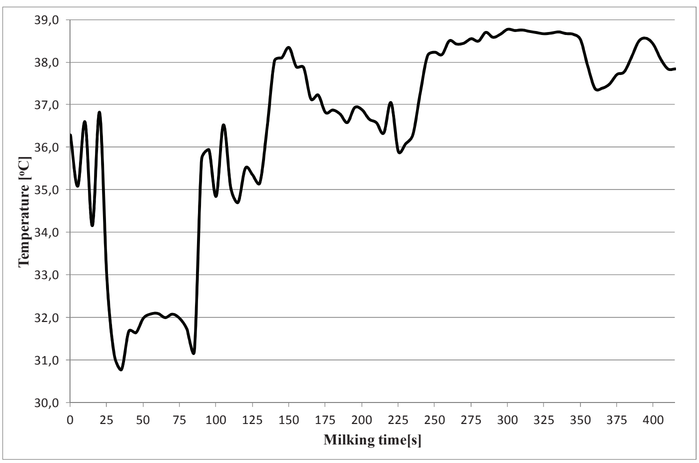

Figure 3. Thermograph of milk flow in rear left quarter of cow with cowshed number 1160 and the number of somatic cells equal to 161 thousand in 1 ml of quarter milk

The causes of fluctuation occurrences in milk flow have not been reported. They might have been a result of inappropriate preparation in a premilking phase, a health condition of udder quarter (value of somatic cell count might have been wrongly defined in a lab) or a result of vacuum level oscillation typical for pipeline machine milking. It seems almost impossible that the disturbances occurring were a result of milk secretion, which may occur when somatic cell count ranges between 100-200 thousand in 1 ml of milk, as Jarmuż and Skrzypek (2006) indicate.

In figure 4 another thermograph of quarter milk flow for a healthy udder quarter has been shown.

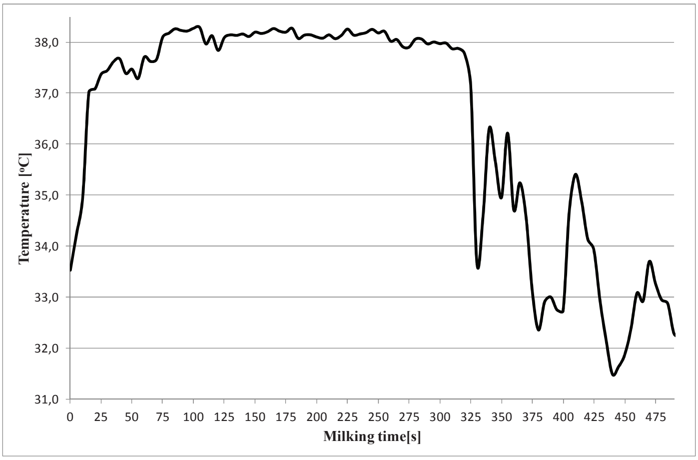

Figure 4. Thermograph of milk flow in rear right quarter of cow with cowshed number 0816 and number of somatic cells equal to 15 thousand in 1 ml of quarter milk

Temperature values recorded in the ascending phase revealed a correct heating process for a temperature sensor. In a time of plateau there occurred disturbances in milk flow observed through fluctuations appearing in quarter milk flow (but of a lower amplitude than in the previous cases). After the descending phase, a correct process of thermistor's cooling have been registered. It was followed by fluctuations of greater amplitude. First of all, they were a result of stripping and air inlet taking place during the milking unit removal. However, these are common phenomena appearing during cow machine milking.

In figure 5 a milk flow thermograph with a single break in milk flow recorded in the ascending phase of milking was shown.

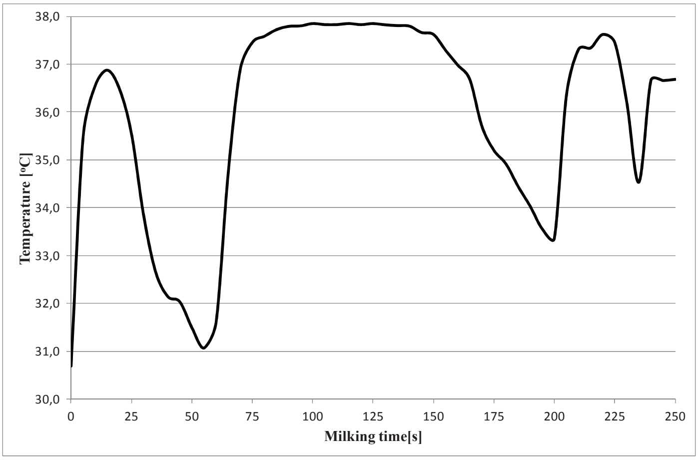

Figure 5. Thermograph of milk flow in front right quarter of cow with cowshed number 0816 and number of somatic cells equal to 15 thousand in 1 ml of quarter milk

In literature, breaks occurring in milk flow in the ascending phase of milking have been reported. They are believed to be an effect of an atypical physiology of milk flow in cows (Jędruś and Lipiński, 2008). However, the disturbances might also result from insufficient udder preparation for milking. Analysis of the quarter milk flow thermographs needs to take into account individual characteristics of cows: disturbances taking place in milk production, milking process or physiological changes depending on age, lactation phase, heat and others (Gil and others, 1993; Jędruś and Lipiński, 2008).

Still another reason for disturbances occurrence are the breaks in temperature sensors power supply. Jędruś and Lipiński (2007) observed supply breaks in 'hot-wire' sensors, which made a proper operation of the quarter milking process impossible. High-stable integrated current sources were used to supply thermistors. They are mounted in a cover of microprocessor recorder and connected to the sensors through a conductor that is 2.5 metres long (inside a long pulse tube). The crucial part of a measuring circuit is the connection conductor-metal cover. At this stage some problems with connection continuity were observed.

In figure 6 an exemplary temperature course when there is a temporary break in thermistors power supply has been shown.

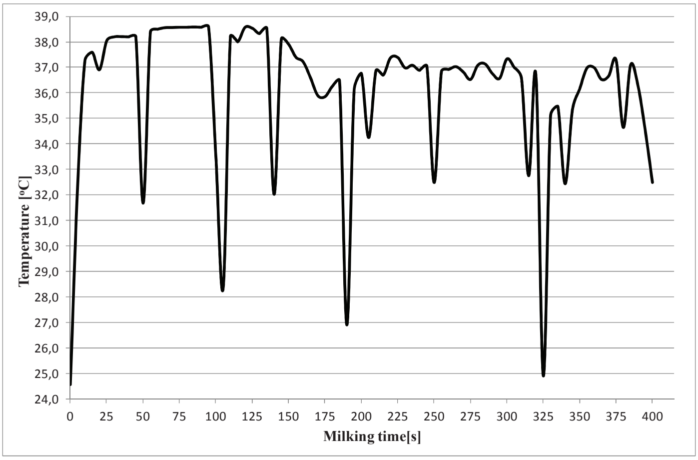

Figure 6. Thermograph of milk flow from exemplary quarter of cow's udder at incorrect supply of temperature sensor

Since the run of thermistors during cow machine milking is incorrect, the values of milk temperature recorded during milking cannot be used for a diagnostic purpose. They are particularly useless for determining the health condition of cows' udder quarters.

The preliminary analysis of disturbances that influence the shaping of temperature in teat cups will make it possible to improve the design of the computer system for cow temperature diagnostics. It will mainly enable to improve the software responsible for measurement signals processing in order to evaluate the health condition of udder quarters.

The analyses of quarter milk flow thermographs recorded during cowshed tests revealed that there are numerous factors that disturb the shaping of temperature in teat cups. Strong fluctuations in milk flow have been observed both in cows with healthy and unhealthy quarters. Some disturbances have been recorded in every phase of milking: ascending, plateau and descending. The cases of disturbances occurrence in cows with healthy udder quarters simply confirm the difficulties in proper monitoring of milking process during everyday operation of milking machines. Still another issue is evaluation of health condition on the basis of somatic cell count in a milk quarter. As Jarmuż and Skrzypek (2006) indicated, only SCC up to 100 thousand in 1 ml of milk allows to treat a quarter as a healthy one. In earlier research (Gil, 1988), the assessment of the udder quarter condition was a resultant of SCC as well as measurement of milk conductivity and the chlorine content in milk. When palpation research was added, it gave a more precise evaluation of the health condition of the examined cows' udder quarters.

In literature, there is no information about the impact of vacuum level fluctuation and other phenomena taking place during machine milking on the shaping of temperature in a milking cluster's teat cup. As Ślipko and Wiercioch (2000) reported, because of muscle weakness we observe constriction in a teat canal, which leads to a temporary reduction of milk flow and takes the shape of oscillation. Such factors as individual characteristics of cows, a working vacuum level, and constructional solutions in a milking cluster have a great influence on the duration of milk flow fluctuation in cows' teats. Still another phenomenon taking place particularly in the descending phase (when a teat gets limp) is a process of air inlet between a mouthpiece and a teat (Krzyś and Szlachta, 2001). A too high value of air stream sucked by the leak around a teat may lead to the vacuum drop much below the value necessary for a correct milking process, such as holding the milking machine on teats. Jędruś and Lipiński (2007) also pointed out the turbulent nature of quarter milk flow as a disturbing factor in a proper controlling of quarter milking.

To conduct further analysis of the problem of impact of the phenomena occurring during machine milking on the shaping of temperature in the milking cluster's teat cups a laboratory stand needs to be constructed. The use of water instead of milk for the research in a laboratory conditions possesses a number of advantages (Szlachta et al., 2000). Vacuum parameters both in the case of milk and water have been indicated as similar (Wiercioch, 1998). In the Institute of Biosystems Engineering at Poznan University of Life Sciences there are works being carried out aiming at construction of a new stand. It is going to possess a unique measuring and milking equipment. Thanks to this solution it will be possible to create conditions typical for machine milking in a laboratory. Temperature measurement in teat cups will be realised with the use of this stand.

Conclusions

1. The analysis of milk flow thermographs in cow udder quarters recorded during cowshed tests showed that there are numerous factors which affect the conditions of temperature measurement in teat cups.
2. Once the disturbances influencing the shaping of temperature in teat cups are singled out, it will be possible to improve the diagnostic software responsible for the processing of milk temperature values in order to evaluate the health condition of cow's udder quarters.
3. To be tested precisely, the issue of the impact of the disturbances occurring during machine milking process on the shaping of temperature in teat cups requires a new laboratory stand to be designed. Current normalised methods of assessment of metrological properties of temperature sensors need to be applied.

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Aleksander Jędruś

WŁAŚCIWOŚCI FUNKCJONALNE KOMPUTEROWEGO SYSTEMU DIAGNOSTYKI TEMPERATUROWEJ KRÓW

Streszczenie. Celem pracy była analiza termogramów spływu mleka z ćwiartek wymion krów pod kątem wstępnego wyodrębnienia czynników zakłócających wpływających na warunki pomiaru temperatury mleka w czasie doju maszynowego krów. Badania przeprowadzono w warunkach oborowych z wykorzystaniem specjalnego urządzenia udojowego, wyposażonego w termistorowe czujniki temperatury zamontowane w kubkach udojowych oraz mikroprocesorowy rejestrator sygnałów pomiarowych. Na podstawie analizy termogramów uzyskanych w trakcie badań oborowych stwierdzono wpływ stanu zdrowotnego płatów wymion krów, osobniczej fizjologii oddawania mleka przez krowy, fazy doju krów, poprawności działania czujnika na kształtowanie się temperatury w kubku udojowym dojarki mechanicznej.

Słowa kluczowe: diagnostyka krów, system udojowy, temperatura, zakłócenia

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CORRELATIONS BETWEEN GERMINATION CAPACITY AND SELECTED PROPERTIES OF PARSNIP SEEDS (*PASTINACA SATIVA* L.)

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ABSTRACT

Critical transport velocity, basic dimensions (length, width and thickness) and the mass of parsnip seeds were determined. The resulting values were used to calculate the geometric mean diameter, aspect ratio, sphericity index and specific seed mass. A seed germination test was carried out, the results were checked every 12 hours, and the germination rate index was determined for each seed. The above parameters and indices were compared with the use of the independent t-test and correlation analysis. Germinated and non-germinated seeds differed significantly only in their thickness. A certain improvement in seed germination capacity can be achieved by separating lighter seeds from heavier seeds. In the study, the achievement of 65% germination capacity resulted in the loss of 27% germinating seeds.

List of symbols:

C_g – germination capacity, (%)
D_g – geometric mean diameter, (mm)
m – seed mass, (mg)
m_D – specific seed mass, ($g \cdot m^{-1}$)
R – aspect ratio, (%)
S – standard deviation of trait,
T, W, L – seed thickness, width and length, (mm)
T_g – time required to produce a healthy germ, (days)
T_o – duration of germination test, (days)
v – critical transport velocity of particles, ($m \cdot s^{-1}$)
V_g – seed viability, (%)
V_s – coefficient of trait variability, (%)
W_g – germination rate index,
x, x_{max}, x_{min} – average, maximum and minimum value of trait,
Φ – sphericity index, (%)

Introduction

Parsnip (*Pastinaca sativa L.*) is a biennial plant which, in its wild form, colonizes habitats in temperate regions. It is predominantly found along roads, streams, in forests and meadows (Berenbaum and Zangerl, 2006; Tokarska-Guzik et al., 2012). Parsnip thrives on deep, sandy loam soils rich in calcium and potassium. Parsnip, a member of *Apiacea* family, produces a tuberous root in the first year of cultivation and flowering stems in the second growing season. The fruits are flattened schizocarps comprising two achenes. Parsnip seeds mature in the second half of July (Orłowski et al., 1993; *Polowa*… 2000). The edible taproot is white, gray, yellow or brown-yellow. Parsnips have three times the nutritional value of carrots, they are a rich source of minerals (potassium, calcium, phosphorus and iron), vitamins (C, B1, B2, E, PP) and carotene, and they are a highly recommended snack for people suffering from obesity, atherosclerosis and cardiovascular diseases. All parts of the plant contain aromatic essential oils, and parsnips can be consumed on their own or in combination with other food products (Matuszkiewicz, 2006; Zangerl et al., 2008).

During cultivation, every seed handling operation leads to the loss of seeds, and the greatest losses are noted during harvest and cleaning. The weight of the seed bulk can be reduced by as much as 50% during cleaning and sorting (Orłowski et al., 1993; *Polowa*… 2000).

The quality of crops is influenced by both genetic and environmental factors (Górnik and Grzesik, 1998; Nik et al., 2011). The latter include the chemical composition of soil, fertilization, water availability, temperature, light exposure, and location of seeds on the plant (Schopfer et al., 2001; Martinez-Villaluenga et al., 2010; Grzesik et al., 2012; Gruszecki, 2013). Seed germination efficiency can be improved with the involvement of chemical, physical and physiological treatments, such as seed dressing, pelleting, conditioning, irradiation and electromagnetic field stimulation (Andreoli and Khan, 2000; Schopfer et al., 2001; Podleśny, 2004; Lynikiene et al., 2006; Ciupak et al., 2007; Kornarzyński and Pietruszewski, 2008; Muszyński and Gładyszewska, 2008; Domoradzki and Korpal, 2009; Maroufi and Farahani, 2011; Grzesik et al., 2012; Jamil et al., 2012; Krawiec et al., 2012). The results of laboratory and field studies (Vera, 1997; Domoradzki et al., 2002; Mut and Akay, 2010; Hojjat, 2011; Nik et al., 2011; Sadeghi et al., 2011; Ahirwar, 2012; Amin and Brinis, 2013) indicate that germination efficiency is determined by the dimensions and mass of seeds. Larger and heavier seeds germinate faster and more abundantly, which contributes to a higher crop yield. Seed germination seems to be most highly correlated with seed mass because plump seeds contain more nutrients for sprouting. The above observations were confirmed by studies investigating the germination capacity of tree seeds (Shankar, 2006; Upadhaya et al., 2007; Norden et al., 2009; Kaliniewicz et al., 2012a; 2012b).

There is a general scarcity of the published data on the correlations between the physical parameters of parsnip seeds vs. their germination capacity and viability. Those relationships should be investigated and described in detail to maximize the efficiency of seed cleaning and sorting processes and produce seed material of the highest quality.

Objective of the study

The objective of this study was to determine correlations between the physical parameters of parsnip seeds and their germination capacity to maximize the efficiency of the seed separation process.

Material and methods

The experimental material comprised seeds of a parsnip cultivar characterized by semi-long, white roots, grown in a farm in Dobielno (52,17ºN, 18,85ºE). Seeds were supplied in the amount of 1,211 kg to the TORSEED S.A. Horticultural Seed Production Company in Toruń where they were sorted in the Super Petkus K-541 cleaner (upper screen – ≠ 2.4 mm, lower screen – ø2.7 mm, seed grader – ø2.5 mm). Graded seeds were characterized by 98.5% purity, 9.4% relative moisture content and 57% germination capacity. The analyzed material did not meet ISTA quality standards applicable to seeds that are intended for retail distribution: minimum 97% purity, maximum 10% relative moisture content, and minimum 70% germination capacity. A sample of approximately 1 kg was halved, and one half was randomly selected for successive halving (*Nasiennictwo…,* 1995). The above procedure was repeated to produce samples of the minimum 150 seeds each. The analytical sample comprised 160 seeds.

The physical parameters of parsnip seeds were determined with the use of Petkus K-293 pneumatic classifier, MWM 2325 laboratory microscope, dial thickness gauge and WAA 100/C/2 laboratory scale in accordance with the methods described by Kaliniewicz et al. (2012a). Seed weight *W* and seed length *L* are presented in figure 1, and seed thickness *T* was the dimension perpendicular to seed length and seed width.

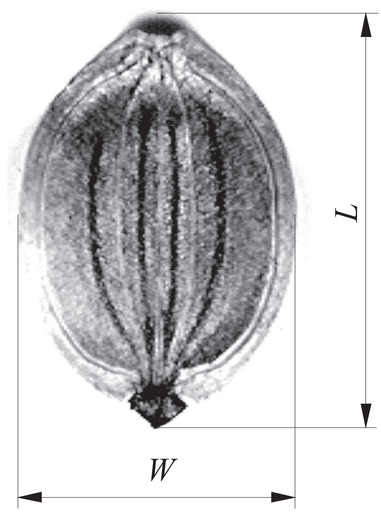

Figure 1. Length L and width W of parsnip seeds

The following parameters were calculated for every seed:

– Geometric mean diameter, aspect ratio and sphericity index (Mohsenin, 1986):

$$D_g = (T \cdot W \cdot L)^{1/3} \quad (1)$$

$$R = \frac{W}{L} \times 100 \quad (2)$$

$$\Phi = \frac{(T \cdot W \cdot L)^{1/3}}{L} \times 100 \quad (3)$$

– specific mass (Kaliniewicz, 2013):

$$m_D = \frac{m}{D_g} \quad (4)$$

– germination rate index:

$$W_g = \frac{T_o + 1 - T_g}{T_o + 1} \quad (5)$$

A germination test was carried out by placing parsnip seeds on moistened filter paper in a container with a glass lid. Evaporated water was supplemented daily with a sprinkler. The experiment was performed under exposure to natural light at a temperature of 25ºC. Germination progress was evaluated daily between 8 and 9 a.m. Seeds that produced sprouts with a minimum length of 75% seed length were classified as germinated (*Nasiennictwo…,* 1995). Observations were continued for 14 full days (12 to 26 June). Seed viability V_g and germination capacity C_g were determined as the ratio of the number of seeds that had sprouted in 7 and 14 days to the number of seeds in the analyzed sample.

The results were processed statistically in Statistica v. 10 application with the use of the independent t-test and correlation analysis (Rabiej, 2012) at a significance level of 0.05.

Results and Discussion

The physical parameters and the calculated indices of parsnip seeds are presented in Table 1. The highest value of the coefficient of variation was reported for the germination rate index (approximately 87%), and the lowest – for the sphericity index (9.5%). In the group of analyzed physical properties, the greatest variation was noted in seed mass (approximately 33.5%), and the smallest variation – in seed length (approximately 13.5%). The variation in the physical attributes of seeds exceeded 10%, which indicates that the analyzed material was diverse and that the sampling method was effective. Basic seed dimensions varied in the following ranges:

– thickness – from 0.40 to 1.11 mm,
– width – from 2.45 to 4.94 mm,
– length – from 3.01 to 6.22 mm.

Table 1
Distribution of physical properties and calculated indices of parsnip seeds

Property / index	x_{min}	x_{max}	x	S	V_s
v	1.38	3.58	2.50	0.399	16.00
T	0.40	1.10	0.66	0.094	14.23
W	2.45	4.94	3.67	0.541	14.77
L	3.01	6.22	4.63	0.625	13.51
m	0.9	9.0	4.36	1.459	33.45
D_g	1.60	2.79	2.22	0.225	10.13
R	52.36	114.55	76.76	10.942	13.72
Φ	38.89	73.65	48.45	4.603	9.50
m_D	0.43	4.00	1.98	0.688	34.79
W_g	0	0.667	0.305	0.265	86.85

The mean thickness of parsnip seeds was similar to that of *plantago ovata* (Ahmadi et al., 2012), common alder (Kaliniewicz and Trojanowski, 2011), dill, carrot, bell pepper, tomato, leek and celery seeds (Orłowski et al., 1993). In terms of mean width, parsnip seeds resembled spring barley (Hebda and Micek, 2007), cucumber, bell pepper and spinach seeds (Orłowski et al., 1993). The mean length of parsnip seeds was similar to that of flax (Pradhan et al., 2010) and coriander seeds (Coşkuner and Karababa, 2007). Mean seed mass was higher than that noted by Gruszecki (2013) and Hendrix (1984), which testifies to the plumpness of the analyzed seeds. The evaluated seeds were similar to flax seeds in terms of their geometric mean diameter (Pradhan et al., 2010), and to *plantago ovata* seeds in terms of their sphericity index (Ahmadi et al., 2012).

The analyzed seeds were characterized by germination energy of V_g=35.6% and germination capacity of C_g=62.5%. The evaluated material did not meet minimum germination capacity requirements for seed distribution (65%) (Orłowski et al., 1993). Our results suggest that germination can be improved through seed treatment. A seed quality can be improved by separating non-germinating seeds, parameters of which differ from those of germinating seeds.

The results of the independent t-test (fig. 2) indicate that germinated and non-germinated seeds differed only in thickness, and non-germinated seeds were characterized by smaller thickness. No significant differences in the remaining physical parameters and indices were observed between groups, but non-germinated seeds were characterized by lower critical transport velocity, mass, sphericity index and specific mass, and greater width and aspect ratio in comparison with germinated seeds. The reported differences in the mean thickness of germinated and non-germinated seeds could indicate that germination efficiency can be improved by sorting seeds with the use of mesh screens with longitudinal openings. A detailed analysis of separation efficiency of the thinnest seeds with anticipated 5% loss of germinating seeds did not confirm that hypothesis.

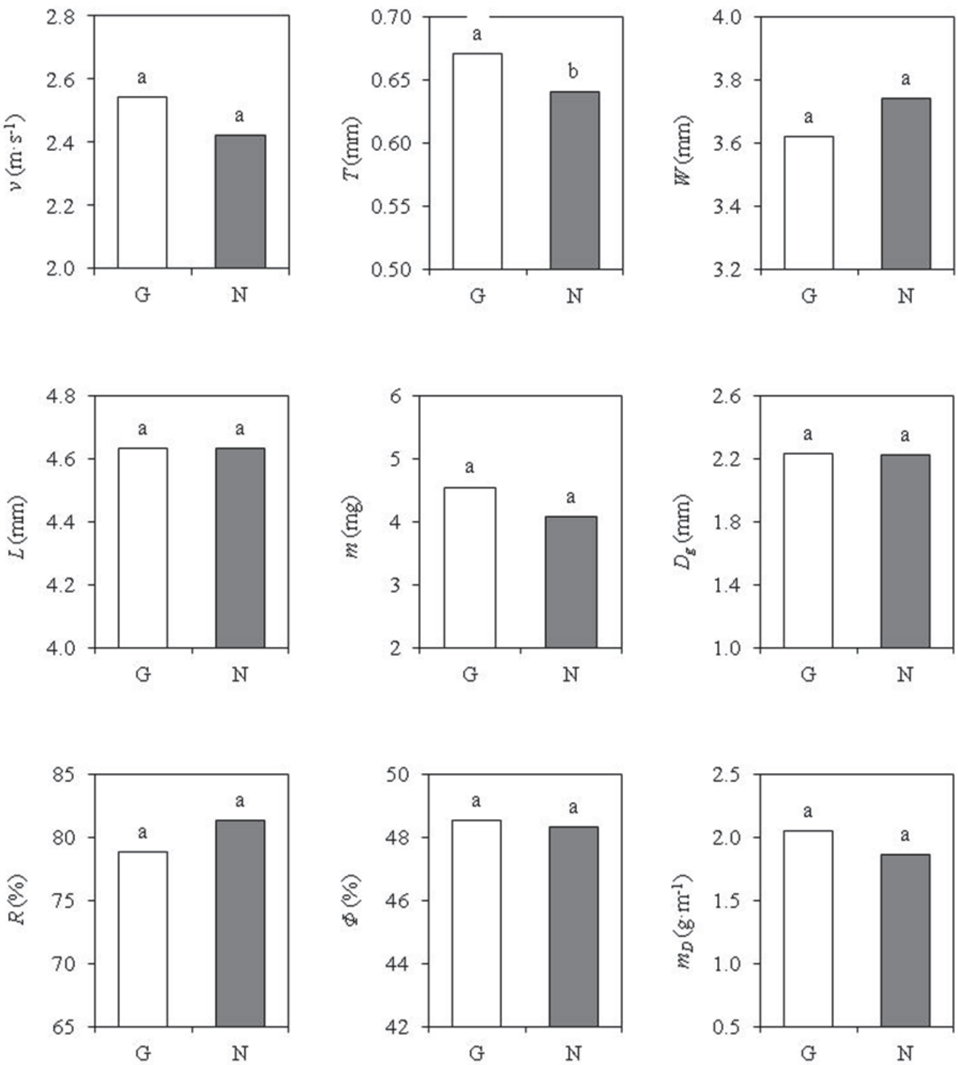

Figure 2. Comparison of significance of differences between physical properties and calculated indices of germinated (G) and non-germinated (N) parsnip seeds: a, b – different letters denote statistically significant differences

The results of a correlation analysis involving physical parameters and the calculated indices of parsnip seeds are presented in Table 2. The critical value of the correlation coefficient was exceeded in only 20 out of 45 comparisons. Seed length was most correlated (6 out of 9 comparisons) and the germination rate index was least correlated (1 out of 9 comparisons) with the remaining parameters. Interestingly, the seed width and seed length were not correlated with seed thickness or seed mass. The above could be attributed to the presence of seed "wings",development of which is probably unrelated to the above parameters. The germination rate index was most highly correlated with seed mass, but the correlation coefficient was not practically significant (> 0.4).

Table 2
Coefficients of Pearson's linear correlation between the physical properties and the calculated indices of parsnip seeds.

Property / index	T	W	L	m	D_g	R	Φ	m_D	W_g
v	**0.513**	-0.132	**-0.199**	**0.588**	0.081	0.077	**0.401**	**0.558**	0.140
T	1	0.147	0.057	**0.231**	**0.546**	0.137	**0.523**	0.062	0.140
W		1	**0.572**	-0.034	**0.818**	**0.507**	0.052	**-0.287**	-0.078
L			1	-0.005	**0.764**	**-0.404**	**-0.656**	**-0.241**	-0.036
m				1	0.081	-0.017	0.124	**0.947**	**0.174**
D_g					1	0.120	-0.033	**-0.227**	0.006
R						1	**0.774**	-0.059	-0.043
Φ							1	0.132	0.063
m_D								1	0.154

Values in bold indicate that the critical value of correlation coefficient were exceeded.

The structure of the germination rate index before and after seed separation into three mass fractions (of almost identical size) is presented in figure 3. The values of the germination rate index indicate that seeds germinated between the 5^{th} and 13^{th} day, and the highest number of seeds sprouted on the 6^{th} day. When seeds were separated based on the mass criterion at the threshold of m=5 mg, the germination capacity of the heavier fraction was estimated at 72%. The heavier fraction contained a high number of early germinating seeds (W_g=0.51-0.60), which substantiates the assumption that germination capacity is correlated with seed mass. The calculated indices demonstrate that the lightest seeds should be separated at the threshold of m=4.8 mg to produce material with 70% germination capacity. In this scenario, approximately 64% of parsnip seeds will be discarded, including 42% of non-germinating seeds and 58% of germinating seeds. The described separation process will result in the loss of 63% of germinating seeds.

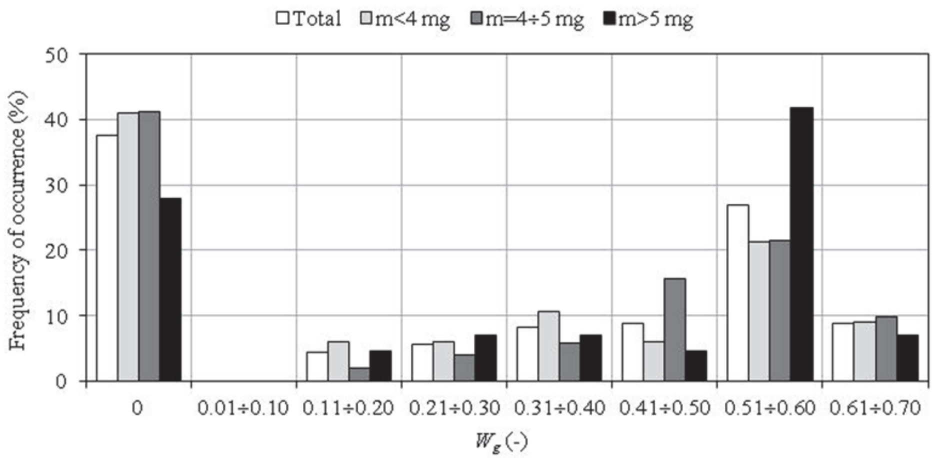

Figure 3. Distribution of germination rate index values of parsnip seeds

Conclusions

1. The physical parameters of parsnip seeds were determined in the following ranges of values: critical transport velocity – 1.38-3.58 $m \cdot s^{-1}$, thickness – 0.40-1.10 mm, width – 2.45-4.94 mm, length – 3.01-6.22 mm and mass – 0.9-9.0 mg.
2. Germinating seeds were characterized by greater thickness than non-germinating seeds, and the observed differences were statistically significant. The differences in the remaining physical parameters and the calculated indices of germinating and non-germinating were not statistically significant. Non-germinating seeds were characterized by a lower critical transport velocity, mass, sphericity index and specific mass, and greater width and the aspect ratio in comparison with germinating seeds.
3. The germination efficiency of parsnip seeds can be improved through the separation of the lightest seeds. In this study, the achievement of 70% germination capacity resulted in the loss of 63% viable seeds. Such a high loss of germinating seeds does not justify the described separation process. For this reason, other treatment and processing methods should be used to improve the quality of parsnip seeds.

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WSPÓŁZALEŻNOŚĆ MIĘDZY ZDOLNOŚCIĄ KIEŁKOWANIA A WYBRANYMI CECHAMI NASION PASTERNAKU ZWYCZAJNEGO (*PASTINACA SATIVA L.)*

Streszczenie. Określono prędkość krytyczną unoszenia, podstawowe wymiary (długość, szerokość i grubość) i masę nasion pasternaku zwyczajnego. Na podstawie dokonanych pomiarów obliczono geometryczną średnicę zastępczą, wskaźnik proporcji, wskaźnik sferyczności i masę jednostkową. Następnie przeprowadzono próbę kiełkowania nasion, sprawdzając jej efekty co 12 godzin, a każdemu z nasion przypisano odpowiednią wartość wskaźnika czasu kiełkowania. Porównano ze sobą powyższe cechy i wskaźniki wykorzystując test t dla prób niezależnych i analizę korelacji. Stwierdzono, że skiełkowane i niekiełkujące nasiona różnią się statystycznie istotnie jedynie pod względem swojej grubości. Pewną poprawę zdolności kiełkowania materiału nasiennego można uzyskać przez oddzielanie od niego nasion najlżejszych. W badanym surowcu nasiennym uzyskanie 65% zdolności kiełkowania wiązało się ze stratami nasion prawidłowo wytwarzających kiełki na poziomie ok. 27%.

Słowa kluczowe: pasternak, nasiona, cechy fizyczne, kiełkowanie

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INFLUENCE OF THE ULTRASONIC TREATMENT ON THE PROCESS OF OBTAINING ESSENTIAL OIL FROM CARAWAY SEEDS

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ABSTRACT

The paper presents research results concerning the influence of ultrasonic pre-treatment on the process of distillation of essential oils from caraway seeds. Tests were carried out in two variants. In the first one, the whole seeds and in the second one ground seeds were subjected to a distillation process. An ultrasonic processor (Sonic VC 750) with a head of 19 mm diameter operating with frequency 20 kHz was used for generating ultrasounds. The following parameters of initial sonication of seeds were applied: treatment time from 20 to 60 minutes, intensity of ultrasounds: 28 and 42 W·cm^{-2}. It was found out that the initial ultrasonic treatment of caraway considerably speeds up the rate of obtaining essential oils and increases the final efficiency of the process. Depending on the time and intensity of ultrasounds the increase of efficiency from 9 to 40% was reported. Moreover, a significant impact of seeds fragmentation on the kinetics of the distillation process was reported.

Introduction

Caraway (*Carum carvi L.*) is one of the most important herbs. It is grown on the area of about 8.000 hectares in Poland (Seidler-Łożykowska et al., 2010). Caraway seeds constitute medical raw material and also commonly known dietetic spice. They are used as a supplement for bread and other baker's goods, meat dishes, soups, vegetables, salads, some brands of cheese and alcoholic drinks, such as *vodka*, liqueurs, etc (Peter, 2006). The medical properties of caraway seeds are important due to a high content of essential oils (from 2% to 8%) in which carvone and limonene are the main active compounds (Bailer et al., 2001; Chemat et al., 2004). Essential oil from caraway seeds is given by mouth as a cholagogue, choleretic and eccoprotic. It is also used as a microbicide, fungicide and parasticide. Essential oils are applied as an additive for soaps, decontaminators, cosmetic creams, toothpastes and perfumes (Ożarowski and Jaroniewski, 1987). It is also used as a mean that prevents potatoes germination (Oosterhaven et al., 1996).

The most common method applied for obtaining essential oils is steam distillation. Due to low contain of essential oils in raw material new methods for increase of the yield of distillation are being searched for (Kowalski and Wawrzykowski, 2009). One of them can be applied of preliminary ultrasonic treatment. Ultrasound causes many physical phenomena that influence mass transfer in a solid-liquid system. The most important are cavitation and microstreamings. These phenomena provide a greater penetration of solvent into cellular materials, destroy plant tissues and improve the release of cell contents into the bulk medium.

The use of an ultrasonic treatment for the extraction of essential oil proved to diminish the risk of thermal degradation and aid extraction by significantly reducing extraction times (Kimbaris et al., 2006).

Objective of the study

The objective of the study was to examine the influence of preliminary ultrasonic treatment on the kinetic and final yield of distillation of essential oils from caraway seeds.

Research methodology

The research material was in the form of caraway seeds (*Carum carvi L.*) Kończewicki variety bought in the local chemist's shop. The research was conducted in two stages, one involving a distillation process of the whole seeds and the second of comminuted seeds. The raw material was ground in colloid mill WŻ-11 in the time of 12 seconds. Then, the material was divided into fractions using a laboratory screeing device with round meshes. One fraction with particle size of 150-250 μm was taken for testing. The ultrasonic treatment was carried out with the use of an ultrasonic processor (Sonic VC 750) with a horn of 19 mm diameter and working at a frequency of 20 kHz. The following parameters of ultrasonic treatment were applied: sonication time – 20, 40 and 60 minutes and intensity of ultrasound – 28 and 42 $W \cdot cm^{-2}$.

The preliminary ultrasonic treatment was conducted in a distilling flask of 1000 ml capacity. For this purpose, samples of 25 g were placed in the flask and filled with 600 ml of water. After ultrasonic treatment the flask was connected to Deryng apparatus and essential oil was distillated for 3 hours. The readings were taken for every 10 minutes during the distillation process.

The percent content of essential oil was calculated from the following formula:

$$X = \frac{a \cdot 100}{m} \ (\%) \tag{1}$$

where:

m – weight of sample, (g)

a – volume of essential oil, (cm^3)

Figure 1. Ultrasonic processor Sonic VC 750

For comparative purposes the distillation process of essentials oil according to the standard procedure (Farmakopea Polska, 2002) was conducted. The experiments were carried out in 3 replications. Achieved results were subjected to statistical processing applying variance analysis. Significance of differences between means was tested by Tukey's test, with a significant level of 5%. All computations were made using Statistica 6.0 software.

Results and discussion

The influence of preliminary ultrasonic treatment on the yield of essential oil obtained from the whole caraway seeds is shown in figure 2-3.

The preliminary ultrasonic treatment had significant effect on distillation curves of essential oil. The sonication of caraway seeds increased the velocity and final yield of distillation of essential oils for all the examined cases.

The obtained results showed that preliminary sonication at intensity of 28 $W \cdot cm^{-2}$ (fig. 2) allows achieving the same yield of process after 70 minutes like 180-minutes distillation of untreated seeds and improves final yield of distillation by 12%.

The distillation yield depended on time and intensity of preliminary ultrasonic treatment. The extension of sonication to 60 minutes resulted in increasing the processing yield by 40%. The increase in intensity of ultrasound resulted in the speed acceleration and final distillation yield. Sonication of seeds at intensity of 42 $W \cdot cm^{-2}$ allows achieving after 40 minutes the same results like 60 minutes treatment at intensity of 28 $W \cdot cm^{-2}$.

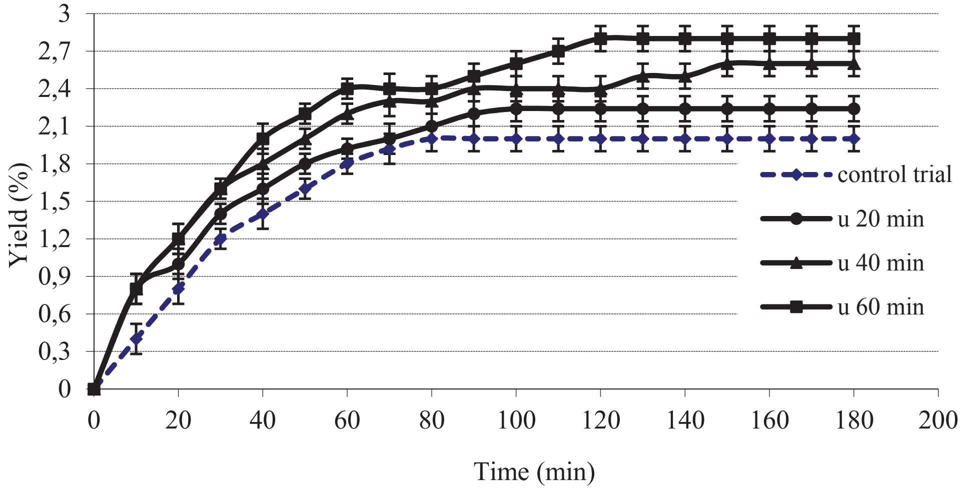

Figure 2. Influence of ultrasound pre-treatment of intensity 28 W·cm^{-2} on the process of obtaining essential oil from whole caraway seeds

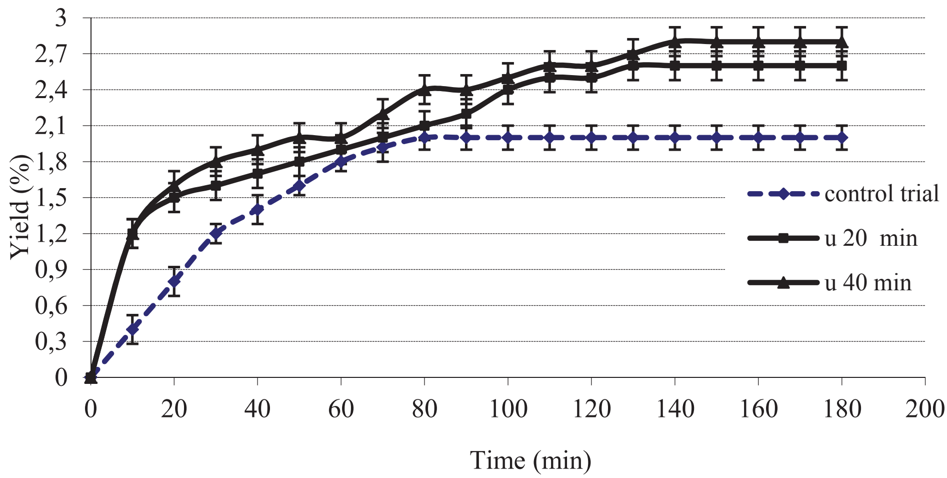

Figure 3. Influence of ultrasound pre-treatment of intensity 42 W·cm^{-2} on the process of obtaining essential oil from whole caraway seeds

The influence of the preliminary ultrasonic treatment on the yield of essential oils obtained from the ground caraway seeds is shown in fig. 4-5.

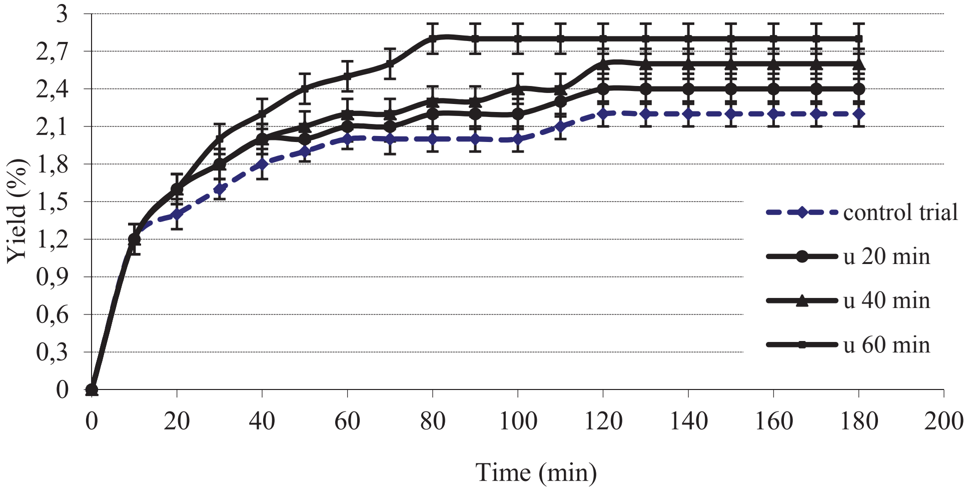

Figure 4. Influence of ultrasound pre-treatment of intensity 28 W·cm^{-2} on the process of obtaining essential oil from fragmented caraway seeds

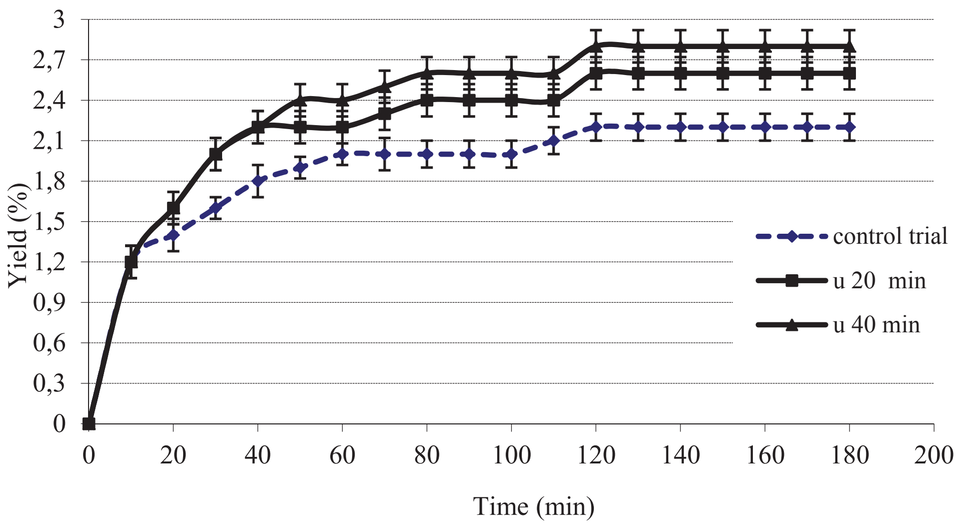

Figure 5. Influence of ultrasound pre-treatment of intensity 42 W·cm^{-2} on the process of obtaining essential oil from fragmented caraway seeds

The grinding of caraway seeds had an important effect on the shape of distillation curves. In the case of the classical distillation the grinding of seeds resulted in increasing the speed and the final efficiency of the process. The yield of essential oils from the ground seeds was 10% higher in comparison to the yield from the whole seeds. In the case of distillation which was preceded by the preliminary ultrasonic treatment only the increase of the distillation speed was observed. There was no influence of the seeds grinding on the final efficiency of the process.

The list of the final efficiencies of distillation of essential oils from caraway depending on the degree of fragmentation and the type of ultrasonic pre-treatment was shown in Table 1.

Table 1

The list of the final efficiencies of distillation of essential oil from caraway depending on the degree of fragmentation and the type of pre-treatment

Raw material/ Parameters of processing	Intensity of ultrasound ($W \cdot cm^{-2}$)	Time of treatment (min)	Yield (%)	Standard devitation (%)
Whole caraway seeds	0 (control trial)	0	2	0.05
	28	20	2.24	0.05
		40	2.6	0.05
		60	2.8	0.05
	42	20	2.6	0.06
		40	2.8	0.06
Ground caraway seeds	0 (control trial)	0	2.2	0.05
	28	20	2.4	0.06
		40	2.6	0.06
		60	2.8	0.06
	42	20	2.6	0.06
		40	2.8	0.06

The mechanism of intensification of essential oils distillation from caraway seeds in the presence of ultrasound is strictly connected to their physical effects. Sonication of seeds breaks cell walls and releases contents of cells into the extraction solvent. Ultrasonic treatment increases the speed of distillation process and also can improve the final efficiency of the whole process. The evidence for the mechanical impact of ultrasounds are structural changes in caraway seeds after ultrasonic treatment (Chemat et al., 2004). The kinetics of steam distillation is depended on intensity of ultrasounds. Assami et al. (2012) examining the influence of ultrasonic treatment at intensity of 1 $W \cdot cm^{-2}$ obtained significant acceleration of process distillation, but they didn't observe increase in the final efficiency of the process.

Application of higher intensity of ultrasounds results in the increase of the yield of process distillation (Kowalski and Wawrzykowski, 2009).

Conclusions

1. Preliminary ultrasonic treatment accelerates distillation of essential oils from caraway seeds and increases the final yield of process. The increase of the distillation yield depends on the time and intensity of ultrasound and ranges from 9% to 40%.
2. Grinding of caraway seeds increases the speed and final efficiency of essential oils only in case of the classical distillation. In case of distillation which was preceded by the preliminary ultrasonic treatment only the increase of the distillation speed was observed. There was no influence of the seeds grinding on the final efficiency of the process.

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WPŁYW OBRÓBKI ULTRADŹWIĘKOWEJ NA PROCES POZYSKIWANIA OLEJKÓW ETERYCZNYCH Z NASION KMINKU ZWYCZAJNEGO

Streszczenie. W pracy przedstawiono wyniki badań dotyczące wpływu wstępnej obróbki ultradźwiękowej na proces destylacji olejków eterycznych z nasion kminku zwyczajnego. Badania przeprowadzono w dwóch wariantach. W pierwszym procesowi destylacji poddano całe nasiona, zaś w drugim nasiona rozdrobnione. Do generowania ultradźwięków wykorzystano procesor ultradźwiękowy (Sonic VC 750) z głowicą o średnicy 19 mm, pracujący z częstotliwością 20 kHz. Zastosowano następujące parametry wstępnej sonifikacji nasion: czas obróbki od 20 do 60 minut, natężenie ultradźwięków: 28 i 42 $W \cdot cm^{-2}$. Stwierdzono, że wstępna obróbka ultradźwiękowa nasion kminku znacząco przyśpiesza tempo pozyskiwania olejków oraz zwiększa końcową wydajność procesu. W zależności od czasu i natężenia ultradźwięków zanotowano wzrost wydajności od 9 do 40%. Zaobserwowano także istotny wpływ rozdrobnienia nasion na kinetykę procesu destylacji.

Słowa kluczowe: kminek zwyczajny, olejki eteryczne, destylacja, ultradźwięki

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ANALYSIS OF POSSIBILITIES OF OBTAINING ESSENTIAL OILS FROM HERBACEOUS PLANTS WASTE

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ABSTRACT

The paper presents research results concerning the impact of the degree of crushing dried herbs on the content of essential oils. Herbaceous waste from lemon balm, garden sage and camomile was used for the research. Raw material was divided into fractions with the use of a laboratory pneumatic separator LPS 200 MC. Dried herbs, which stayed at the sieve of meshes provided below, was selected for analysis: 100 µm and 250µm. Determination of the content of essential oil in dried herbs was carried out according to the recommendations of a norm BN-88/8192-04. It was stated that the degree of crushing of herbs influences the content of essential oil. Higher values of essential oils were reported in a fraction of a lower degree of crushing. The results prove that the obtained herb waste may be used for further processing into essential oils.

Introduction

Herbs are the source of many valuable bioactive constituents as well as fragrance substances (Kowalski and Wawrzykowski 2009a; Raal et al., 2012). One of the main quality indicators of herbs and other spicy plants, which is one of the best descriptors of their organoleptic properties is essential oils retention (Rudy et al. 2011). These substances are mixtures of volatile organic chemical compounds which belong to carbohydrate aromatic, alcohols, aldehyde, ketone, esters and phenols (Klimek, 1957). Essential oils are valuable additives to food, beverages, cosmetics, cleaners and medical applications. (Seidler-Łożykowska et al. 2013; Argylopoulos and Műller, 2014). Antibacterial and antioxidant properties of these substances are highly rated. Essential oils have also free radical scavenging activities (Burt, 2004; Sacchetti et al. 2005).

The raw material is susceptible to disaggregation during harvest, drying process, transportation and storage. The significant percentage of herbs is then fractionated to very small particles. Crushing process causes disintegration of the internal structure of the material that influences chemical changes or lost of thermolabile compounds (Nowak and Syta 2009). One of these herbs is subjected to agglomeration, which creates new finely crushed fractions of herbs (Kowalski and Wawrzykowski, 2009b). All of these fractions are treated as a waste, while they contain a significant volume of essential oils.

Objective of the paper

The objective of the paper was to estimate the essential oils content in different crushed fractions of lemon balm, sage and chamomile. The raw material used in the experiment was provided by courtesy of Herabapol Lublin Inc.

Materials and methods

Dried herbs of sage, lemon balm and camomile were used in the experiment (fig. 1).

Figure 1. Mixtures of specific material used for research: lemon balm, camomile and sage

The partition of specific mixtures into fractions was performed by the use of laboratory pneumatic separator LPS 200 MC, equipped with interchangeable screens (fig. 2). The screening enables material partition to the following fractions: 315 μm, 250 μm, 200 μm, 100 μm, 40 μm and smaller particles. For detailed studies dried herbs which stayed at the sieve of meshes provided below were selected for analysis 100 μm and 250 μm. An assessment of essential oils content in dried herbs was carried out according to the recommendations of standard BN-88/8192-04. Essential oils were analyzed by distillation with water vapour in Deryng apparatus. The principle of this method consists of two processing stages: a) essential oils distillation with water vapour, b) collecting distillate inside measuring apparatus and reading its volume. Oil content (X), expressed in ml per 100 g of raw material, was calculated as follows:

$$X = \frac{V}{m} \cdot 100 \qquad (1)$$

where:
X – oil content, ($ml \cdot 100\ g^{-1}$)
V – oil volume, (ml)
m – mass of raw material used for distillation, (g)

The measurements were repeated 5 times. Factors that influences the efficiency of distillation were estimated by the use of Anova analysis and Tukey's test as additional statistical tool. The analysis was carried out at α=0.05 significance level by the use of Statistica 6.0 software.

Figure 2. Laboratory pneumatic separator LPS 200 MC

Results and discussion

The content of essential oils in the fraction of 250-315 μm particle size range was shown in fig. 3. The highest essential oils content was provided from sage whereas the lowest one was achieved from lemon balm. The yields of oils provided in the experiment are in accordance to the lowest levels in the standard range values of raw materials used in the experiment. Figure 4 illustrates essential oils content provided from the particle range of 100-200 μm.

The main factor that affected the yield of extracted essential oils was the particle size of crushed material. A detailed analysis of results obtained from the measurement of essential oils was shown in table 1. The oil content obtained from dried material of high reduction ratio was lower than that obtained from coarse-grained material. The yield disparity between particular herbs was statistically significant and was approximately of 40% for lemon balm, 24% for chamomile and 9.3% for sage. This phenomenon could be explained as follows. The greater size reduction is the more essential oils are evaporated from the crushed raw material, which is effected in the lower oil content. A significant dispersion of the oil content caused by the sieve effect for particular herbs is probably strictly related to the initial total oil content. For herbs of lower essential oils content (e.g. lemon balm) a minor loss of oils effects in a significant difference between the tested fractions.

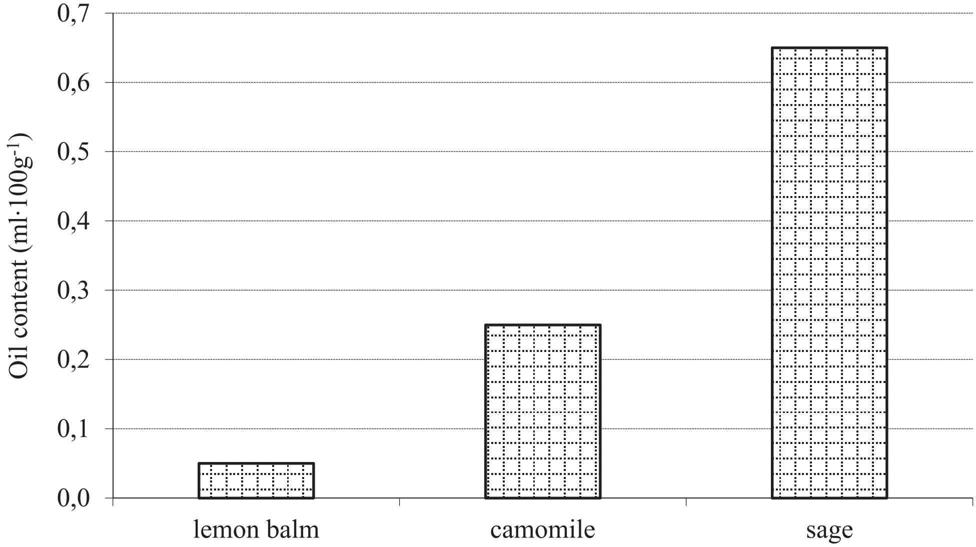

Figure 3. Content of essential oils in herbaceous waste which come from fraction of particles size within the scope of 250-315 μm

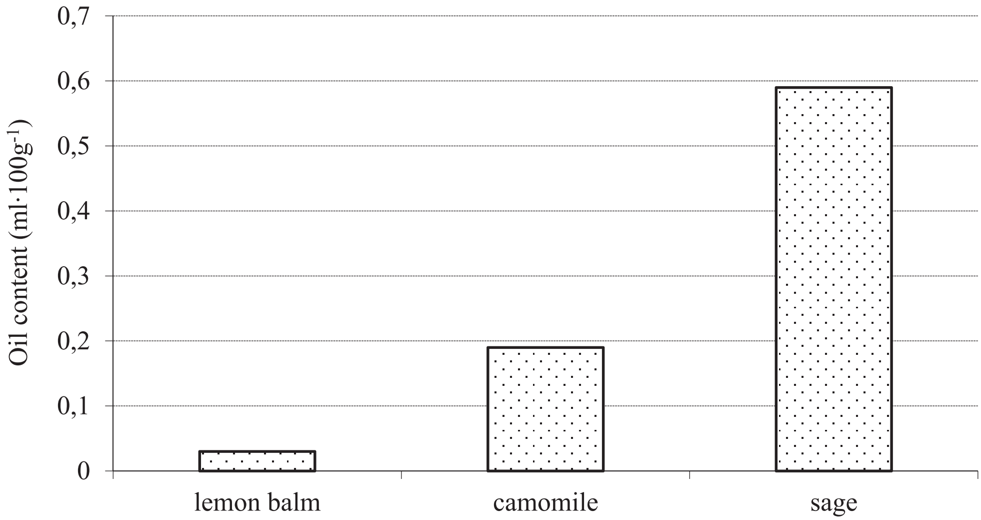

Figure 4. Content of essential oils in herbaceous waste which come from fraction of particle size within the scope of 100-200 μm

Table 1
Detailed analysis of results of measurement of the content of essential oils in lemon balm, camomile and sage

Raw material		Lemon balm		Camomile		Sage	
Parameter		Oil content (mean)	Homogeneous groups	Oil content (mean)	Homogeneous groups	Oil content (mean)	Homogeneous groups
Grinding level	Fraction 100-200 µm	0.03	a	0.19	a	0.59	a
	Fraction 250-315 µm	0.05	b	0.25	b	0.65	b

Conclusions

1. Coarse graining results in higher essential oils content.
2. The yields of oils obtained in the process meets the requirements of lowest values in materials tested. Results obtained accentuates that waste of herbs used in the experiment can be employed as a valuable source of essential oils.
3. The research should be continued in order to create a new technology for effective recovering of essential oils from herbal waste as well as to extend this solution to other herbal plants.

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ANALIZA MOŻLIWOŚCI UZYSKANIA OLEJKÓW ETERYCZNYCH Z ODPADÓW ROŚLIN ZIELARSKICH

Streszczenie. W pracy przedstawiono wyniki badań dotyczące wpływu stopnia rozdrobnienia suszu zielarskiego na zawartość olejków eterycznych. Do badań użyto odpady zielarskie pochodzące z następujących roślin: melisy lekarskiej, szałwii lekarskiej i rumianku. Surowiec podzielono na frakcje wykorzystując laboratoryjny separator pneumatyczny LPS 200 MC. Do analiz wybrano susz, który zatrzymał się na sitach o wielkości oczek: 100 μm i 250μm. Oznaczenie zawartości olejku eterycznego w suszu wykonano zgodnie z zaleceniami normy BN-88/8192-04. Stwierdzono, że stopień rozdrobnienia ziół ma wpływ na zawartość olejku eterycznego. Większe wartości olejków zaobserwowano we frakcji o mniejszym stopniu rozdrobnienia. Otrzymane wyniki wskazują, że pozyskany odpad zielarski może być użyty do dalszego przerobu na olejki eteryczne.

Słowa kluczowe: melisa, szałwia, rumianek, olejki eteryczne, odpady zielarskie

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OPTIMIZATION OF THE MILKING MACHINE CLAW SHAPE WITH THE USE OF THE FLOW SIMULATION SOFTWARE[1]

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ABSTRACT

The objective of the research was to optimize the shape of the milk chamber of a claw using Computational Fluid Dynamics (CFD) software. The results of the liquid flows simulation in claw models of various shapes, in particular with different aspect ratios defined as height to diameter ratios were presented. The velocity of fluid and interactions between different streams of liquid flowing out of inlets were analysed. The research was carried out at the flow of liquid from 0 to 10 kg·s^{-1}, vacuum of 38 to 50 kPa, simulating air injection into the claw model. It was found that the best conditions are for models with an aspect ratio of approximately 3. Computed liquid flow rates ranged from 0.05 to 1.2 m·s^{-1}.

Introduction

Since the last decade of the previous century, a dynamic development of production informatization has taken place, which is possible due to more technically advanced computer systems and also due to timprovement of software and constant decrease of computer equipment prices. IT techniques are applied in many stages of production processes also at designing for agriculture (Szczepaniak, 2010). Designing of devices and their elements more often takes place only directly in a computer, without creating physical prototypes. To begin with simple objects of everyday use through car bodies and to end with elements of a power station, computer designing creates many advantages. These advantages include decrease of costs, optimization of work time of a designer and possibility of testing numerous variants of a design. Moreover, visualization of the final product is possible. It is helpful, inter alia, in a situation, when the designed element is a part, which may cooperate with elements constructed by other designers. As a result an optimal version, designed for making the final prototype or almost directly for production, may be obtained. There are numerous systems which comprise the Computer Integrated Manufacturing. One of them is CAD system - Computer Aided Design and CFD system –

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Computer Fluid Dynamics. Due to the mentioned systems, elements or systems of elements may be designed and liquid and gas flow inside or around those elements may be analysed.

There are many programmes both commercial (e.g. Fluent ANYSYS, FIDAP, STAR CD, Abaqus, SolidWorks Flow Simulation) as well as OpenSource (e.g. OpenFOAM, Free CFD, OpenFlower), thanks to which liquid and gas flow may be simulated in real conditions.

In the structure of milking machines, including claws, more advanced solutions are applied, such as e.g. quarter milking, intelligent milking machines, which allow limitation of overmilking from particular quarters (Jędruś and Lipiński, 2007; Jędruś 2011) or solutions which automatize the milking process on account of smooth adjustment of negative pressure to the changing milking conditions (Juszka and Tomasik, 2005; Juszka et al.., 2008). However, costs and low complexity of traditional milking machines and claws with one milk part of a chamber common for milk obtained from all teats cause that such solutions are and probably will be applied for a long time. Thus, optimization of each element of the milking machine on account of reaching efficient milking without disturbances, the least harmful for an animal is important (Pazzona et al., 2010; Krzyś et al., 2010; Sharif and Muhammad, 2008; Sitkowska, 2008).

Objective and scope of the study

The objective of the study was to design milking machines claws with a possibly optimal shape and volume and optimization of the claw shape with the use of a fluid and gas flow simulation software, including current research results.

The studies covered few hundred models of collectors designed in CAD system. Simulations were carried out with the use of CFD software.

Methodology of research

The starting point for construction of claw models were tests carried out including the existing 13 variants of available claws, their geometric parameters, shaping pressure parameters of mechanical milking with the use of those claws and determined impact of a claw on pressure conditions inside it (Krzyś et al., 2013). Moreover, researches consisting in the measurement of milking parameters with claws of various shape factors, that is, ratios of diameters of the milk part to their height, constituted the basis (a schematic representation and pictures of exemplary models from this part of research were presented in figure 1, whereas parameters in table 1). The research results allowed stating that the most advantageous pressure conditions exist in claws with the highest and the lowest values of the aspect ratio. Due to practical reasons, models with the lowest aspect ratio were not taken into consideration (models with high milk chamber) because they are functional during milking in a cowshed - a milking machine cannot hang freely from teats, it leans against the floor. Thus, the starting point for the research was the claw model with the aspect ratio amounting to 3 (after including the research results of the existing claw solutions (Krzyś et al., 2013) and research results on machines with claws presented in fig. 1).

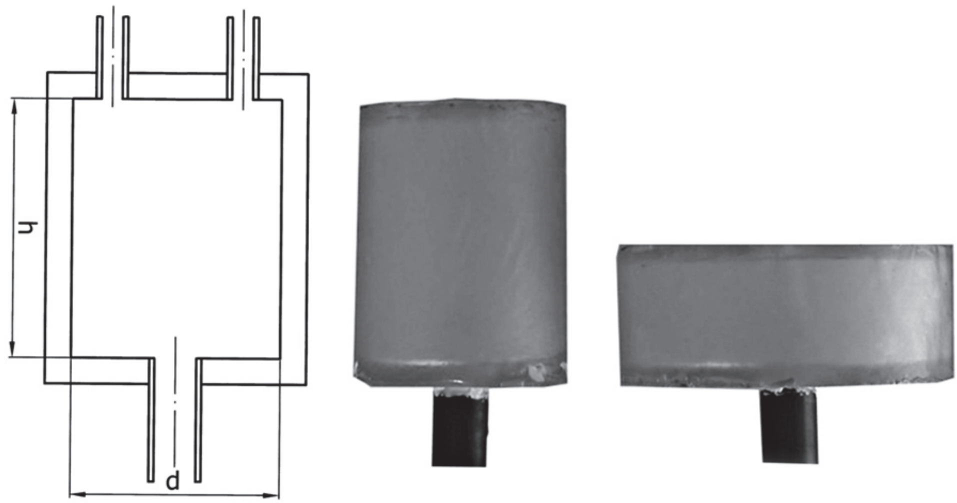

Figure 1. Schematic representation of claw and exemplary epoxide resin models used in the initial tests

Table 1
Dimensions of milk claw parts made for initial tests

Claw	1	2	3	4	5	6
Diameter of milk part, (mm)	70	80	90	100	120	130
Diameter of milk part, (mm)	130	100	79	64	44	38
Aspect ratio, (-)	0.54	0.8	1.39	1.56	2.73	3.42

Claws, the structure of which was developed in the modelling software of CAD type were the objects of investigation. With the use of the fluid flow simulation software, behaviour of the liquid flowing through claws was analysed. The obtained results were used for initial optimization of the claw shape, physical models of which will be made in the next stage of research and tested in the laboratory and cowshed conditions.

Few hundred models were developed in CAD software. Models differed with the shape of a milk chamber. Differences (presented in figure 2) covered the diameter to height ratio, cross and diagonal sections and ellipticity of the horizontal section. The process of creating models and conducting simulation of flow was not labour consumptive. Thus, decision was taken to test the whole range of the designed models and based on the obtained results (velocity vectors and the distribution of liquid layers, which reflect the disturbances of the streams flowing through particular connection pipes) an initial attempt to determine an optimal shape of a claw was made.

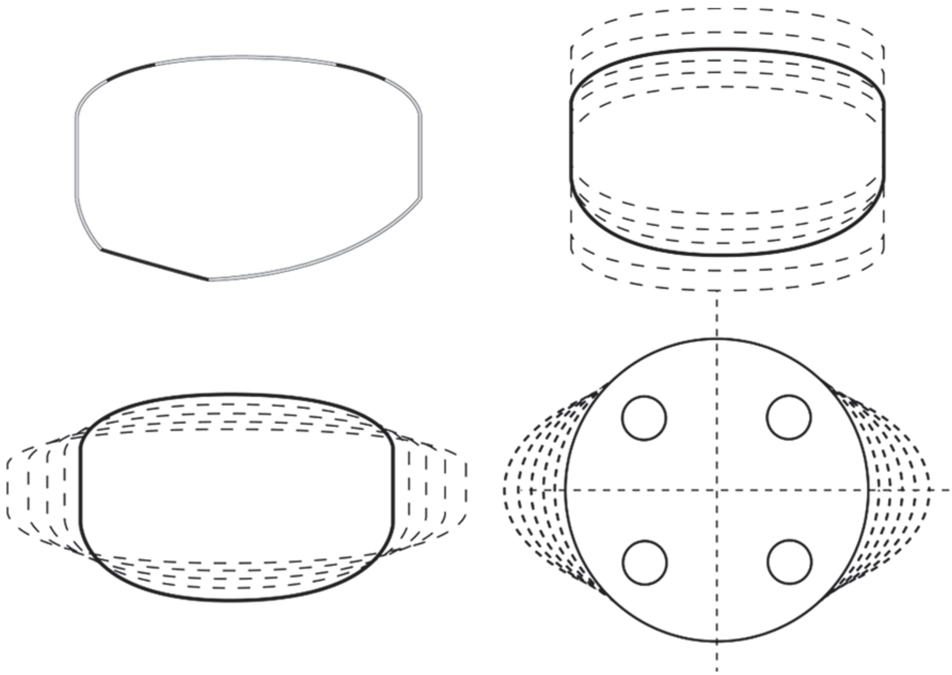

Figure 2. Schematic representation of variants of claw models used for research

The place and manner of mounting inlet and outlet connection pipes and distance of outlet connection pipes from each other at this stage of research were fixed. In the following tests, flows were also modelled including the whole range of diameters and location of connection pipes. However, results of this research are being developed.

The following were simulated:

- intensity of the liquid outflow in the amount of up to 10 $kg \cdot min^{-1}$,
- the level of the system under pressure within 38 and 50 kPa,
- introduction of air into a claw,
- simultaneous and alternative introduction of liquid through the inlet connection pipes.

It should be emphasised that the selected software enables provision of one medium through one inflow. In order to obtain a mixture of liquid and air, separate introduction of liquid and air through each connection pipe was simulated through designing of an additional opening for injection of air for each inlet connection pipe.

The following were analysed:

- liquid flow velocities,
- shape of streams of the flowing liquid,
- relocation of layers with various velocities,
- formation of flow disturbances caused by the claw shape,
- mutual disturbances of liquid streams from particular inlet openings,
- decrease and increase of pressures in various points of a claw.

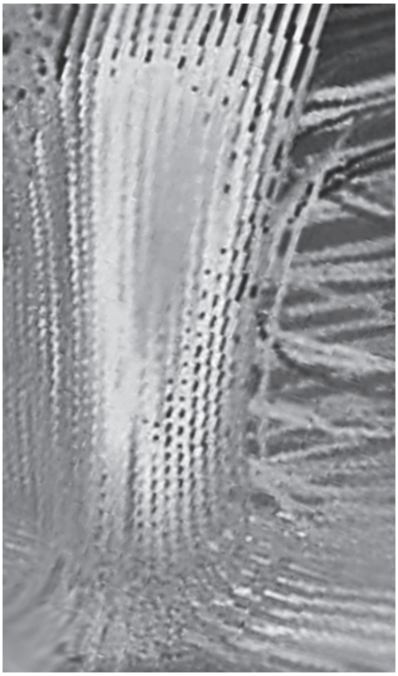

Figure 3. Fragment which illustrates liquid flow from inlet connection pipe to claw

Research results

Figure 3 shows an image of liquid flowing in through the inlet connection pipe. A disturbance caused by liquid streams mowing through the claw (flowing through the remaining connection pipes), which causes decrease of the liquid stream velocity. Light colours are layers moving with higher velocity, darker colours - with lower.

Figure 4 presents the liquid stream velocities in a claw showed on exemplary cross sections closer to the bottom part of the claw. Similarly to figure 3, lighter colours stand for higher velocity of liquid. After conversion to grey shades (for the needs of printing), the contrast was additionally increased in order to visualise differences, which in original images are visible as subtle gradients of colours. The presented example show mutual disturbances of liquid streams and the third capture presents a stream with the increased velocity in the place of an outlet connection pipe. In practice, analysis of liquid flows in claw models is the most comfortable and effective when it is carried out in a moving image with a possibility to stop the movement and watch the analysed spot from each side. Such a possibility is enabled by operation in the CFD software environment, where rotation of a 3D model is possible. Decisively lower number of possibilities of analysis of interaction between streams of the introduced media occurs at the use of a static image in the form of screen captures. Thus screen captures presented in the paper are only examples, which do not reflect the amount of information available directly in the programme.

Considerable differences between particular measurement values (models) were reported. Big differences of the liquid stream velocities in a claw within 0.05 and 1.2 $m \cdot s^{-1}$ were reported at the use of computational methods of the software for computational fluid mechanics (at the highest simulated velocities of fluid outflow *Qm*).

Differences in pressure (from the basic negative pressure established as 38-50 kPa) were within 2 kPa (decrease of pressure) to 7 kPa (increase of pressure).

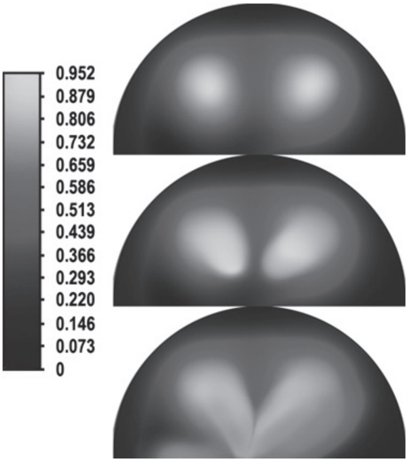

Figure 4. Halves of cross sections of claw in the part with liquid which flows out, on three levels of cross section in horizontal plane, values on the scale are provided in m·s^{-1}

The least disturbed flow was obtained in case of claws with high factor of diameter to height which was 3-1; further decrease of the height to diameter ratio caused another increase of flow disturbances.

The use of an opening which supplies atmospheric air facilitates the flow (removal of liquid from a claw) but at the same time it causes that is decisively more violent and influences the increase of the negative pressure drops.

No considerable influence of the change of the horizontal section of a claw from a round one to an elliptic one on the analysed parameters was reported. However, it should be mentioned that differences became visible in the next stage of research (under investigation) where location of the inlet connection pipes and their mounting, which affects the direction of the inflowing liquid stream to a claw and the distance of connection pipes from each other were taken into consideration. In this case a strict correlation between direction of the liquid flowing in, angles of the claw walls, its horizontal sections and minimization of disturbances between particular streams was reported, which as a result translates into more efficient removal of liquid from a claw. The discussed stage of the research and analysis of its results allowed selection of geometric parameters of the claw model, which ensure the least disturbed liquid flow, which should translate into obtaining optimal pressure and flow parameters of milking at the following stages of research - in the laboratory and cowshed conditions.

The use of additional elements such as a deflector in a structure (extension of the discussed research, which is at the stage of the results analysis) considerably influences the flow, which becomes less violent.

Conclusion

The applied method, not extensively used in agricultural research, seems to be useful not only for the discussed modelling of flows and designing milking devices but also in a wider scope, such as e.g. designing fuel systems or hydraulic systems of agricultural machines. Additionally one may use modules which allows the analysis of flow, heat transfer and convection, e.g. for designing milk cooling systems.

It is planned to continue and extend the research covering:

- making physical models of claw and their testing in controlled laboratory conditions and in a cowshed,
- practical research (laboratory and cowshed) of machines with the designed claws,
- simulation of flows in the whole milking system during milking with the use of a higher number of milking machines and with introduction of additional disturbances.

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OPTYMALIZACJA KSZTAŁTU KOLEKTORA APARATU UDOJOWEGO Z WYKORZYSTANIEM OPROGRAMOWANIA DO SYMULACJI PRZEPŁYWÓW

Streszczenie. Celem badań była optymalizacja kształtu komory mlecznej kolektora z wykorzystaniem oprogramowania do obliczeniowej mechaniki płynów CFD. Przedstawiono wyniki symulacji przepływów cieczy w modelach kolektorów o różnych kształtach, w szczególności o różnych współczynnikach kształtu, definiowanych jako stosunek średnicy do wysokości. Analizowano prędkości przepływającej cieczy oraz wzajemne interakcje pomiędzy poszczególnymi strugami cieczy wypływającej z króćców wylotowych. Badania przeprowadzono przy wypływie cieczy od 0 do 10 $kg \cdot s^{-1}$, podciśnieniu od 38 do 50 kPa, symulowaniu wprowadzania powietrza do modelu kolektora. Stwierdzono, że najkorzystniejsze warunki przepływu osiąga się w modelach o współczynniku kształtu przyjmujących wartość około 3. Obliczone prędkości przepływu cieczy mieściły się w granicach od 0,05 do 1,2 $m \cdot s^{-1}$.

Słowa kluczowe: milking, milking machine, milking unit, claw

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COMPUTATIONAL FLUID DYNAMICS CFD AS AN INNOVATIVE TOOL FOR SIMULATION OF THE SMOKE DRYING PROCESS AND FOR MODELING THE STRUCTURAL ELEMENTS OF A SMOKE-DRYING CHAMBER[1]

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ABSTRACT

This paper elaborates upon the use of Computational Fluid Dynamics (CFD) tools in the engineering practice as an integral part of progress of the chemical engineering of smoke-drying taking into consideration the technical progress and smoke-drying methods. The use of tools connected to CDF modeling allowed collecting crucial information concerning the performed process of smoke-drying for the assortment geometrically shaped similarly to a piece of oval ham. A single truck chamber was a base construction for solutions of the suggested modification of the powering elements (nozzles) as well as for computer model geometry of the structure of an empty chamber and a full chamber itself. Discretization has been made in ANSYS Mechanical APDL 12.1 software and on this basis a model of the suggested solution for construction of power nozzles as well as nozzles spreading the smoke substance inside the smoking chamber has been prepared. On the basis of simulating models and received feedback we can unequivocally say, that more advantageous conditions of spreading the smoke substance in the smoking chamber had been found. The tests performed in real conditions with the use of modified power nozzles in comparison to a classic arrangement confirm dependences obtained during simulation.

Introduction

The objective of the smoking process in the technological aspect is to fix and provide the smoke-dried products with highly specific sensory properties and to remove the water part and antimicrobial properties of the produced components of smoke, mainly phenols (Sikorski and Kołakowski, 2010). However, vagueness of definition does not reflect a complex and balanced smoking technology. The smoking process depends on many

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factors e.g. smoke components (wood species and its form used for production of smoke, manner and speed of wood combustion), temperature, moisture and density of the produced smoke (Tóth and Potthast, 1984; Bratzler et al., 1969) and indirectly on the speed and the manner of providing and flow (distribution) of the smoke mixture inside a chamber and the structure and distribution of supply nozzles (Sikorski and Kołakowski, 2010; Kubiak and Jakubowski, 2010a, 2013).

The increasing awareness concerning ecology and health influenced the progress in the entire smoking technology including development of smoking treatment techniques and methods. A modern production practice, regardless the food processing branch aims at searching for solutions which enable reduction of costs at the simultaneous maintenance of the technological regime (Kubiak, 2012). With time and due to cultural changes and the progress in technical thinking, smoke-drying has become a finely refined process and has taken a new generation form (Wilms, 2000; Kubiak, 2012). The need to meet the raising quality requirements, including health requirements at maintaining a traditional nature of the smoked product was emphasised (Sikorski and Kołakowski, 2010; Kubiak and Jakubowski, 2013).

During smoke-drying the smoke particles constantly move influenced by diffusion forces (Brownian motion), gravitational, convectional, centrifugal, electrostatic forces, etc. Particularly great function is performed by Brwnian motions, which are the main reason for coalescence, coagulation and deposition of smoke particles on the product. An approximate diameter of a single particle of smoke is 0.08-0.15 μm and the density of the smoke mixture and its medium (air) is within 0.02-1.30 $g \cdot cm^{-3}$ (Šimko, 2009; Sikorski and Kołakowski, 2010; Sikorski, 2004). Proper placement of the feeding nozzles and guidance of the smoke mixture direction of propagation allows achieving its uniform distribution, as well as reduction of pollution resulting from the preservation process.

Objective of the paper

The objective of the research was to use one of many available numerical modeling methods (CFD) to obtain information related to improvement of the smoking process, by better propagation of smoke mixture inside the chamber, while having regard to the geometrical shape of the batch.

Material and methods

The subject of the study was a KWP-1et type single-trolley chamber by Pek-Mont Sp. z o.o. (fig. 1a, b) with the overall internal dimensions of the working part: length – 1,440 mm, width – 1,200 mm, height – 2,950 mm. The choice was a result of the fact, that such chambers are currently in use in small to medium size factories, where production is oriented toward diverse groups of meat products, smoking of which requires the ability to instantly change conditions under which the process is carried out (PEK-MONT, 2010; Kubiak and Jakubowski, 2010a, 2010b).

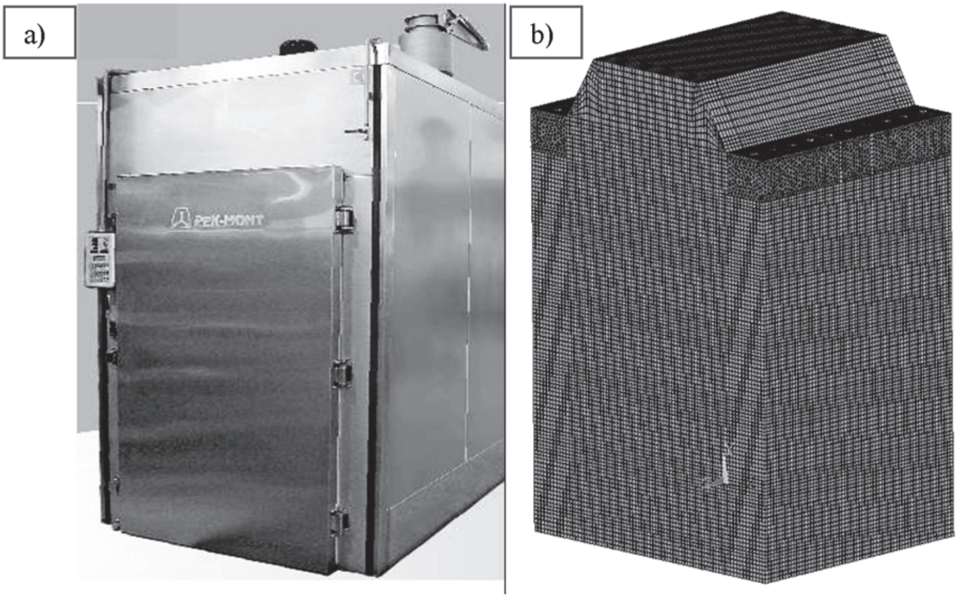

Figure 1. Single-trolley smoke and cooking chamber of Pek-Mont Sp. z o.o. company: a – general view (www.pekmont.pl), b – geometrical model of the inside with a discretization grid

Based on the actual data, a basic (classic) model of the internal space of the chamber was prepared. The entire geometry of the computer model of the empty chamber structure (with classic and modified system of nozzles) and its discretization was made in ANSYS Mechanical APDL 12.1 (ANSYS Mechanical, 2010) software. At the construction of the finite elements grid, a tetragonal element of Fluid 142 type available in the software library was applied (ANSYS Mechanical, 2010). In the simulation analysis geometry of a batch similar to filling in actual conditions was used: an oval shaped product. Dimensions of a single item from the batch corresponded to average dimensions characteristic for the product. The used geometry and distribution itself constitutes in simulation some kind of simplification related to assumption of regular and uniform dimensions of the processed batch. A generated grid for the base (a classic system of supply nozzles) and the suggested solution (a modified structure of supply nozzles: long nozzles up to 15 cm from the floor) for an empty and loaded chamber were within the number of elements which were respectively approx. 1, 250, 000 - empty chambers (fig.2 a-c) and approx. 1, 500, 000 – loaded chambers (fig. 2 b-d).

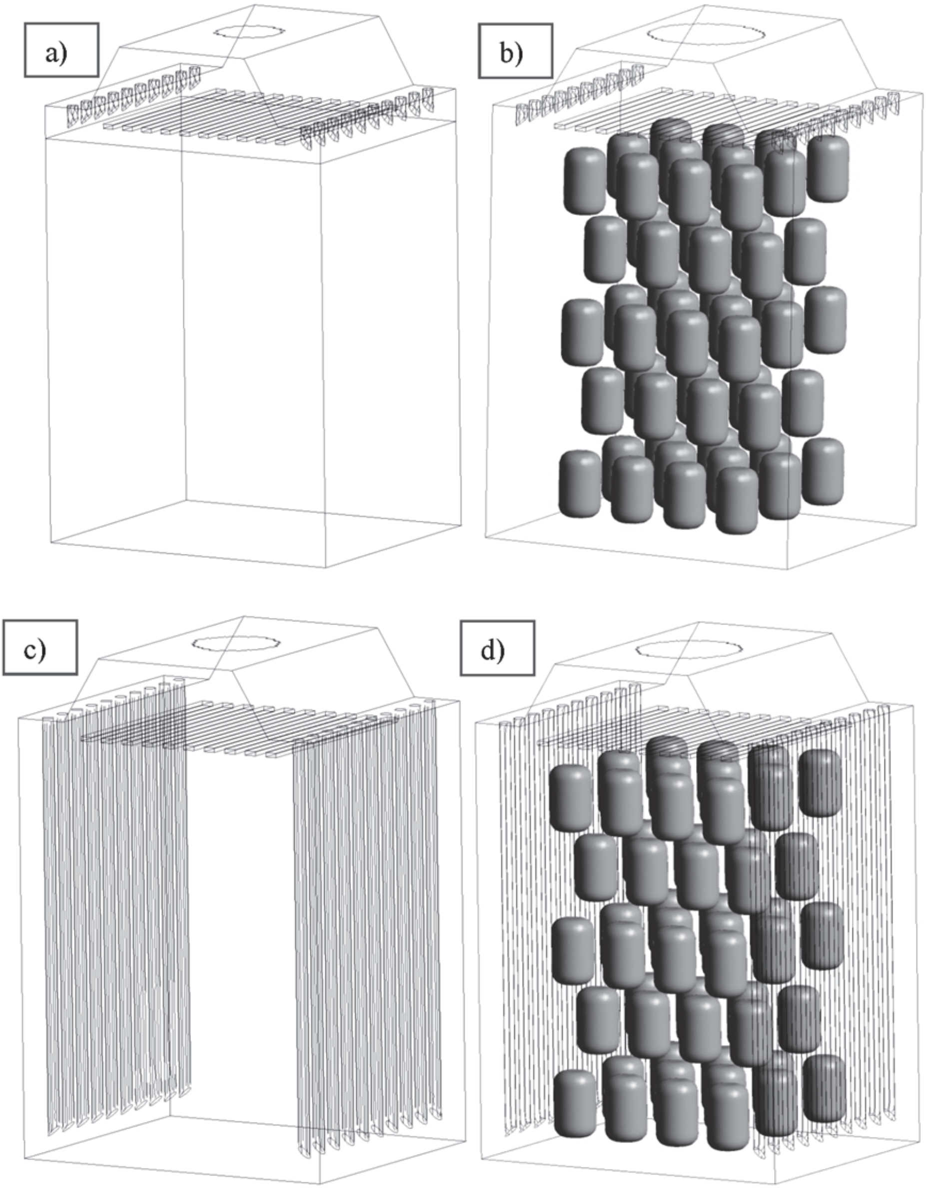

Figure 2. Generation of grid for empty chamber and with batch: a,b – base (classic) and c,d – modified structure of supplying nozzles

The prepared models were then fed into the preprocessor of CFX program, in which boundary and initial conditions, corresponding to the conditions and parameters of the actual smoking, were declared. The next phase for the performed simulational analyses was to feed the prepared models into the solver module and commence the simulation (ANSYS CFX, 2010).

In this paper the phrase "smoke mixture flow" inside the smoking chamber is used interchangeably with "motion" and "propagation", which is dictated by the definitions comprising domain-specific nomenclature.

Research results

Generated graphic files of the finite elements grids enable presentation of data in the form of maps of flow velocity distribution (movement) in spaces of the analysed chambers (classic and the suggested modification) and the analysis of tracking of the dispersed phase particles. Presentation in the form of velocity distribution maps enabled processing of the output values of the parameters specifying the motion of the mixture.

Velocity distribution in the entire space of the internal chamber filled with a batch for the classic variant (basic) and with a modified structure of supplying nozzles has been presented in figure 3.

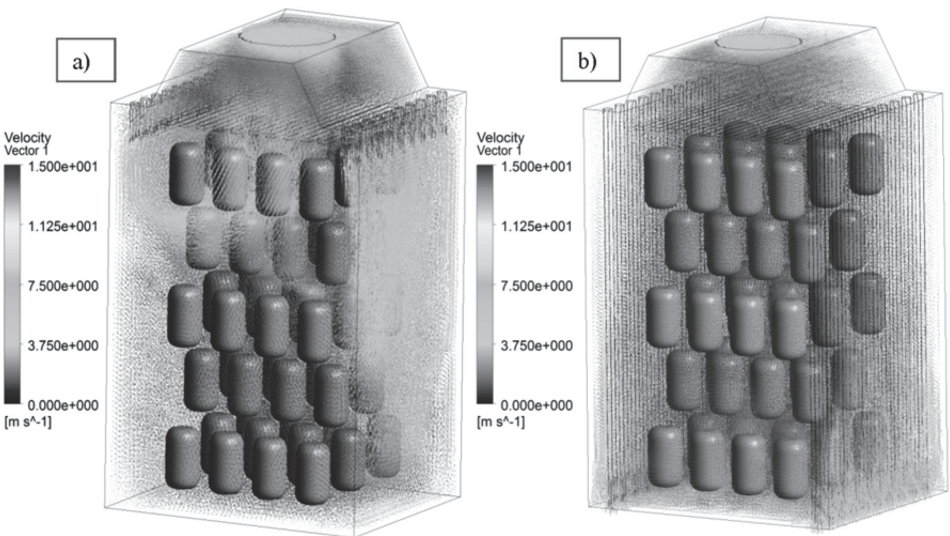

Figure 3. Space maps of distribution of flow speed (movement) vectors in smoke single-trolley chamber with batch: a – base (classic), b – of modified structure of supplying nozzles

The compared distribution of the flow velocity of mixture in the smoking chambers in both variants of structure proved considerable variability, which proved lack of flow symmetry despite equal distribution of feeding nozzles (fig. 3 a-b).

The presented velocity maps (fig. 3a) may indicate considerable irregularities of the smoke mixture flow in the entire space of a chamber loaded with a batch. Obstacles in the form of particular pieces of a batch explicitly prove the problem of irregular propagation with the smoke mixture and thus the possibility of technological faults e.g. insufficient or excessive smoking with a classic arrangement of supply nozzles. Figure 3b, which depicts the proposed longer feeding nozzles, shows better velocity distribution, which leads to more even propagation.

The dispersed phase particles tracking analysis performed to better portray the differences of smoke mixture flow, allows to locate the areas of its concentration. This allows to recognize the areas with insufficient propagation conditions, which impact the correctness of the smoking process. Figures 4a-b present smoke particles motion path for the analyzed variants of nozzles feeding the smoke mixture. In both cases it was assumed that smoke particles which come in contact with any of the chamber walls or the batch items settle onto their surfaces.

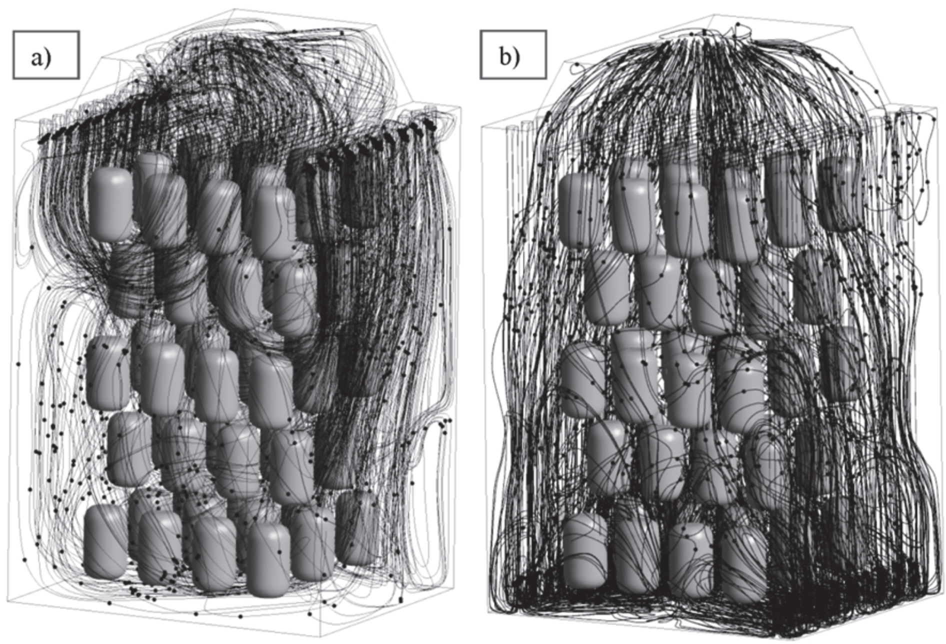

Figure 4. Tracking of smoke particles in smoke single-trolley chamber with batch: a – base (classic), b – of modified shape of supplying nozzles

Comparing the results of the smoke particles tracking in the chamber with a classic (basic) structure and with a batch it may be stated that the so-called “blank spaces” of the smoke mixture concentration occur (fig. 4a). Those “blank spaces” (zones) prove the thesis about the unfavorable smoke mixture propagation conditions with this type of nozzle arrangement, which can further impact the final product. A different situation is observed when the modified nozzles are used (their length up tp 15 cm from the floor). In the suggested arrangement of supplying nozzles, a more favourable movement of smoke mixture is emphasised both in the bottom as well as in the central part of the smoking chamber, which improves concentration and conditions of the smoke propagation. Including lower values of the smoke flow velocity both in simulation conditions as well as in real conditions, better conditions for smoking may be obtained in the form of a longer contact of smoke with the processed raw material (regardless its geometry, size or even shape).

Conclusions

1. The developed and tested model and results obtained based on calculations constitute a valuable tool for persons, who in the production practice deal with the smoking process. It concerns both technologists who guard the conditions of the correct course of the technological process as well as deisgners of smoking chambers for searching for new solutions in optimization of the complex smoking process.
2. The tested model showed stability, which allows, after extending the computational power of the working station, declaring the multi-phase flow and including additional factors, which affect the smoking process.
3. It is also possible to modify the batch’s geometry, nozzle placement, which allows performance of simulational analyses for different load variants.
4. The aim of the presented simulational model is to be a tool for seeking new structural solutions to the feeding nozzles of the smoking chamber, and also other elements which can improve the smoking process.

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COMPUTATIONAL FLUID DYNAMICS (CFD) INNOWACYJNE NARZĘDZIE DO SYMULOWANIA PROCESU WĘDZENIA ORAZ MODELOWANIA ELEMENTÓW KONSTRUKCJI KOMORY WĘDZARNICZO-PARZELNICZEJ

Streszczenie. Omówiono Computational Fluid Dynamics (CFD) w praktyce inżynierskiej jako integralną część postępu w całej inżynierii procesowej wędzenia z uwzględnieniem rozwoju technik i metod przeprowadzania obróbki wędzarniczej. Wykorzystanie narzędzi związanych z modelowaniem CFD pozwoliło na uzyskanie istotnych informacji dotyczących przeprowadzanego procesu wędzenia dla asortymentu o kształcie geometrycznym zbliżonym do szynki (myszka). Komora jednowózkowa stanowiła konstrukcję bazową dla rozwiązań proponowanej modyfikacji elementów zasilających (dysz), jak również geometrię modelu komputerowego samej konstrukcji komory pustej i z wsadem. Dyskretyzacja została wykonana w programie ANSYS Mechanical APDL 12.1 i na jej podstawie stworzono model o proponowanym rozwiązaniu konstrukcji dysz zasilających i rozprowadzających mieszaninę dymu wewnątrz komory wędzarniczej. Na podstawie modeli symulacyjnych i uzyskanych z nich wyników można jednoznacznie stwierdzić, że osiągnięto korzystniejsze warunki rozprowadzenia mieszaniny dymu w komorze wędzarniczej. Przeprowadzone w warunkach rzeczywistych badania z wykorzystaniem zmodyfikowanych dysz zasilających w porównaniu z klasycznym układem potwierdzają zależności uzyskane z symulacji.

Słowa kluczowe: Computational Fluid Dynamics (CFD) model symulacyjny, komora wędzarnicza, proces wędzenia, konstrukcja dysz zasilających

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EFFECTS OF THE FEED NOZZLES STRUCTURE MODIFICATIONS IN A SMOKE-DRYING CHAMBER ON REDUCTION OF PAH COMPOUNDS CONTENT IN MEAT PRODUCTS[1]

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ABSTRACT

The objective of the study was to reduce PAH compounds content in meat products subjected to industrial conditions of smoking in a chamber when changing the feed nozzle structure in the smoke mixture. Smoked meat products oval shaped taken from two primary smoke chambers of different structure of feed nozzles and nozzles diffusing the smoke mixture constituted material samples. Qualitative and quantitative analysis of PAHs was carried out with the use of liquid chromatography with a selective detector (HPLC-FLD-DAD). Research on the content and compounds of the PAH group in meat products, smoked with the use of a modified feed nozzle compared to a traditional system of nozzles, indicate clearly to more favourable conditions for distribution of the smoke mixture in a smoking chamber due to their reduced level.

Introduction

Smoking is a treatment of food products, mainly meat and fish with smoke obtained during slow combustion of wood and sawdust. The basic purpose of this treatment is to provide products with suitable taste properties and increase their storing endurance (Wilms, 2000; Jensen et al., 2004; Toldrá, 2010; Kubiak, 2012a, 2012b). Smoke treatment with simultaneous partial drying, particularly during cold smoking is one of the manners of preservation of products. The most characteristic features of the smoked product are formed mainly as a result of smoke deposition on the surface and penetration inside the product. Smoke components dye the surface of products brown or golden giving them a characteristic appearance. Moreover, the smoke components influence the specific smell

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and taste and ensure antioxidizing and germinicide effect of smoking (Tóth and Potthast, 1984; Toldrá, 2010). Based on numerous information from researches in chemical technology of wood, many analogies may be conducted, which allows obtaining a precise notion on the formation of chemism of smoke components. However, one should remember that the quality and composition of smoke, changes in relation to the combustion conditions and the entire smoking process, including the use of devices and their characteristic structures (Bratzler et al., 1969; Tóth and Potthast, 1984). On account of small and average enterprises, where production is oriented to varied groups of meat products, smoking of which requires fast change of parameters of the process realization, single-trolley smoke-drying chambers are used (PEK-MONT, 2010). Both the amount of air flowing into the combustion zone and the speed of smoke removal, temperature and degree of combustion as well as moisture of used wood have an impact on the obtained mixture of smoke, particularly in this type of chambers. Despite many factors, which influence the intensity of colour, accumulation of compounds included in smoke, inter alia, contaminations, regularity of dye of the smoked products and the amount of harmful substances depends also on the appropriate structure of feed nozzles and the direction of setting towards the treated product (Kubiak, 2012b; Kubiak and Jakubowski, 2013). The progress related to civilization and technology caused the increase of exposure to harmful compounds, resulting from technologies of treatment, preservation and providing products with specific features. Thus, improvement of parameters, which may be controlled, seems to be so crucial. In case of smoke chambers, inter alia through adjustment of inlet nozzles (feed) structure. Regularity and intensity of smoke mixture and air flow in the smoke chamber and between the meat product allows reduction of the quality faults and decrease of concentration of pollutions from polycyclic aromatic hydrocarbons PAH group (Kubiak 2012a).

Objective of the paper

The objective of the paper was to reduce the content of PAH compounds in meat products, subjected to industrial conditions of smoking at the change of feed nozzles structure into the smoke mixture.

Materials and methods

The entire technological process of preparing raw material and smoking was carried out in industrial conditions in the meat processing plant I.Z. Grabowscy Sp. j. in Ościęcin. The smoking process was carried out in a single-trolley chamber of KWP-let type by Pek-Mont Sp. z o.o. company. (fig. 1a, b) with internal dimensions of the working part: length – 1,440 mm; width – 1,200 mm, height – 2,950 mm, with classic and modified length of feed nozzles into the smoke mixture and diffusing nozzles.

Variants of structure of feed nozzles and nozzles diffusing the smoke mixture in a chamber: the base one (classic arrangement of nozzles) – the structure of nozzles without modification (fig. 1a) and a suggested modification of structure of feed nozzles distribution which consists in elongation of nozzles 100 mm above the level of the chamber flow on both sides of the chamber (fig. 1 b). A variant of a modified structure was carried out as an arrangement contrary to the feed nozzles (inlet) into the smoke and air mixture in the chamber with a classic arrangement. Modification consisted in supplying the smoke mixture: into the chamber of a classic arrangement of nozzles from the top and in the suggested solution from the bottom.

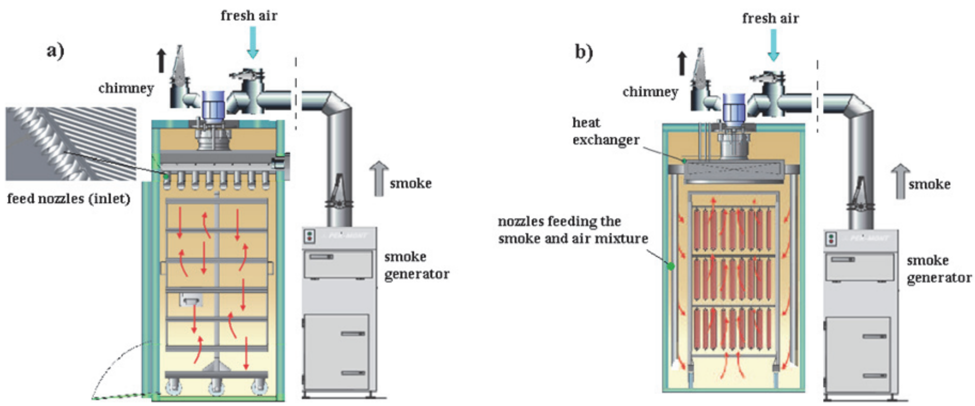

Figure 1. Graphic schematic representation of one-trolley smoke and cooking chamber KWP-1et type: a) classic input nozzles system-supplying; b) modified structure of supplying nozzles (www.pekmont.pl)

Conditions of the smoking process for products were modified and included in the programme of smoking. They included particular stages of the whole smoking treatment (tab. 1).

The plan of the research included 16 cycles for each smoke-drying chamber (a classic arrangement of nozzles and a modified arrangement of nozzles). Samples from each smoking cycle were collected by means of an envelope method (n=19). The collected samples from the smoked products by means of the envelope method (each time after the smoking process) were divided, uniformed and subjected to chromatographic analysis to check the content of polycyclic aromatic hydrocarbons (PAH). Preparation of samples consisted in taking out a collagen cover, which was also subjected to analysis of the content of PAH. Then, samples of the external layer to 1 cm were collected from bars and the external layer. All samples were averaged and subjected to freeze-drying, which facilitied further process of analysis.

Table 1
Stages and parameters of the smoking process

Stages of the smoking process	Time (min.)	Bar temperature (ºC)	Temperature in smoke chamber (ºC)
Drying	60	36.5	60
Smoking	50-60	48	60
Ventilation	2	-	60
Burning		72	75
Drying	>100	-	60
Drying of bars to the moment of obtaining a specific mass			

Source: www.grabowscy.pl

The analytical procedure for determination of PAH compounds included the use of liquid chromatography equipped with a fluorimetric detector. For isolation of PAH from the fixed matrix, accelerated solvent extraction (ASE), cleaning and enriching with the use of the solid-phase extraction (SPE) on silica gel was applied. An analytic unit consisted of a liquid chromatograph by Agilent Technologies company equipped with a four-fold pump, a degassing system of the mobile phase, a diode detector (DAD) (model 1100) and an automatic conveyor, a thermostat for a conveyor, a column thermostat and a fluorometric detector (FL) (Infinity 1260). ChemStation B. 04.03 software was used for data collection and processing. Division of analytes was carried out on the chromatographic column PAH Baker Bond (no of series G320Y010, batch number 993967-902) with dimensions 250 x 3 mm, seed diameter 5 μm) with a forecolumn. For isolation of PAH from fixed samples, an accelerated extraction by means of a solvent was carried out in Dionex ASE300 unit. The analytical procedure (isolation, cleaning and enriching PAH from samples) were subjected to validation (accuracy, precision of dosing and methods, linear character, limit of detection (LOD) and limit of quantitation (LOQ).

Results were set and subjected to statistical calculations (average, standard deviation, border of the measurement error), with the use of Statistica® 2012 and Microsoft Excel 2010 programme.

Research results

The research which was carried out proves that the average content of determined 15 PAH and the sum of 15PAH, 8PAH, 4PAH and BaP in the smoked products was varied on account of the system of nozzles.

In the chamber with the classic system of nozzles structure the content of PAH compounds for the oval batch, subjected to the smoking process was at a higher level in all collected samples (cover, external and internal part) compared to the products collected from the chamber, where the suggested variant of the structural solution of nozzles was used (tab. 2). The sum of the determined 4PAH (BaP, CHR, BaA, BbF) and 8PAH (BaP, CHR, BaA, BbF, BkF, BgP, DhA, IcP) and the presence of BaP decreased in products collected from the chamber with the modified structure of feed nozzles. Insignificant differences were only reported in the content of BaP for covers, both in the classic system of nozzles and in the modified one.

Table 2
PAH content in meat products subjected to industrial conditions of smoking in chamber with classic and modified system of feed nozzles

PAH ng/g of the Product	Product with geometrical centre of the bar – oval					
	classic system of nozzles			modified system of nozzles		
	cover	external layer	internal layer	cover	external layer	internal layer
Naphthalene	47.53	39.68	25.35	45.03	34.25	25.02
Benza(a)anthracene	23.23	20.47	10.66	26.12	19.23	9.68
Chrysene	81.86	79.24	12.18	22.01	18.32	9.22
Acenaphthene	227.58	186.59	158.07	212.07	176.87	124.27
Fluorene	112.3	67.36	34.55	115.42	68.18	33.73
Benzo(b)fluoranthene	53.58	38.12	19.73	26.98	7.03	5.16
Benzo(k)flouranthene	7.96	6.23	nd	7.34	4.23	nd
Benzo(a)pyrene	11.22	5.37	3.83	10.94	4.04	1.42
Dibenz(a,h)anthracene	nd	nd	nd	nd	nd	nd
Anthracene	93.41	16.30	nd	90.78	17.69	nd
Benzo(g,h,i,)perylene	4.58	nd	nd	4.73	nd	nd
Indeno(1,2,3-c,d)pyren	1.02	nd	nd	0.97	nd	nd
Phenanthrene	10.52	nd	nd	3.15	nd	nd
Fluoranthene	84.35	nd	nd	86.18	nd	nd
Pyrene	nd	nd	nd	nd	nd	nd
Total of 15 PAH	759.14	459.36	264.37	651.72	349.84	208.50
Total of 8 PAH	183.45	149.43	46.40	99.09	52.85	25.48
Total of 4 PAH	169.89	143.20	46.40	86.05	48.62	25.48

nd- not detected

Thus, in a chamber, where the suggested solution for modification of the nozzles structure was used, the PAH compounds values in the smoked products differed significantly from the values obtained for products from the chamber with the classic structure of nozzles. Their level considerably decreased which proves lower accumulation of PAH compounds which results from the circulation of the smoke mixture in a chamber and their deposition on the product. Although, the smoke and air mixtures had the same parameters, the method of supplying and then "washing" the product with smoke and deposition of compounds included in it had a significant meaning.

Work performed within the scope of optimization of the smoking process showed the next significant aspect related to the factor of propagation of the smoke mixture and enabled possibility of lowering accumulation of PAH compounds by modification of feed nozzles.

The suggested structural solution of the arrangement of feed nozzles and nozzles diffusing the smoke mixture inside the smoke chamber were more favourable on account of the values obtained from PAH analysis for the sum of 15, 8 and 4 PAH in comparison to the values obtained for products from a chamber with a classic arrangement of nozzles.

A classic arrangement of the structure of feed nozzles influenced the increased accumulation of PAH compounds contrary to the suggested modification, where the level of PAH compounds in the processed food products decreased significantly.

Meat products, smoked in the chamber with the modified structure of feed nozzles had a lower content of PAH compounds by 35-55% in all analysed samples (cover, external and internal layer) in comparison to the processed products from a chamber with a classic structure and arrangement of feed nozzles. It indicates a real possibility of lowering the PAH content in meat products subjected to smoking. Appropriate adjustment and regulation of the length of feed nozzles and the shape of arrangement towards each other on both side walls of a chamber will allow obtaining a product with required admissible limits of harmful compounds from the PAH group. After experimental verification which has been carried out, one may confirm with great possibility that such solutions should prevent the quality faults of both under-smoking as well as over-smoking of the processed meat products. The mentioned verification, carried out in industrial conditions, confirms the usefulness of structural changes, thanks to which a final product with a required standard with regard to reduction of pollutions (PAH) which result from the smoking process may be obtained.

In foreign publications there are no papers related to the change of structural elements of the smoke chamber, including feed nozzles (inlet). Thus, the issue related to modification of feed nozzles in the smoke chamber poses many new challenges in further research, which allow introduction of changes in multi-module smoke chambers. Probably, in many cases such solutions may also influence the production hygiene as well as effective use of the smoke mixture during appropriate smoking. Thus, the obtained information concerning the impact of the change of structure of chamber elements (feed nozzles) constitute a factor, which should be taken into account during the process of smoking.

Conclusions

1. The content of PAH in meat products from a smoke chamber with a classic arrangement and the structure of feed nozzles exceeded admissible limits of PAH compounds pursuant to EU Commission regulation.
2. The presented variant of modification of feed nozzles favourably influenced the conditions of the mixture flow in a smoke chamber, which resulted in reduction of accumulation of PAH compounds in meat products.
3. Modification of the structure of feed nozzles, which distribute the smoke mixture in connection to the possibility of introduction in the smoke process parameters, will allow many enterprises to meet the requirements for admissible levels of PAH in smoked meat products.

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WPŁYW MODYFIKACJI KONSTRUKCJI DYSZ ZASILAJĄCYCH W KOMORZE WĘDZARNICZO-PARZELNICZEJ NA OBNIŻENIE ZAWARTOŚCI ZWIĄZKÓW WWAW PRODUKTACH MIĘSNYCH

Streszczenie. Celem pracy było obniżenie zawartości związków z grupy WWA w przetworach mięsnych poddanych przemysłowym warunkom wędzenia w komorze przy zmianie konstrukcji dysz zasilających w mieszaninę dymu. Materiał do badań stanowiły próbki produktów mięsnych wędzonych o kształcie owalnym pobrane z dwóch komór wędzarniczych o różnej konstrukcji dysz zasilających i rozprowadzających mieszaninę dymu. Jakościową i ilościową analizę związków WWA wykonano techniką chromatografii cieczowej z selektywnym detektorem (HPLC-FLD-DAD). Badania nad zawartością i kumulacją związków z grupy WWA w przetworach mięsnych wędzonych z wykorzystaniem zmodyfikowanych dysz zasilających w porównaniu z klasycznym układem dysz wskazują jednoznacznie na korzystniejsze warunki rozprowadzenia mieszaniny dymu w komorze wędzarniczej ze względu na ich obniżony poziom.

Słowa kluczowe: przetwory mięsne, wędzenie, WWA, komora wędzarnicza, konstrukcja dysz

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ASSESSMENT OF VARIABILITY OF THE MAXIMUM CUTTING FORCE IN RELATION TO THE BEETROOT PULP STRUCTURE

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ABSTRACT

The paper presents methodology and results of measurement of the research on the process of cutting Beta vulgaris L beetroot in laboratory conditions, where values of the maximum cutting force of beetroot tissues collected from specific layers (upper layer, central layer, lower layer) were analysed. Variable parameters in the experiment were: knife sharpening angle (2.5º; 7.5º; 12.5º and 17.5º) and velocity of its movement (0.83 $mm \cdot s^{-1}$, 1.66 $mm \cdot s^{-1}$, 2.49 $mm \cdot s^{-1}$, 4.15 and 10 $mm \cdot s^{-1}$). The obtained data were subjected to mathematical analysis with the use of Excel and Statistica 6.0 software. Statistical analysis of results proved significant dependence of the maximum cutting force value on changes of mechanical properties of tissues in relation to the place of collecting samples, the knife sharpening angle and its movement. The highest value of force was obtained during cutting with a knife of the sharpening angle of ϕ=17.5º and the lowest during the use of a knife with ϕ=2.5º. Along with the increase of the knife movement velocity, the cutting force decreased. The best quality of samples was obtained with the use of the velocity which was 2.49 $mm \cdot s^{-1}$ and 4.15 $mm \cdot s^{-1}$ with knives with the cutting angle of 2.5º and 7.5º.

Introduction

Cutting applied in the fruit and vegetable industry is most frequently used at the processing of vegetables and fruit. It is used for generation of such stress conditions in the required place, that tissues are seperated into layers, which leads to the breach of the processed plant structure (Nadulski et al., 2013).

The cutting process is one of fragmentation methods, which aims at obtaining a product of a particular dimension and shape. It follows from organoleptic, technological and utility reasons. Vegetables for salads or juices require a higher degree of fragmentation while those designed for thermal processing require lower one (Sykut et al., 2005).

Factors, which have a considerable impact on the course of the material cutting process are mainly its strength properties which are strictly related to its structure, a plant habit and individual varietal properties, the place of collecting pulp and crop conditions (Bohdziewicz and Czachor, 2010; Ślaska-Grzywna, 2008).

Kinematic and dynamic parameters are the second group of factors. Tests on the cutting process are carried out in particular on account of improving the structure of cutting units, analysis of the blade parameters and their function in the cutting process. The cutting device structure must be adjusted to the characteristic properties and the raw material dimensions (Kowalik et al., 2013).

A beetroot (*Beta vulgaris L.*) is among vegetables, which are often consumed in Poland. It is characterized with a high content of vitamins, mineral salts (Ca, P, Mg, Fe), protein, sugars and biologically active compounds, which have a considerable significance in the human nutrition. Annual consumption of this vegetable is within 12 to 14 kg per one citizen (Kazimierczak et al., 2011; Rekowska and Jurga-Szlempo, 2011).

Popularity of this raw material is determined by simple cultivation, which does not require high expenditures, low climatic and soil requirements and a possibility of long storing, which allows consumption of a fresh raw material almost through an entire year. Popularity of this crop results also from a possibility of its storing. Roots of beetroot are used in the industry for production of juices, frozen vegetables, beetroot salad or natural food colour (Czapski et al., 2011).

During various technological processes (during collection of crops, storage and processing) changes which cause decrease of the value and quality of a vegetable may take place in the product (Kidoń and Czapki, 2007). Thus, so much attention is paid to the investigation of the structure of a beetroot root. Additionally, suitably selected cutting method may ensure high quality of the final product (Kusińska and Starek, 2012).

The objective and the scope of research

The objective of the paper was to examine the impact of the place from which a sample is collected of the root pulp on the cutting force of a beetroot. Variable parameters in research were: the knife sharpening angle and its movement velocity.

The scope of the paper included initial preparation of raw material, cutting out tissues from beetroot bulbs from three places, carrying out the test of cutting the material and its statistical description.

Research methodology

Average density for the investigated raw material was 1,061 $kg \cdot m^{-3}$, and moisture 86.1%. New Napoleon variety beetroots constituted the research material. It is an early variety. It has a rounded root with a smooth polished skin. The inside of the root is dark red and rings are visible in the cross section of a root.

Vegetables were from private field crops of Lubelskie Voivodeship. Beetroots were cultivated on the second class soil. Fertilization and conditioning as well as protective treatments were carried out with the use of mechanical equipment. Manual collection in the technological maturity stage was carried out. The harvested vegetables were selected on account of the shape and size, specimens with visible damage or with disease symptoms were rejected. Mature bulbs were selected. The beetroot shape was similar to the round one with an average dimension of 8±0.5 cm.

Material for research was collected after the second day from the harvest date to the seventh day. Vegetables were stored in a ventilated room in the temperature which was 4ºC and the relative moisture of air of 95%.

Pulp tissues were cut along the axis *y* from the layer: upper (wg), central (ws) and lower (wd). The place of cutting the material was presented in figure 1.

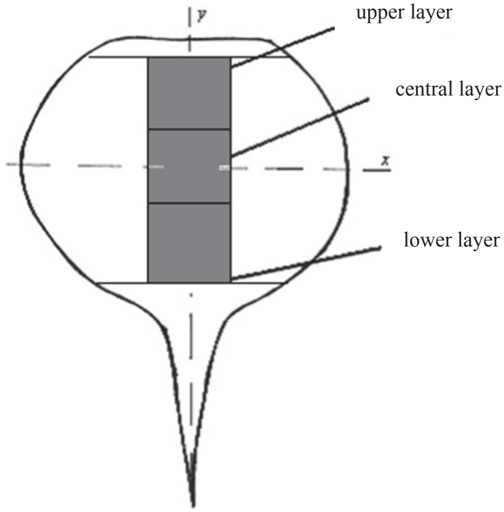

Figure 1. Place from which materialwss cut out

From the root along axis *y* a cuboid 60 mm high and with the side of the base of 20 mm was cut out and then divided into three cubes with 20 mm side. The top part and a rootlet was rejected. The material prepared this way was subjected to cutting with the use of TA.XT plus texturemeter maintaining a fixed orientation of a blade towards tissue, which was cut in half. The knife setting angle towards the axis of the collected material was 0º. Simple knives with the following sharpening angle were used: 2.5º; 7.5º; 12.5º; 17.5º. Knives were of the following dimensions: length 900 mm, width 70 mm, thickness 3 mm. Pulp tissues of a beetroot were placed on the base of the device along the axis *y*, and then where loaded with a cutting element with speeds which were: 0.83 $mm·s^{-1}$, 1.66 $mm·s^{-1}$, 2.49 $mm·s^{-1}$, 4.15 $mm·s^{-1}$ and 10 $mm·s^{-1}$. These speeds were selected due to the possibility of observation of the material deformation course, breaching its structure during cutting and outflow of juice from the beetroot.

As a result of the measurement, plots which presented relation of the cutting force and the knife movement, were obtained. From them the maximum value of the cutting force was determined (fig. 2). In the A-B area, the force increases from zero to the value, which causes squeezing of the material by a knife. In this area material is thickened. It is a threshold value of the cutting process. In the C point, there is a maximum cutting force, which decreases gradually to) (point D), in which the process ends.

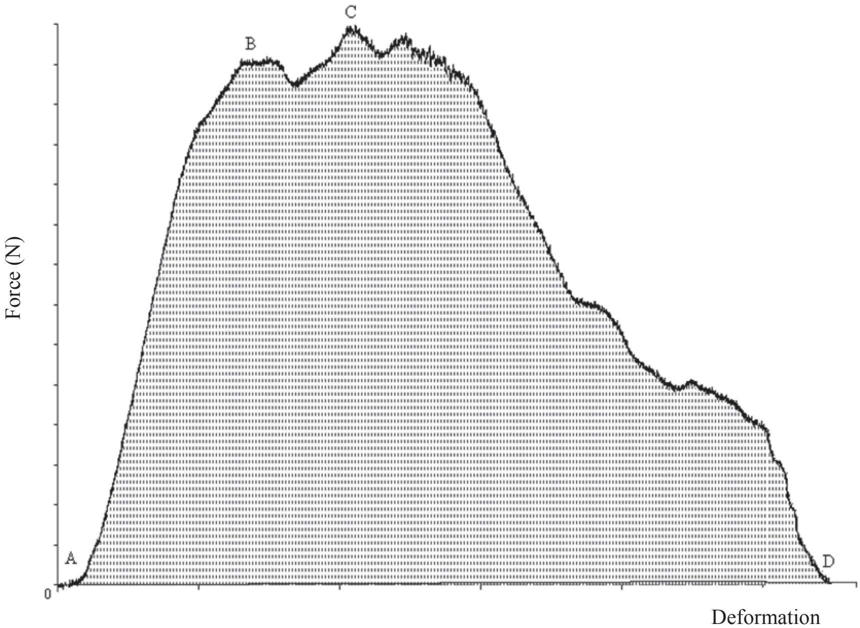

Figure 2. Exemplary relation force-deformation obtained during cutting

Tests were carried out in 10 repeats (for each knife, each speed and the place of collecting the material). The tests results were subjected to the regression analysis and the analysis of variance at the level of significance α = 0.05.

Research results and their analysis

Results of measurements of the maximum cutting force of a beetroot F_{max} were presented in figure 3-7. Various letters provided at the average values prove the significant differences.

Based on the results obtained in the experiment of cutting the root tissues of a beetroot with the knife movement velocity of 0.83 mm·s^{-1} it was reported that the average values of the maximum cutting force are within 12.4 to 35.3 N. The highest average value of the cutting force was obtained at the knife sharpening angle of ϕ=17.5º (for the upper layer of a beetroot), whereas the lowest average value of the cutting force is assigned to the angle of ϕ =2.5º (for a lower layer of the investiagted material). A considerable increase of force at the change of the knife sharpening angle from ϕ=7.5-12.5º takes place. For example for the material from the upper layer, value of the maximum cutting force increased from 16.5 N to 29.3 N.

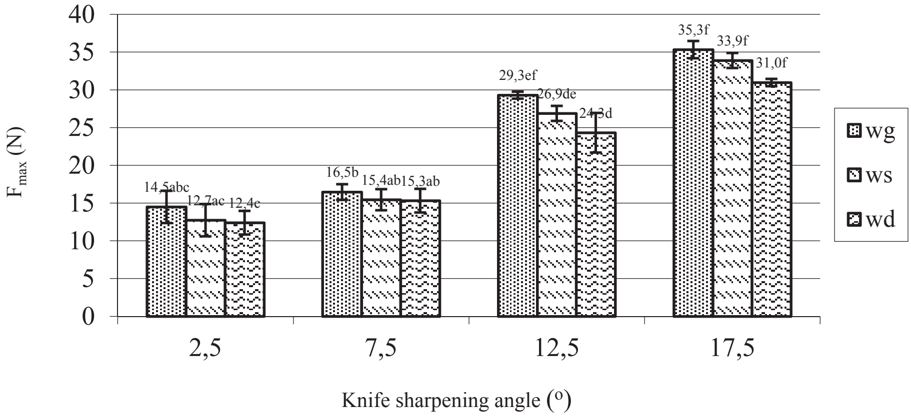

Figure 3. Maximum cutting force of beetroot in relation to the place from which samples were collected and knife sharpening angle at the velocity of knife movement of 0.83 mm·s^{-1}

Figure 4 presents the set of average maximum values of cutting forces obtained at the knife speed of 1.66 mm·s^{-1}. Nature of changes is the same as in figure 3. In this case also along with the increase of the knife sharpening angle, the maximum cutting force increases. The highest cutting force occurs for the knife with the sharpening angle of ϕ=17.5° for tissues which come from the upper layer of a beetroot and is 33.9 N, whereas the lowest for ϕ=2.5° for the bottom layer of the investigated root – 9.9 N. Along with the increase of the knife movement velocity the maximum cutting force decreases. The biggest difference in forces values during the speed changes was reported for a knife with the sharpening angle of ϕ=7.5° for the lower layer. At the knife speed of 0.83 mm·s^{-1} the cutting force value was at the level of 15.3 N, and after the increase of the speed, the value decreased to 11.5 N.

Further increase of the knife movement velocity resulted in the decrease of the maximum cutting force. Average values of the cutting force of the investigated biological material are within 9.8 N to 32.7 N. After cutting the material, the highest force is required for tissues from the upper layer of raw material and the lowest for the lower layer. For the raw material cut with the knife with the sharpening angle of ϕ=7.5° the cutting force of material from the upper layer is 14.5 N, from the central layer 11.5 N and from the lower layer 10.9 N.

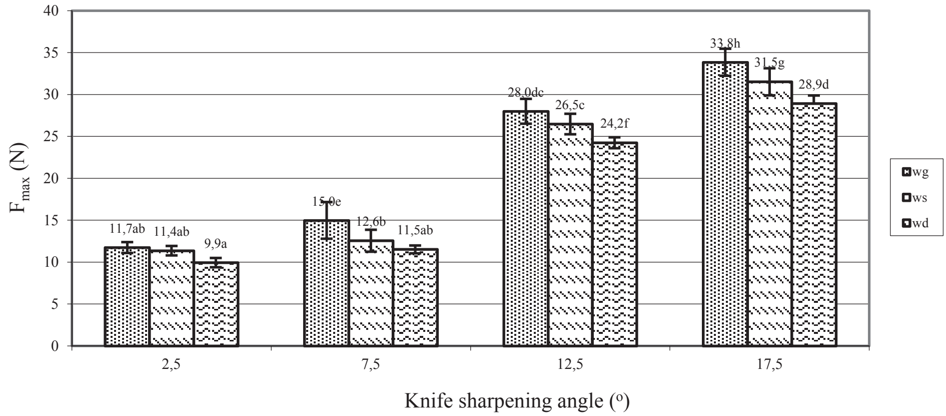

Figure 4. Maximum cutting force of beetroot in relation to the place samples from which samples were collected and the knife sharpening angle at the knife movement velocity of 1.66 mm·s^{-1}

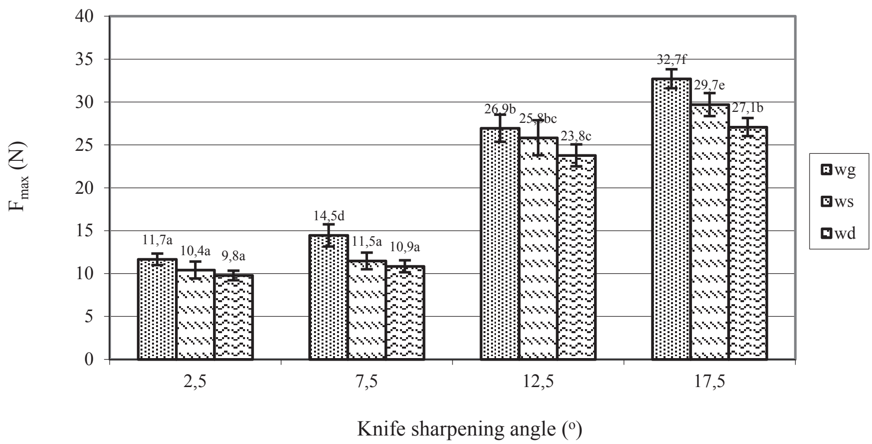

Figure 5. Maximum cutting force of beetroot in relation to the place from which samples were collected and the knife sharpening angle at the knife movement velocity of 2.49 mm·s^{-1}

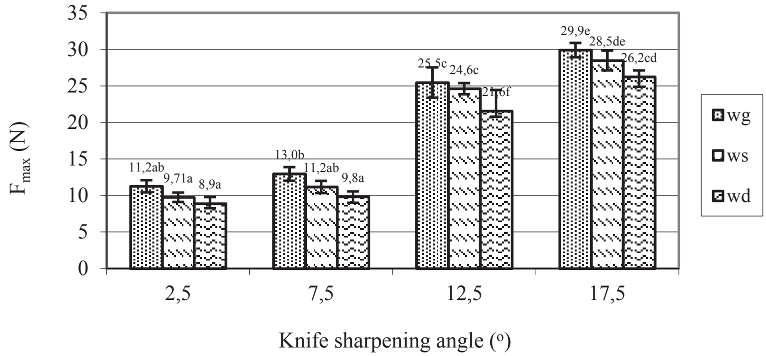

Figure 6. Maximum cutting force of beetroot in relation to the place from which samples were collected and the knife sharpening angle at the knife movement velocity of 4.15 mm·s^{-1}

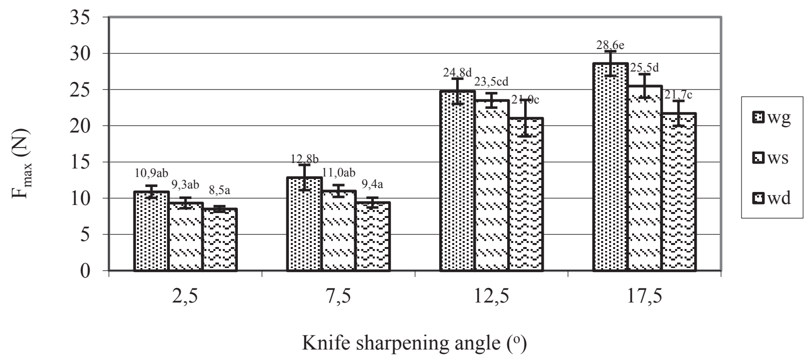

Figure 7. Maximum cutting force of beetroot in relation to the place from which samples were collected and the knife sharpening angle at the knife movement velocity of 10 mm·s^{-1}

It was found out that the lowest values of the cutting force occurred when the set knife movement velocity was 10 mm·s^{-1}. For the knife sharpening angle of ϕ=2.5º the value of the cutting force from the upper layer was 10.9 N, from the central layer 9.3 and from the lower layer 8.6 N in comparison to the results at the speed of 0.83 mm·s^{-1} it is respectively lower by 3.6 N, 3.4 N and 3.9 N. Figure 7 shows that the highest value of force was used for cutting tissues from the upper layer of the root with a knife of the sharpening angle of ϕ=17.5º (28.6 N).

During the research, the attention was paid to deterioration of the quality of the cut material along with the increase of the knife sharpening angle and the decrease of the knife movement velocity.

The researched relations were described with the following regression equations:

$$F_{wg} = 22{,}794 + 12{,}767\phi - 1{,}91\ln v - 0{,}296\phi^2 - 42{,}527\ln\phi \quad (1)$$

$R^2 = 0.991$, $\alpha \le 0.05$

$$F_{wś} = 23{,}397 + 14{,}59\phi - 1{,}969\ln v - 0{,}347\phi^2 - 49{,}143\ln\phi \quad (2)$$

$R^2 = 0.988$, $\alpha \le 0.05$

$$F_{wd} = 21{,}464 + 12{,}74\phi - 2{,}222\ln v - 0{,}302\phi^2 - 42{,}91\ln\phi \quad (3)$$

$R^2 = 0.978$, $\alpha \le 0.05$

where:

F_{wg}, F_{ws}, F_{wd} – the maximum cutting force respectively for the upper, central and lower layer, (N)
ϕ – knife sharpening angle, (°)
v – knife movement speed, ($mm \cdot s^{-1}$)
R^2 – coefficient of determination,
α – level of significance of differences.

Analysis of variance showed that the place of sample collection, the knife sharpening angle and its movement velocity has a significant impact on the value of the maximum cutting force of a beetroot.

Observations made during cutting the raw material may be presented as follows: for the speeds of the cutting test which were 0.83 $mm \cdot s^{-1}$ and 1.66 $mm \cdot s^{-1}$ of the maximum cutting force are the highest. After cutting samples have a smooth surface, however, low speeds cause considerable stresses on the surface of the material when the knife gets deeper in the material, which causes great deformations of raw material and the outflow of juice.

For the speed which was 10 $mm \cdot s^{-1}$ values of the cutting force are the lowest. However, it has no advantageous reference to the quality of the final raw material. During the test, a sample breaks down instead of being cut. Pieces of a beetroot have a discontinuous structure and uneven thickness of the cut off part, which causes losses in the material and decreases the quality.

When planning laboratory research of another raw materials, one should focus on setting speeds which are 2.49 $mm \cdot s^{-1}$ and 4.15 $mm \cdot s^{-1}$. At both set speeds, samples are cut one time and the cutting surface is quite uniform. In such cases the cut off fragments of a beetroot have a strictly defined structure, a regular shape and a desired form without damages.

The obtained standard deviations from the values of average cutting forces prove a considerable heterogeneous nature of the investigated raw material. Probably they result from a heterogeneous internal structure of a beetroot.

Conclusions

1. The place of tissue collection has a significant impact on the value of the maximum cutting force of a beetroot. The highest cutting force was obtained for tissues from the upper layer and the lowest for the material collected from the lower layer. It is related to the non-uniform structure of beetroot pulp and various mechanical features.
2. The relation of the maximum cutting force of the knife sharpening angle proved that the biggest angle of knife sharpening the highest cutting force of pulp. The highest force was obtained during cutting with a knife of the sharpening angle ϕ=17.5º and the lowest during the use of a knife with ϕ=2.5º.
3. The cutting speed in the tested scope from 0.83 $mm \cdot s^{-1}$ to 10 $mm \cdot s^{-1}$ significantly influences the cutting force of a beetroot. Along with the increase of the knife movement speed, the maximum cutting force decreases.
4. The best quality of samples was obtained with the use of the speed which was 2.49 $mm \cdot s^{-1}$ and 4.15 $mm \cdot s^{-1}$ with knives with a cutting angle 2.5º and 7.5º.

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OCENA ZMIENNOŚCI MAKSYMALNEJ SIŁY TNĄCEJ W ZALEŻNOŚCI OD BUDOWY MIĄŻSZU KORZENIA BURAKA ĆWIKŁOWEGO

Streszczenie. W artykule przedstawiono metodykę oraz wyniki pomiaru badań procesu cięcia buraka ćwikłowego *Beta vulgaris* L. w warunkach laboratoryjnych, gdzie analizowano wartości maksymalnej siły cięcia tkanek korzenia buraka ćwikłowego pobranych z określonych warstw (warstwa górna, warstwa środkowa, dolna). Parametrami zmiennymi w doświadczeniu były: kąt zaostrzenia noża (2,5º; 7,5º; 12,5º i 17,5º) oraz prędkość jego przemieszczania (0,83 $mm \cdot s^{-1}$, 1,66 $mm \cdot s^{-1}$, 2,49 $mm \cdot s^{-1}$, 4,15 $mm \cdot s^{-1}$ i 10 $mm \cdot s^{-1}$). Uzyskane dane poddano analizie matematycznej korzystając z programu Excel i Statistica 6.0. Analiza statystyczna wyników wykazała istotną zależność wartości maksymalnej siły cięcia od zmian cech mechanicznych tkanek zależnie od miejsca pobrania próbek, kąta zaostrzenia noża i jego przemieszczenia. Największą wartość siły uzyskano podczas cięcia nożem o kącie zaostrzenia ϕ=17,5º, a najmniejszą podczas użycia noża o ϕ=2,5º. Wraz ze wzrostem prędkości przemieszczenia noża siła cięcia malała. Najlepszą jakość przeciętych próbek otrzymano przy zastosowaniu prędkości wynoszących 2,49 $mm \cdot s^{-1}$ i 4,15 $mm \cdot s^{-1}$ nożami o kącie zaostrzenia 2,5º i 7,5º.

Słowa kluczowe: burak ćwikłowy, siła cięcia, kąt zaostrzenia noża, przemieszczenie

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UNEVENNESS OF COVERAGE OF THE SPRAYED OBJECTS WITH THE SELECTED SINGLE- AND DOUBLE-STREAM NOZZLES

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ABSTRACT

The paper presents the results of studies on uneven coverage of sprayed objects using single- and double-stream nozzles. Studies were conducted in laboratory conditions, using a nozzle carrier. To facilitate the interpretation of the study results on uneven coverage and to demonstrate the existing relations, the authors used an indicator of the average degree of coverage of sprayed objects, which is a relation of cumulative coverage of particular sprayed objects to the number of these objects. Although the same experimental conditions for all studied nozzles were used the obtained results of the average degree of coverage and uneven coverage were characterised by considerable differences for particular nozzles. The analysis of the study results did not reveal the existence of the direct dependence between the average degree of coverage of the sprayed objects and the coefficient of coverage uniformity. Both in case of single- and double-stream nozzles, the ones in case of which the lowest and highest average coverage was reporte , were characterised by a similar coefficient of uneven coverage.

Introduction

Effectiveness of the spraying procedure depends, inter alia, on the degree and uniformity of liquid spray application as well as on the uniformity of liquid precipitation and the coverage degree of sprayed surfaces (Godyń et al., 2010). The quality of spraying is largely affected by the applied nozzles. Given the wide range of nozzles on the market, farmers have difficulties choosing the right type and size to get the right effect of a treatment. Every quality analysis of work available on the market of nozzles therefore makes this choice easier. Most of all, selection of the right criterion for assessment of the spraying quality is not only a practical, but also a scientific problem.

One of the indicators characterising the quality of procedure, and thus the proper operation of the applied equipment, is the indicator of the transverse non-uniformity of the spray liquid distribution / liquid spray precipitation. The least complicated procedure of assessment of nozzles operation is conducted during attestation of a sprayer, among others, determining the transverse unevenness indicator (CV). According to the Polish regulations on the requirements for the field sprayers, the value of the coefficient of variation CV% should not be greater than 10% (Szewczyk, 2010; Ch. MRiRW).

Literature includes reports of possible automation of this process (Lodwik and Pietrzyk, 2013a). Such solutions would greatly facilitate operation of the sprayer control station. The solutions used so far to assess the transverse distribution of liquid on the sprayed surface are, however, quite expensive, therefore experiments use the method of photography and the computer image analysis (Lodwik and Pietrzyk, 2013b).

Liquid distribution under nozzles depends on many factors and conditions of liquid spraying. According to Koszel and Sawa (2006) the liquid distribution assessment index under the nozzle depends on the wear condition of a nozzle. Measurement of the liquid flow of a single nozzle in the time unit compared to the nozzle's manufacturer data (nominal expense) indicates the wear condition of nozzles (Koszel and Sawa, 2006; Koszel and Hanusz, 2008; Koszel, 2009). Also important during the liquid precipitation on the sprayed objects is the spraying velocity, direction and wind power (Szewczyk and Wilczok, 2008; Szewczyk and Łuczycka, 2010).

A method of comparing the quality of nozzles operation with the use of assessment of the coverage degree of the sprayed objects is more sophisticated and advanced, because in this method you can also take into consideration the conditions during spraying, both in the laboratory and in field conditions. The objects covering quality can be determined with a chemical method of transferring the traces of droplets after spraying with Miedzian 50WP fungicide from leaves to paper and classifying the obtained images in the scale from 0-400 (where 400 means the leaves covered very well) (Wachowiak and Kierzek, 2007; Kierzek and Wachowiak, 2009). The coverage degree is expressed in percentage and is defined as the relation of the surface covered with liquid to the total surface area to be measured. This ration indicates what part of the protected object is in direct contact with the sprayed liquid (Hołownicki et al., 2002; Lipiński et al., 2007; Godyń et al., 2008; Szewczyk et al., 2012). Both the coverage degree and application of liquid spray may be useful for comparative purposes – for assessing the changes in the spraying technique, verification of the selected parameters of operation of the sprayer and assessment of nozzles operation depending on technical and technological factors (Hołownicki et al., 2002; Derksen et al., 2006; Szewczyk et al., 2012). Research results show that there is a correlation between the coverage degree and the biological efficacy. According to some researchers, the satisfactory effectiveness (for most p.p.m.) in the control of pests is provided by 30% degree of coverage with spray liquid (Hołownicki et al., 2002). However, the studies do not clearly show whether this value applies to the average calculated coverage degree taking into account all components of the sprayed plants and in relation to which pesticides this degree of coverage should apply – with the systemic or contact effect.

The efficiency of plant protection procedures in areas such as: biological efficacy, the use of spray liquid and economic balance, according to many experts in this field, depends mainly on the implementation technique. Labels of p.p.m. contain little information about the application technique. There is no comprehensive technical and utility information on nozzles, which can result in fatal improper use of p.p.m. According to Czaczyk (2013) operators' and consultants' ability to professionally chooose parameters for spraying liquid based on the support information developed in the accessible form is significant. High skills and awareness of effects thanks to the use of modern equipment advantages allow using lower doses of spray liquid and preparations in the given conditions without the risk of failure. Conscious and professional selection of the optimal spray according to the needs of the treatment conditions should result in production of the greatest volume of spray liquid in the form of the most desired fraction of sprayed droplets.

However, according to the authors, the presented indicators do not allow a full assessment of the spraying quality. They can only serve as basic parameters for comparing the equipment applied in the procedure and its accessories of different types and kinds of nozzles. Contrary, additional information for assessment of the spraying procedure can be provided to a sprayer user by such indicators as proposed by the authors – the average coverage of the sprayed objects and the indicator of coverage unevenness of the sprayed objects differently located in relation to the direction of the liquid stream.

Objective of the studies and methodology

The objective of this study was to determine the effect of the type and size of a nozzle on the average coverage degree and unevenness of coverage with sprayed liquid using the selected single- and double-stream nozzles for the fixed flow rate from the nozzles and the spraying speed.

The following nozzles were selected for the studies: single-stream: IDK 12005; DGTJ 11005; AI 11004; IDK 12004; DGTJ 11004; TJ 11003A; AI 11003; DGTJ 11003; IDK 12003 and double-stream: AI 3070-03; AITTJ 11003; HiSpeed 11003; DGTJ 60 11003; CVI TWIN 11003; TJ 60 11003; Lo-Drift 110015 – in the double-nozzle body.

In the studies the following spraying parameters were used:

- dose of liquid $Q=166.8\ l\cdot ha^{-1}$,
- spraying speed $v=2.78\ m\cdot s^{-1}$ ($10\ km\cdot h^{-1}$),
- flow rate from a nozzle $q=1.39\ l\cdot min^{-1}$,
- spraying height h=0.5 m,
- liquid pressure p for:
  - nozzles size 03-0.4 MPa,
  - nozzles size 04-0.225 MPa,
  - nozzles size 05-0.145 MPa.

The studies were performed on the test rigs presented in figure 1. The basic element on the presented diagram was the nozzle carrier imitating the sprayer operation. The nozzle carrier consisted of the liquid system, responsible for maintaining the set pressure and the chassis, allowing its passage. The route of the carrier was divided into three parts – run, measurement and final. During the passage on the run line, the carrier obtained the desired speed, then it moved along a 10-meter long measurement line, on which three artificial plants were set in 3-metre spacing. Each plant constituted one iteration. Samplers placed on them in the form of water-sensitive papers were the sprayed objects marked as: horizontal and vertical transverse and longitudinal (fig. 2). The fixed operating speed was set by adopting the appropriate value on the frequency converter, which for the speed of $2.78\ m\cdot s^{-1}$ was 30.7 Hz.

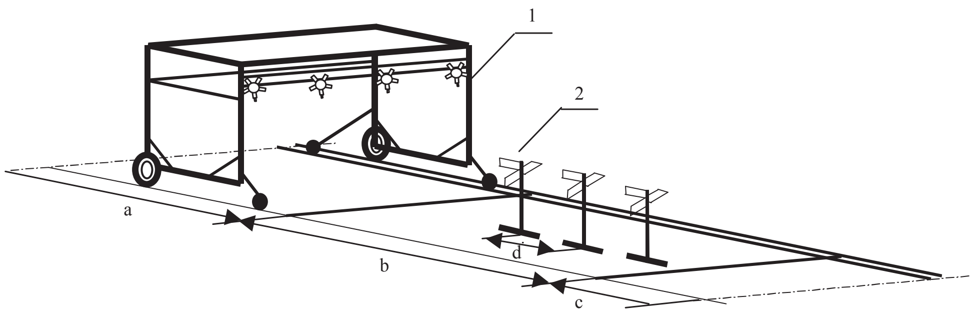

Figure 1. Diagram of test rigs: 1 – carrier of nozzles, 2 – artificial plant, a – run line, b – measurement line, c – final line, d – distance between artificial plants

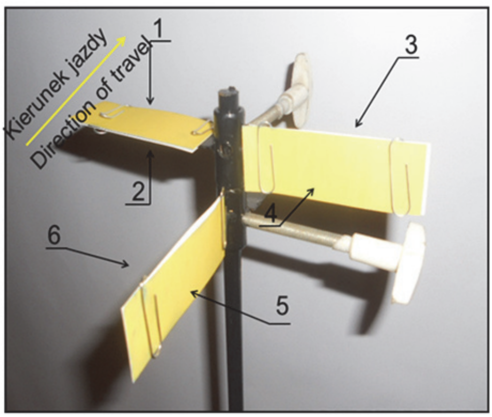

Figure 2. View of artificial plant with marked tested objects: 1– upper horizontal (A_{pog}), 2 – lower level (A_{pod}), 3 – vertical diagonal depart (A_{oj}), 4 – vertical diagonal approach (A_{nj}), 5 – vertical right longitudinal (A_{bp}), 6 – vertical longitudinal left (A_{bl})

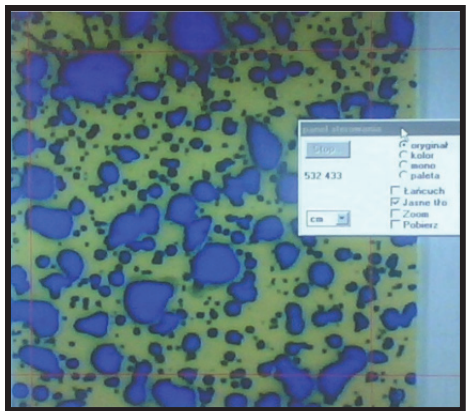

Figure 3. View of analysed sampler

The coverage degree of the sprayed objects was assessed in the Institute of Plant Protection – National Research Institute in Poznan in the laboratory, equipped with a microscope and computer with CSS Video Frame Grabber software. The surface of samplers after contact with the spray liquid changed its colour from yellow to navy blue.

The coverage degree of the sprayed surfaces was determined as the relation of the surface covered with liquid to the remaining one taken into account in the measurement. Sections of a sampler with the dimensions 20x20 mm were taken for analysis in three randomly selected locations. The view of the analysed sampler is presented in figure 3. In order to facilitate the interpretation of the study results of the coverage degree and indication of the existing relations, the authors used the so-called indicator of the average coverage degree of the sprayed objects obtained by summing the coverage degrees of particular sprayed objects and dividing this sum by the number of these objects.

The coefficient of uneven coverage (symbol from the formula) of the sprayed objects was determined by the equation (1) (Gajtkowski, 2000), treating the degree of coverage as the abstract number:

$$\eta = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(q_i - q_{śr})^2}}{q_{śr}} \quad (-) \tag{1}$$

where:

q_i – coverage degree of the given object,
$q_{śr}$ – average degree of coverage of the sprayed objects,
n – number of the sprayed objects

Test results

The results of measurements of the average coverage degree for single- and double-stream nozzles are presented in figures 4 and 5, while the indicator of uneven coverage of the sprayed objects – in figures 6 and 7. Since during measurements no traces of coverage of horizontal bottom objects were reported, the results of coverage only for 5 objects were used for further studies. The order of setting the nozzles in the presented graphs has no significance for the comparative purposes, whether in the case of the average degree of coverage, or the indicator of unevenness. The important value of the presented results of studies is to highlight the clear differences in the values of the coverage degree or the uniformity index, which occurred in case of both indicators relating to the studied nozzles.

It should be emphasized here that the conditions of measurements of the studied indicators for all the investigated nozzles were the same. For one-stream nozzles the difference between the smallest and largest value of the average degree of coverage was approximately 8%. While for double-stream nozzles over 11%.

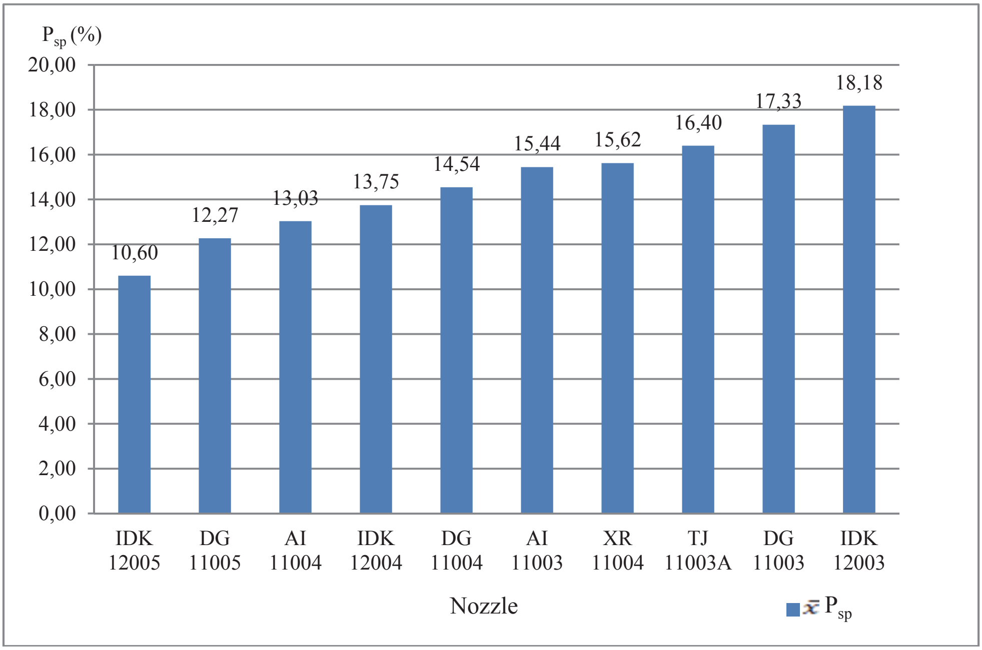

Figure 4. Mean degree of coverage of sprayed objects for single-stream nozzles

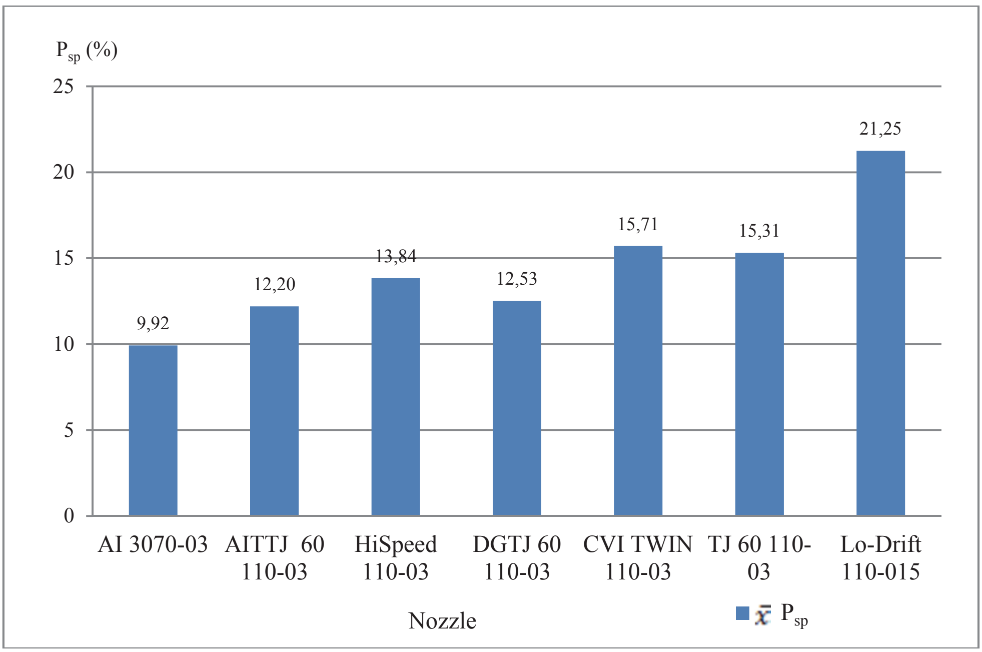

Figure 5. Mean degree of coverage of sprayed objects for double-stream nozzles

In case of double-stream nozzles these results may surprise the specialists, as it could have been expected that two streams of the sprayed liquid should significantly reduce the potential shortcomings of heterogeneity of the liquid stream or the limited ability to cover differently situated sprayed objects. The results of the measurements of the average coverage degree for both studied types of nozzles confirm the known dependency, saying that the greater degree of liquid spraying results in better coverage of the sprayed objects. When, in case of single-stream nozzles, where different sizes of nozzles were selected for tests, the mentioned phenomenon does not evoke any doubts, double-stream nozzles were represented by the same size of nozzles. Their comparison to the Lo-Drift 110015 nozzles placed in the double-stream body clearly indicates that a much better average coverage degree was obtained for the mentioned double-nozzle spraying system.

Analysis of the results of coefficients of uneven coverage of the sprayed objects obtained during the studies leads to similar conclusions, as in case of the average coverage degree. Despite the same conditions of experimentation, the obtained results for particular nozzles are quite different. This applies equally to single- and double-stream nozzles.

The difference between the smallest and largest value of the calculated coefficient of uneven coverage for single-stream nozzles was over 0.30, and in case of double-stream ones – 0.36. In practice, this often means that over one hundred percent differences in the coverage of the sprayed objects occur.

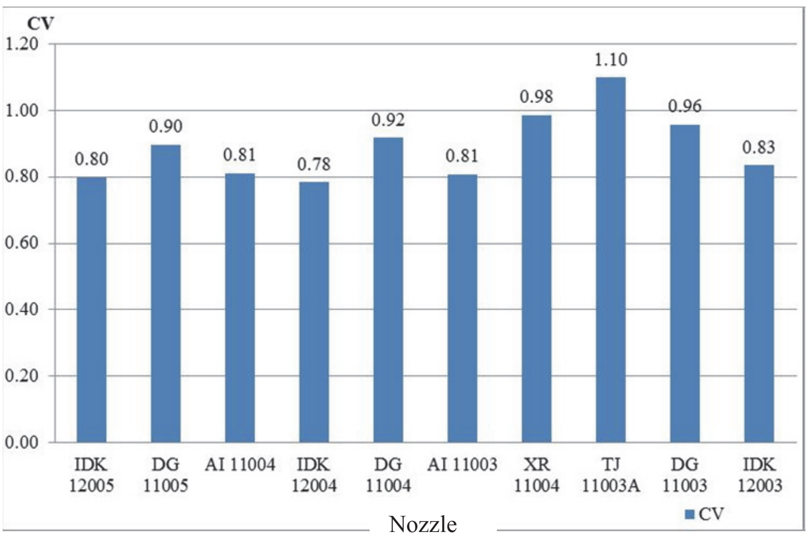

Figure 6. Ratio of coverage unevenness of sprayed objects for one-stream nozzles

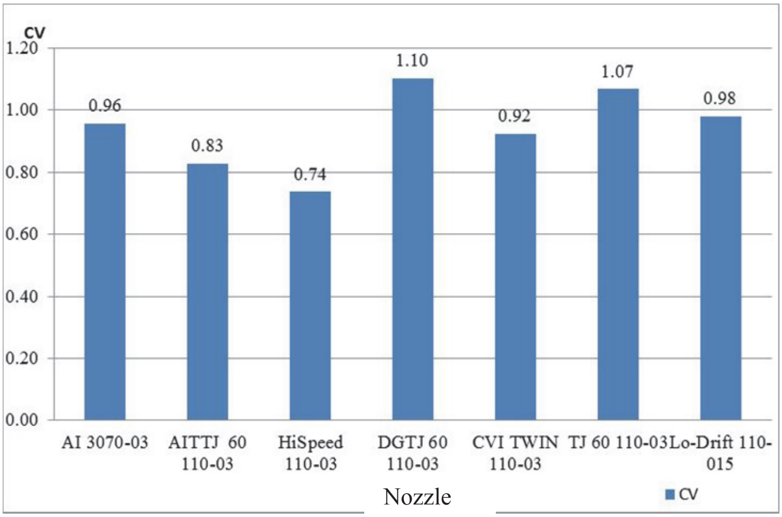

Figure 7. Ratio of coverage unevenness of sprayed objects for double-stream nozzles

There were no dependencies between the average coverage degree and the uneven coverage coefficient. The nozzles, for which the highest average degree of coverage was reported, were not characterised at the same time by the greatest coefficient of unevenness.

Conclusions

During the studies there were not stated any traces of coverage of the objects referred to in the methodology as the horizontal lower surface, both in case of single- and double-stream nozzles. This finding is contrary to the general opinion that double-stream nozzles better cover the underside of a leaf.

The obtained test results and their analysis did not show any direct relationship between the average coverage degree of the sprayed objects and the coefficient of uneven coverage. In case of one-stream nozzles, those nozzles, for which the smallest and largest average coverage was stated, were characterised by a similar coefficient of uniformity of coverage.

The test results using double-stream nozzles of the same size showed great diversity both of the average coverage degree (differences exceeding 100%) and the coefficient of uneven coverage (differences over 30%). A similar phenomenon was observed while comparing the one-stream nozzles of the same size.

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NIERÓWNOMIERNOŚĆ POKRYCIA OPRYSKIWANYCH OBIEKTÓW WYBRANYMI ROZPYLACZAMI JEDNO- I DWUSTRUMIENIOWYMI

Streszczenie. W pracy przedstawiono wyniki badań nierównomierności pokrycia opryskiwanych obiektów przy użyciu rozpylaczy jedno- i dwustrumieniowych. Badania przeprowadzono w warunkach laboratoryjnych, wykorzystując nośnik rozpylaczy. Dla ułatwienia interpretacji wyników badań nierównomierności pokrycia i wykazania istniejących zależności autorzy posłużyli się wskaźnikiem średniego stopnia pokrycia opryskiwanych obiektów, który jest stosunkiem sumarycznego pokrycia poszczególnych opryskiwanych obiektów do ilości tych obiektów. Mimo zastosowania takich samych warunków eksperymentu dla wszystkich badanych rozpylaczy uzyskane wyniki średniego stopnia pokrycia i nierównomierności pokrycia charakteryzowały się dużymi różnicami dla poszczególnych rozpylaczy. Analiza wyników badań nie wykazała istnienia bezpośredniej zależności między średnim stopniem pokrycia opryskiwanych obiektów a współczynnikiem nierównomierności pokrycia. Zarówno w przypadku rozpylaczy jedno-, jak i dwustrumieniowych te, dla których stwierdzono najmniejsze i największe średnie pokrycie, charakteryzowały się podobnym współczynnikiem nierównomierności pokrycia.

Słowa kluczowe: stopień pokrycia, współczynnik, nierównomierności pokrycia, rozpylacz

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DETERMINATION OF SEPARATION POTENTIAL OF PEA SEEDS TO BE USED AS SOWING MATERIAL BASED ON DIFFERENCES IN EXTERNAL FRICTION COEFFICIENTS

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ABSTRACT

The paper presents research results concerning differences in basic separating features of batches of pea, which enable efficient separation of material fractions of high germination ability. It was found out that based on differences in such properties, such as: dimensions, mass and critical velocity of lifting seeds, this technological operation may not be sufficiently carried out. In order to solve a practical problem, an attempt was made to determine possible differences in external friction coefficients of seeds on bases made of: steel, gum, cotton, linen, polar and cotton-linen. It was determined that statistically significant differences for this feature occur only for steel. It was suggested that in practice for selection of pea seeds of high germination ability, a 'flighting' [screw conveyor] should be used.

Introduction

Pea (*Pisum sativum L.*) is an annual plant from the Fabaceae family that has been cultivated in temperate climate since ancient times (Grudnik, 2005). Seeds and young pods are the edible parts. Apart from taste characteristics, this vegetable is a valuable source of protein, carbohydrates, mineral salts and vitamins (Gumienna et al., 2006). Lee et al. (2008) demonstrated that legumes are capable of reducing blood pressure. Compared to other leguminous plants, pea contains more potassium, magnesium, iron, and zinc with a lower content of sodium (Grela et al., 2005). Niehues et al. (2010) showed that bioactive peptides of pea (*Pisum sativum L.*) proteins may be used as a component of functional food that protects children against infections such as *Helicobacter pylori*. Pea demonstrates uneven maturation that starts from pods located in the lowest parts of the plant and then moves upwards. When the lowest pods become mature, a two-phase harvest should begin; such procedure involves cutting plants and leaving them on frames for drying, or a one-phase harvest with desiccation should be initiated. A one-phase harvest without desiccation may result in a substantial loss of seeds. After harvesting, pea seeds are further dried up to 14% of humidity. Depending on cultivation conditions, the yielding of this plant ranges from three to approximately eight tonnes per hectare (Doré et al., 1998).

Initial analysis of the tested material

The study was carried out with cv. "Cud Kelvedonu" pea seeds provided by "Przedsiębiorstwo Nasiennictwa Ogrodniczego i Szkółkarstwa S.A. TORSEED" located in Toruń. These included three samples of 1 kg each, packed in paper (brand) bags and sealed. The samples were prepared by the employees of the company's laboratory. Information on the packages indicated that these seeds were destined for sowing and that they originated from a single batch (delivered by a farmer to the above-mentioned company). This presented a serious problem to the company, as the material that was treated in the K-541 Petkus treatment facility had an average germination power of approximately 53%. The required germination power of pea seeds destined for sowing should be at least 80% (Michalik and Weiner, 2004). The selected samples differed in seed germination power of 37%, 53% and 65%, respectively.

The delivered seed samples were subjected to an initial analysis in the laboratory at the Department of Working Machines and Research Methodology, University of Warmia and Mazury in Olsztyn. The seed humidity in the individual samples was determined with the drying method (according to PN-91/A-74010) and ranged from 8.3-9.6%. As the range of changes in humidity was insignificant, it was assumed that humidity would not have a significant impact on the results of subsequent measurements.

In addition, max. 0.3 kg of seeds was selected from the sample with the highest germination power (65%); the average germination power after 8 days was approximately 97%. This fraction constituted the so-called "fourth sample" for further experiments.

Further experiments involved a determination of differences in the basic separation parameters that are applied in industrial technological procedures associated with the cleaning of seed mixtures (Grochowicz, 1994). To this end, 300 seeds from each sample were randomly selected and the average values of the following parameters were determined: single seed mass, basic dimensions (length, width and thickness) and critical drift velocities in the vertical air stream.

This data was statistically processed. The basic statistical parameters (mean, standard deviation and minimal random sample size) were determined and the analysis of variance for the average values of individual traits was performed to identify statistically significant differences. In case of such differences, a "post-hoc" Duncan's test was applied to distinguish the so-called "homogenous" groups. Statistica v. 10 statistical software package was used for calculations and hypotheses testing performed at $\alpha=0.05$ (the level of significance) (Greń, 1984; Rabiej, 2012). The results are presented in table 1.

Tabela 1
The list of statistical analyses results which characterize basic separating properties of pea seeds of „Cud Kelvedonu"cultivar for trials of various germination ability

Parameter	Germination ability (%)							
	37		53		65		97	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
Length (mm)*	7.17[a]	0.947	7.71[b]	0.740	7.99[b]	0.654	7.92[b]	0.543
Width (mm)	6.57[a]	0.859	6.56[a]	0.742	6.58[a]	0.688	6.59[a]	0.605
Thickness (mm)*	6.22[a]	0.867	5.95[b]	0.648	5.83[b]	0.582	5.47[b]	0.563
Seeds mass (g)*	0.17[a]	0.034	0.21[b]	0.036	0.20[b]	0.031	0.22[b]	0.019
Critical drift velocity ($m \cdot s^{-1}$)*	11.72[a]	0.119	12.16[b]	0.2406	12.47[c]	0.148	12.59[c]	0.134

$\overline{X}$ – average, S – standard deviation, * averages marked with the same letters in a line do not differ statistically (homogenous group)

The calculated minimum sizes for measurements of the individual characteristics ranged from 28 to 284 seeds for each sample. This means that the assumed initial size (of 300 seeds from each sample) was sufficient.

The results of calculations showed minor differences between the average values for a given trait and for different samples. It was found that seeds with a germination power of 37% significantly differed in the average length, thickness, single seed mass and critical drift velocity in the vertical air stream from seeds from the other samples. The average values of the above-mentioned parameters were statistically and significantly lower, except for thickness which was significantly higher.

Significantly higher average values of critical drift velocity were recorded for seeds with germination powers of 65% and 97% – a separate homogenous group. A pneumatic separator would thus allow for separating seeds with a germination power over 65% although it would not be possible to meet the criterion for seed material (Michalik and Weiner, 2004).

To sum up, it was found that based on the above-mentioned separation parameters, it was not possible to effectively separate seeds with high germination power from the analysed batch of pea.

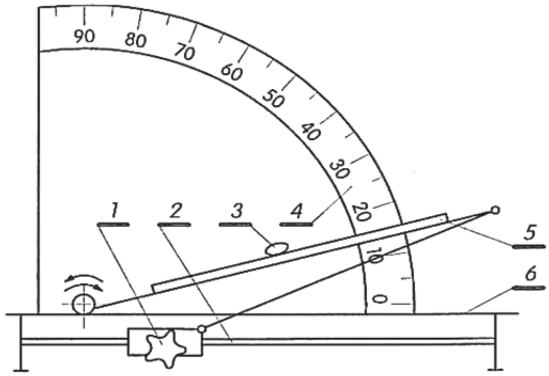
Visual differences in colour and external surface texture in seeds from different samples were a sort of suggestion for further studies on a solution to the described problem. Seeds with the lowest germination power were roughly light yellow in colour and wrinkled to a major degree. Together with the increase in germination power, deformation of seeds was smaller and a change of colour to light green was observed in seeds from the sample with a germination power of 97% (Choszcz et al., 2011). These observations allowed us to prepare a hypothesis assuming significant differences in external friction coefficients in pea seeds with different germination power.

Objective of the study

The objective of the study was to determine potential differences in external friction coefficients over different materials for pea seeds with variable germination power in the context of their potential use in sorting procedures..

Methodology of the study

Measurements of external friction coefficients of pea seeds over different surfaces were taken on a measuring station described by Kaliniewicz and Rawa (2000) and are presented in Figure 1.



Source: Kaliniewicz i Rawa, 2000

Figure 1. Schematic representation of a device for measuring angles of external friction of loose materials on various bases: 1 – wheel for regulation of tilt angle of a plane, 2 – guidebar, 3 – particle (seed), 4 – protractor, 5 – replaceable base, 6 – base

The measurements involved placing a seed on a replaceable surface in the upper part of a movable arm of the level. The arm of the level was then manually lifted with a knob (1) until the seed started to move over a surface. The angle of elevation for the arm of the level was read from the scale of a protractor (4) to an accuracy of 1º. This angle was transformed according to a relation (1) into the value of static friction coefficient (μ) (Grochowicz, 1994; Kram, 2008)

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

with the symbol β - denoting the angle of elevation of the level's arm in relation to the surface, (^{o}).

The steps were repeated for subsequent seeds.

The experiments were carried out for the same seeds that were used in the initial studies, whereas the following materials were used as a surface: St3 steel (with roughness at

Ra=0.46 μm), soft rubber without warp (Ra=0.24 μm) and linen (cotton, flax, fleece and cotton-flax). A relatively large assortment of linen types resulted from the assumption to use the so-called inclined belt seed separator for seed separation. The basic characteristics of the above-mentioned linen types are presented in table 2.

Table 2
The list of parameters of canvas structure

Kind of material	Thread density (the number of threads per 10 cm)		Surface mass ($g \cdot m^{-2}$)	Type of material	
	Warp	Woof	Osnowa	Warp	Woof
Cotton – fabric, plain weave	240	155	126	Cotton	Cotton
Linen – fabric, plain weave	240	150	140	Flax	Flax
Polar – double sided fleece fabric	-	-	244	Polyester	
Cotton-linen – fabric, plain weave	200	125	256	Cotton	Cotton-flax

The analogous calculation procedures as the ones described in the section on the initial analysis of the tested material were applied to compare the significance of differences between the average friction coefficient values.

Results and their analysis

The average values of friction coefficients depicted in figure 2 and their standard deviations ("whiskers") for different materials used as the surface indicate that the highest values of this parameter (regardless of germination power) were recorded on fleece linen. These values differed statistically and significantly from the average values of friction coefficients for the other material types. Considerable differences in this parameter were also recorded for such materials as steel, rubber and cotton-flax linen.

No statistical differences between the average values of friction coefficient for particles over cotton and flax linen (for given germination power values) were observed, although they constituted a separate group in relation to the other surface materials.

However, for practical reasons, the differences in the discussed parameter for a given material are most important. The detailed results of the comparisons are presented in table 3.

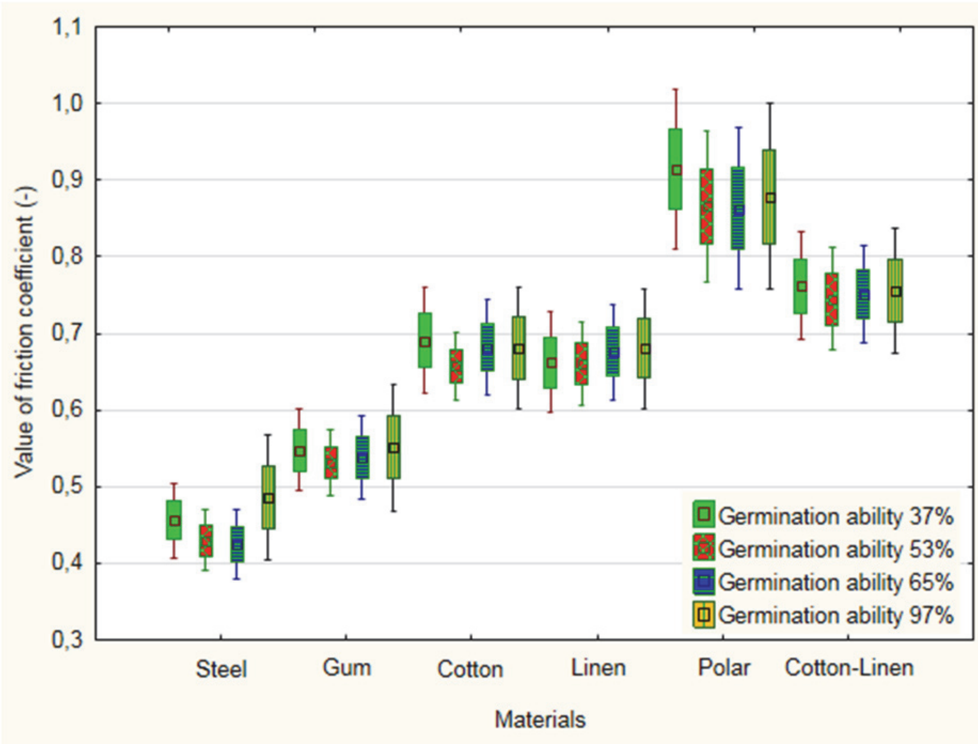


Figure 2. A box plot which illustrates variability of average values and standard deviations of external friction coefficients of pea seeds of various germination ability on the selected materials

Table 3

The list of results of analysis of variance and 'post-hoc" tests for coefficients of pea seeds friction on the selected bases

Germination ability (%)	Steel		Gum		Canvas							
					Cotton		Linen		Micro fleece		Cotton-Linen	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
37	0.46[a]	0.046	0.55[a,c]	0.067	0.69[a]	0.086	0.66[a]	0.082	0.91[a]	0.131	0.75[a]	0.077
53	0.43[b]	0.041	0.53[b]	0.053	0.66[b]	0.054	0.66[a]	0.068	0.87[b]	0.124	0.73[b]	0.075
65	0.42[b]	0.042	0.54[a,b]	0.068	0.68[a]	0.077	0.67[b]	0.078	0.86[b]	0.132	0.74[a,b]	0.076
97	0.49[c]	0.048	0.55[c]	0.103	0.68[a]	0.101	0.68[b]	0.097	0.87[b]	0.151	0.74[a,b]	0.077

$\overline{X}$ – average, S – standard deviation, * averages marked with the same letters in a line do not differ statistically (homogenous group)

While analysing the data in Table 3, it may be concluded that only steel is a material that permits separation of pea seeds with the highest germination power as far as the differences in external friction coefficients are concerned. The average value of external friction coefficient (μ) for this surface and pea seeds with a germination power of 97% was 0.49. This value differed significantly from the average values of this parameter for seeds with lower germination power (a separate homogenous group).

No analogous relation was recorded for the other materials included in the study.

Conclusions

Based on the results of the study and calculations, it may be concluded that separation of the fraction of seeds with high germination power from the analysed batch of sowable material is an extremely difficult technological procedure, which results from a lack of differences in the basic separation characteristics, such as dimensions (length, width and thickness), mass and critical drift velocity in the vertical air stream.

The hypothesis (verified in this study) on the differences in external friction coefficients between seeds with different germination power, demonstrated that this characteristic has a limited practical applicability. Despite the studies being conducted on many different types of materials (steel, rubber, and cotton, flax, fleece, and cotton-flax linen), statistically significant differences in this parameter were only recorded for steel. The average value of external friction coefficient for seeds with 97% germination power was 0.49 and was much higher than for seeds with lower germination power. Therefore, it is finally concluded that it would be necessary to use the so-called "spiral gravity separator" to separate seeds with high germination power.

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OKREŚLENIE MOŻLIWOŚCI WYDZIELANIA NASION GROCHU PRZEZNACZONYCH NA MATERIAŁ SIEWNY PRZY WYKORZYSTANIU RÓŻNIC WE WSPÓŁCZYNNIKACH TARCIA ZEWNĘTRZNEGO

Streszczenie. W pracy przedstawiono wyniki badań dotyczące określenia różnic w podstawowych cechach rozdzielczych partii nasion grochu siewnego, umożliwiających skuteczne wydzielenie frakcji materiału o wysokiej zdolności kiełkowania. Stwierdzono, że na podstawie różnic w takich cechach, jak: wymiary, masa oraz krytyczna prędkość unoszenia nasion nie można skutecznie zrealizować tej operacji technologicznej. W celu rozwiązania praktycznego problemu, podjęto próbę określenia potencjalnych różnic we współczynnikach tarcia zewnętrznego nasion po podłożach ze: stali, gumy oraz płótna (bawełnianego, lnianego, polarowego i bawełniano-lnianego). Ustalono, że istotne statystycznie różnice w tej cesze występują tylko dla stali. Zaproponowano, by w praktyce do wydzielenia nasion grochu o wysokiej zdolności kiełkowania zastosować żmijkę.

Słowa kluczowe: nasiona grochu siewnego, zdolność kiełkowania, cechy rozdzielcze

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IMPACT OF THE SPEED OF THE MEASURING HEAD OF THE TEXTURE MEASURING DEVICE ON THE OBTAINED VALUES OF BASIC DIFFERENTIATORS OF THE TEXTURE PROFILE ANALYSIS OF CAPRESI CHEESE

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ABSTRACT

The objective of the paper was to obtain the impact of the velocity of a measuring head on measuring values of basic differentiators of the texture profile analysis (TPA) such as: hardness I and II, cohesiveness, adhesiveness, elasticity, chewiness and gumminess as well as resilience. The investigated material was subjected to double compression to 50% of original height at the following head speeds: 0.5; 0.83 1.0; 1.2; 1.5 ($mm \cdot s^{-1}$). Cubic samples of cream cheese of Italian type Capresi with the side length of 15 (mm) were analysed. The obtained test results proved that statistically significant differences (at α=0.05) were reported only in few cases between the results obtained for particular analysed levels of the measuring head speed. However, one may report clear trends of changes of TPA differentiators values with increase or decrease. The increase of hardness differentiators I and II may be reported with the increase of the measuring head speed (however without confirmation of statistically significant differences at α=0.05). A similar trend may be also reported for gumminess and chewability differentiator on account of the head speed from 1.0 to 1.5 ($mm \cdot s^{-1}$).

Introduction

Primary sensory properties of food include color, taste, smell and texture. These properties are nowadays closely linked to food quality (Szczesniak, 1963). Instrumental methods of measuring texture are currently more and more widely used for measurments and quality control in food engineering (Kress-Rogers and Brimelov, 2001; Marzec, 2008).

A classic method of analysing texture is to gather a group of trained experts to evaluate each organoleptic characteristic. This method is worked-out in detail and described with a series of standards, however quite cumbersome in aplication. Analytical apparatus, in this case a human, despite having an enormous potential, always more or less introduces an uncertainty as to the obtained result (Marzec, 2008).

In the case of food texture which is closely related to mechanical properties, instruments to determine strenght properties were introduced. These methods allow easier, faster and less control measurements of food texture which in turn enables the end product to be of a better quality (Mazur and Andrejko, 2003; Mazur, 2009; Mazur et al., 2011).

A common procedure is to press a sample to 50% of its original height (however, it is not a rule as many researchers use 25-80% height in their work). Names, terminology and even units of measurements have underwent various modifications in time (Szczesniak, 1963; Bourne, 2002), which was presented in table 1. Moreover, different researchers very often employ different perspectives on each determinants of TPA which leads to errors in refering units to specific determinants.

In the case of head speed range used by the researchers there is also considerable difference (tab. 1).

Table 1
The list of selected variants of methodologies of texture profiled analysis of samples on the example of cheese

Research team	Material	Parametres of samples and test
Serano et al. (2004)	Cheddar Cheese	Cuboid sample 20 (mm); Compression – 50%; Velocity of the measuring head 1.0 ($mm \cdot s^{-1}$).
Kahyaoglu et al. (2005)	Gaziantep Cheese	Cylindrical samples - diameter 22 (mm); and hight 20 (mm); Compression to 25%; Velocity of the measuring head 1.67 ($mm \cdot s^{-1}$).
Cais-Sokolińska et al. (2006)	Mozzarella Cheese	Cylindrical samples - diameter 17 (mm); and hight 12 (mm); Compression to 50%; Velocity of the measuring head 0.5 ($mm \cdot s^{-1}$).
Sołowiej (2007)	Cheese analogues	Cylindrical samples - diameter 15 (mm); no information on smaple height; Compression – no info; Velocity of the measuring head – 1.0 ($mm \cdot s^{-1}$).
Shirashoji et al. (2010)	Cheddar Cheese	Cylindrical samples - diameter 16 (mm); and hight 17.5 (mm); Compression to 80%; Velocity of the measuring head – 0.8 ($mm \cdot s^{-1}$)

A sizeable difficulty in comparing results of Texture Profile Analysis obtained by different researchers, even in the same group of products or even the same product, is brought about by incomplete information as to the applied methods or their different variants, especially a sample size and shape and measuring head speed (Serano et al., 2004; Kahyaoglu et al., 2005; Cais-Sokolińska et al., 2006; Sołowiej, 2007; Shirashoji et al., 2010). Determing the impact of the measuring head speed on values of TPA determinants and potential standarising of this issue requires further research and analysis.

Objective of the study

The objective of the study was to show the impact of the measuring head speed on values of basic Texture Profile Analysis (TPA) determinants, such as hardness I and II, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience.

Scope of research

Determining basic properties of material under study (water content, pH, basic chemical composition).

Measuring of Texture Profile Analysis determinants: hardness I and II, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience of samples of Italian-type Capresi cheese using 5 different measuing head speeds of textere measuring device.

Material and methods

Material under investigation was Italian-type cheese Capresi. Investigation concerned three types of cheese, each of them was from one production batch. Material was stored in refrigeration conditions in temperature of 6ºC ±1ºC. Water content in cheese was determined by drying method in accordance with standard PN-EN ISO 5534: 2005. pH control was realised using pH-meter CP411 in accordance with standard PN 73/A-86232:1973. Texture analysis was carried out using the TPA test with texture analyser TA XT PLUS. Material was subjected to double pressing to 50% of its original height. Measuring head speeds were consistent with the range employed by majority of researchers of this type of material, i.e.: 0.5; 0.83 1.0; 1.2; 1.5 $mm \cdot s^{-1}$ (Serano et al., 2004; Kahyaoglu et al., 2005; Cais-Sokolińska et al., 2006; Sołowiej, 2007; Shirashoji et al., 2010). Analysis was done on cube samples of Italian-type cheese Capresi with the side lenght of 15 mm. Parametres such as hardness I and II, adhesiveness, springiness, cohesiveness, gumminess were acquired quantitatively by looking at a force-time graph, chewiness and resilience were calculated from the relationship (March, 2008). Measurements were done in six iterations. Method of evaluating statistical significance of impact of the measuing head speed on the TPA determinants was variance analysis ANOVA. Basic chemical composition was acquired from the producer.

Results and discussion

The analysed cheese was characterised by the following physical properties and chemical composition (tab. 2).

In the analysed batches of cheese differences in water content, pH and chemical composition were within standard deviations.

Table 2
Basic physical properties and chemical composition of the researched raw material

Name	Cheese I	Cheese II	Cheese III	SD
Water content *u*, ($kg \cdot kg_{s.m.}^{-1}$)/(%)	2.44/70.92	2.43/70.86	2.42/70.8	0.016
Proteins, (%)	13.6	13.6	13.7	0.06
Carbohydrates, (%)	3.7	3.7	3.7	0.07
Fat, (%)	3.6	3.6	3.7	0.09
pH	4.2	4.17	4.21	0.021

Average values of the specific TPA determinants were presented in table 3 along with highlighted homogeneous groups acquired as a result of the test which was carried out – straight cross section ANOVA, post-hoc, Tukey HSD test.

For four variants of the measuring head speed, i.e. 0.5 and from 1 to 1.5 $mm \cdot s^{-1}$ an increase in value of hardness I, however the observed trend is not statistically significant.

Table 3
The list of average values of TPA differentiators of the cream cheese of the Italian type Capresi with marking uniform groups (α=0.05)

Parameter TPA	Velocity of the measuring head ($mm \cdot s^{-1}$)				
	0.5	0.83	1.0	1.2	1.5
Hardness I (N)	5.842^{a}	6.617^{b}	5.823^{a}	6.228^{ab}	6.395^{ab}
Hardness II (N)	4.052^{c}	4.578^{d}	4.064^{c}	4.301^{cd}	4.265^{cd}
Adhesiveness (mJ)	-0.22	-0.34^{ef}	-0.31^{f}	-0.37^{e}	-0.35^{ef}
Springiness	0.817^{g}	0.803^{g}	0.801^{g}	0.798^{g}	0.794^{g}
Cohesiveness	0.424^{j}	0.368^{h}	0.378^{h}	0.389^{hi}	0.408^{ij}
Gumminess (N)	2.478^{kl}	2.432^{kl}	2.197^{l}	2.427^{kl}	2.610^{k}
Chewiness (N)	2.023^{m}	1.953^{mn}	1.760^{n}	1.936^{mn}	2.075^{m}
Resilience	0.134^{r}	0.108^{p}	0.118^{op}	0.122^{o}	0.129^{or}

Average values for particular levels of TPA differentiators marked with the same letters do not differ statistically significantly

With the speed of 0.83 $mm \cdot s^{-1}$ of the measuring head speed the highest values of this determinants were reported, statistically signifant differences occured for values obtained with the measuring head speeds of 0.5 and 1 $mm \cdot s^{-1}$.

Similar occurences were reported for texture determinants – hardness II.

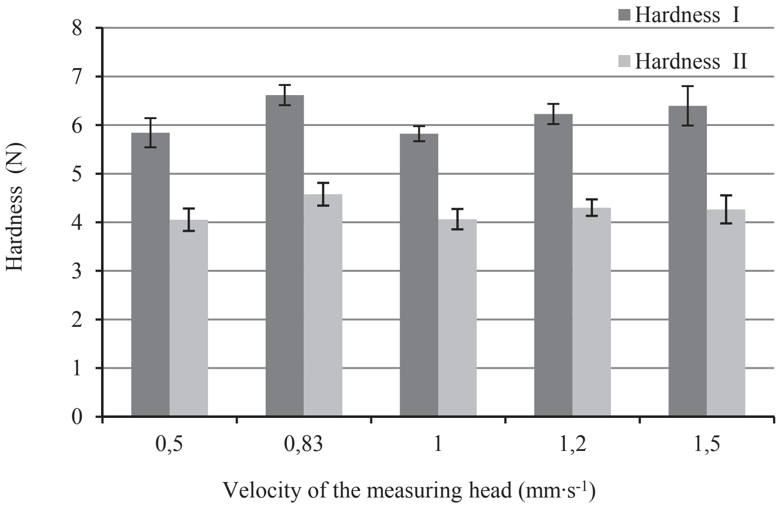

Figure 1. Values of hardness I and II of cream cheese Capresi depending on the applied velocity of the measuring head

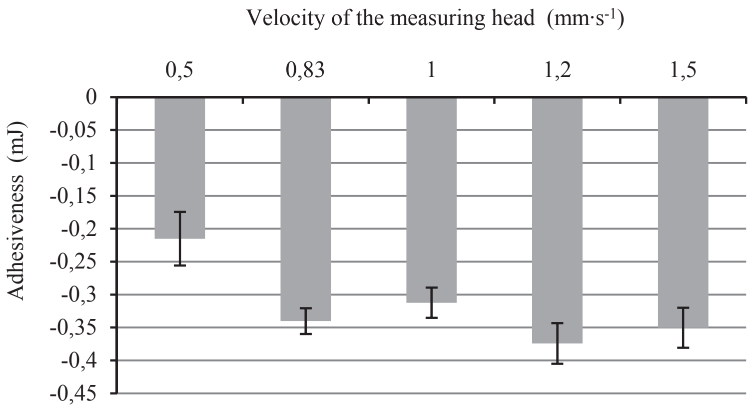

Figure 2. Values of adhesiveness of cream cheese Capresi depending on the applied velocity of the measuring head

The highest values of adhesiveness -0.22 mJ were reported during measurements with the measuring head speed of 0.5 mm·s^{-1} demonstrating statistically significant differences with respect to results obtained with other measuring head speeds.

Statistically signifant differences were observed between results obtained with speeds 1 and 1.2 mm·s^{-1}. As for the latter the lowest values of adhesiveness among the studied cases were reported -0.37 mJ.

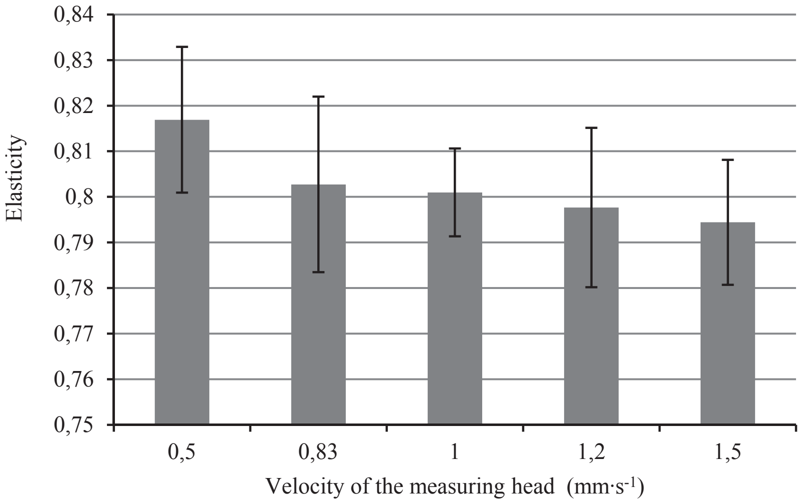

Figure 3. Values of elasticity of cream cheese Capresi depending on the applied velocity of the measuring head

For the entire range of the analysed measuring head speeds of a texture measuring device, with rising speed a decrease in the value of springiness was reported, however statistically significant differences cannot be ascertained using α=0.05.

The highest values of cohesiveness 0.42 were reported during measurements with the head speed of 0.5 mm·s^{-1} demonstrating statistically significant differences with respect to results obtained with the measuring head speeds from 0.83 to 1.2 mm·s^{-1}.

In the case of four variants of the measuring head speed, i.e. 0.83 to 1.5 mm·s^{-1}, an increase in value of cohesiveness was reported, however statistically significant differences occured only for the results obtained with the speed of 1.5 mm·s^{-1} when compared to results obtained with speeds 0.83 and 1 mm·s^{-1}.

The lowest values of gumminess 2.2 N were reported during measurements with the head speed 1 mm·s^{-1} demonstrating statistically significant differences only for the results obtained with extreme among the considered measuring head speeds 0.5 and 1.5 mm·s^{-1}.

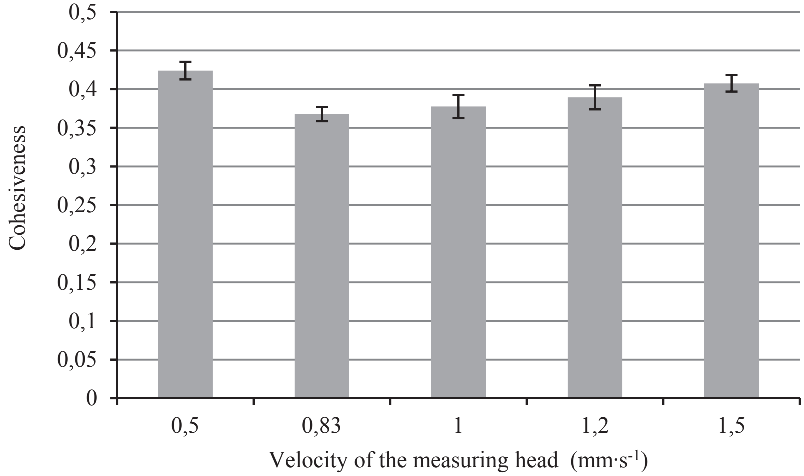

Figure 4. Values of cohesiveness of cream cheese Capresi depending on the applied velocity of the measuring head

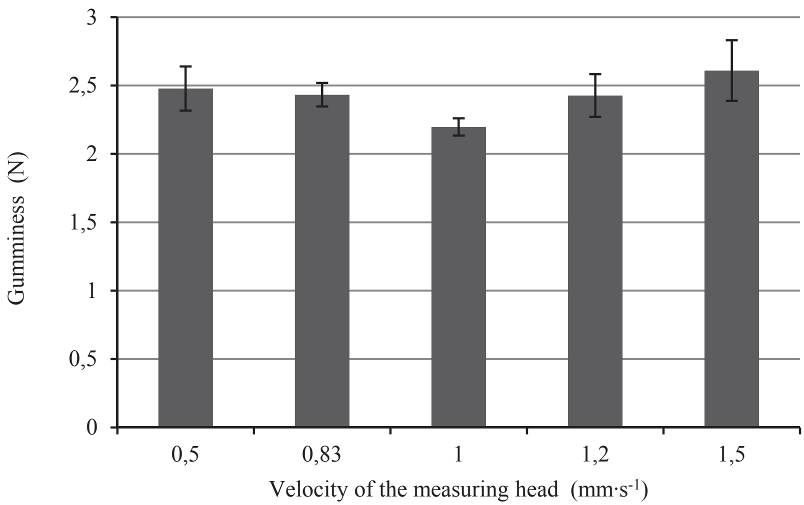

Figure 5. Values of gumminess of cream cheese Capresi depending on the applied velocity of the measuring head

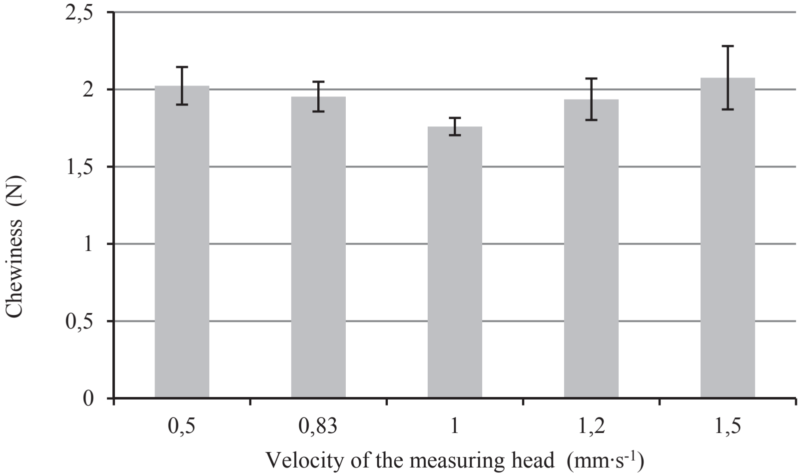

Figure 6. Values of chewiness of cream cheese Capresi depending on the applied velocity of the measuring head

A similar trend as the one observed with gumminess with changes in measuring head speed can be observed also for TPA determinants chewiness.

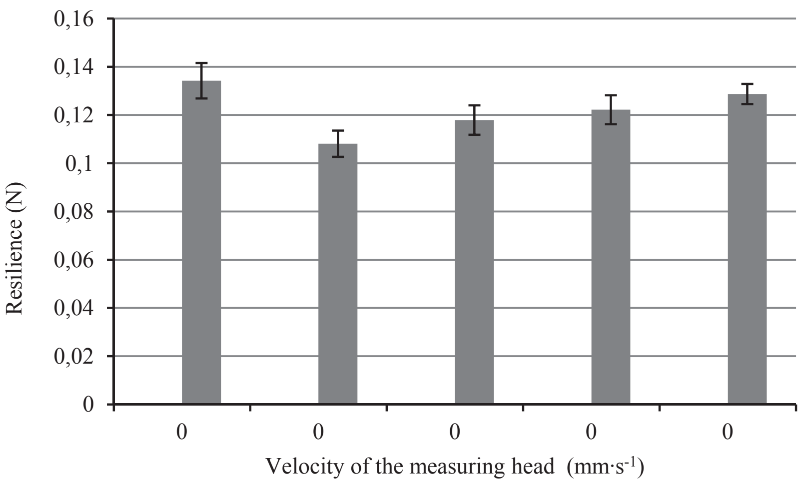

Figure 7. Values of resilience of cream cheese Capresi depending on the applied velocity of the measuring head

The highest values for resilience (0.13) were reported during measurements with the head speed of 0.5 mm·s^{-1} demonstrating statistically significant differences with respect to the results obtained with the measuring head speeds from 0.83 to 1.2 mm·s^{-1}.

In the case of four variants of the measuring head speed, i.e. 0.83 to 1.5 mm·s^{-1}, an increase in the value of resilience was reported as the measuring head speed was increasing.

Statistically signifant differences were not confirmed for results obtained with the head speeds 0.83 and 1 mm·s^{-1} and additionally 1 mm·s^{-1} when comparing to 1.2; 1.5 mm·s^{-1} and additionally with speed 1.2 when compared to 1.5 mm·s^{-1}.

Conclusions

The conducted study allows development of the following conclusions:

1. The obtained test results proved that statistically significant differences (at α=0.05) were reported only in few cases between the results obtained for particular analysed levels of the measuring head speed. However, one may report clear trends of changes of the TPA differentiators values with increase or decrease.
2. The increase of hardness differentiators I and II may be reported with the increase of the measuring head speed (however without confirmation of statistically significant differences at α=0.05). A similar trend may be also reported for the gumminess and chewability differentiator on account of the head speed from 1.0 to 1.5 (mm·s^{-1}).
3. The inrease in the value of the cohesiveness and resilience differentiator was reported as a result of the increasing measuring head speed from 0.83 to 1.5 mm·s^{-1}.
4. The decrease in the value of the TPA differentiators as the measuring head speed increases can be observed for springiness (statistically significant differences were, however, not confirmed using α=0.05). A decrase in the value of resilience was also reported as the measuring head speed rose from 0.5 to 0.83 mm·s^{-1}.
5. A deeper analysis in relation to, for example, the structure of the sample under study is required for values obtained in the TPA test with some levels of the measuring head speed of a texture measuring device, that diverge from trends of other study series. For described material divergences from the trend observed in other study series were reported for the following cases:
   - values of determinants cohesiveness and resilience with the measuring head speed of 0.5 mm·s^{-1},
   - values of determinants hardness I and II and adhesiveness with the measuring head speed of 0.83 mm·s^{-1},
   - values of determinants chewability and gumminess with the measuring head speed of 1.0 mm·s^{-1}.

Investigating only statistically significant differences, one should accept a general conlusion that there is no impact of the measuring head speed on the TPA determinants such as hardness I and II, adhesiveness, springiness, cohesiveness and resilience, gumminess and chewiness for Italian-type cheese Capresi. However, the observed trends require a deeper analysis and the use of a wider range of applied measuring head speeds and more iterations, which may allow for obtaining a more unequivocal answer to the issue of impact of the measuring head speed on the TPA determinants.

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WPŁYW PRĘDKOŚCI GŁOWICY POMIAROWEJ TEKSTUROMETRU NA UZYSKIWANE WARTOŚCI PODSTAWOWYCH WYRÓŻNIKÓW PROFILOWEJ ANALIZY TEKSTURY SERA CAPRESI

Streszczenie. Celem pracy było wykazanie wpływu prędkości głowicy pomiarowej na wartości pomiarowe podstawowych wyróżników profilowej analizy tekstury (TPA), takich jak: twardość I i II, kohezyjność, adhezyjność, elastyczność, żujność i gumiastość oraz odbojność. Badany materiał poddawano dwukrotnemu ściskaniu do 50% pierwotnej wysokości przy prędkościach głowicy: 0,5; 0,83 1,0; 1,2; 1,5 ($mm \cdot s^{-1}$). Analizie poddano sześcienne próbki sera śmietankowego typu włoskiego Capresi o długości boku 15 mm. Uzyskane wyniki badań wykazały, że statystycznie istotne różnice (przy α=0,05) zanotowano tylko w nielicznych przypadkach pomiędzy wynikami uzyskanymi dla poszczególnych analizowanych poziomów prędkości głowicy pomiarowej, jednak można zaobserwować wyraźne trendy zmian wartości wyróżników TPA w miarę jej wzrostu czy spadku. Zaobserwować można wzrost wyróżników twardości I i II w miarę zwiększania prędkości głowicy pomiarowej (jednak bez potwierdzenia statystycznie istotnych różnic przy α=0,05). Podobny trend obserwować można także dla wyróżnika gumiastość oraz żujność w zakresie prędkości głowicy od 1,0 do 1,5 ($mm \cdot s^{-1}$).

Słowa kluczowe: TPA, ser śmietankowy Capresi, prędkość głowicy pomiarowej

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EVALUATION OF EFFICIENCY OF REMOVING PROTEIN DEPOSITS FROM VARIOUS SURFACES BY FOAM CLEANING

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ABSTRAKT

The paper presents results of the research on efficiency of removing the protein deposits by using foam cleaning technique. Eight surfaces used in the food industry (tiles, linoleum, antibacterial and traditional tiles and stainless steel) constituted the research object. Surfaces were contaminated by protein derived from milk and egg proteins and they were cleaned by foam technique at variable parameters of compressed air pressure and the contact time of the detergent with the tested surface. The results of the research confirmed that the compressed air pressure of cleaning solutions has the highest impact on the protein deposits removal..

Introducion

Maintaining a high level of hygiene in a food processsing plant is a big challenge. Development of appropriate procedures and instructions regarding hygiene is the essence of the business and builds customer confidence in the context of the quality of the produced food. Hygiene is very important for the proper cleaning and disinfection processes in which physical, chemical and microbiological impurities accumulated on the surfaces of production, which are a major threat to the production process are removed (Koziróg, 2012). These processes can be conducted in many ways depending, inter alia, on the type of surface being cleaned and its availability (Diakun, 2013). For example, pipelines are washed in CIP systems, small appliances manually or by immersing, and large surfaces with foam cleaning or high-pressure jet. The use of new solutions concerning finishing of surfaces considerably facilitates maintaining cleanness. In addition to traditional materials the finishing ones are increasingly being used in the form of anti-bacterial surfaces of ceramic tiles and epoxy resins (Rai et al., 2009).

They allow maintaining a high level of hygiene between subsequent cleaning and disinfection procedures (Mierzejewska and Stawczyk, 2013). Foam washing is used for cleaning large surfaces such as floors, walls, smoking chambers, worktops and external parts of machines and equipment.

This method, due to a number of advantages, has found wide application in industry, inter alia, fish, meat and milk production. The results are part of a series of studies concerning: removing various types of contaminants (fat, protein and sugar without any treatment and after heat treatment); various foam cleaning process parameters (pressure, temperature, time); impact of different detergents and cleaning susceptibility to a variety of surfaces in the food industry (Mierzejewska and Stawczyk, 2013).

Objective of the study

The objective of the study was to evaluate the effectiveness of removing protein impurities from various surfaces in the food industry. Such surfaces were examined, as tiles, stainless steel, linoleum, ceramic and anti-bacterial tiles. Compressed air pressure and the detergent contact time with the surface constituted variable parameters during the process.

Test stand

The study was conducted on the foam cleaning bench with a foam generator with equipment (fig. 1), a booth for surface mounting and washing operation and tiles made of various materials (fig. 2).

Figure 1. Foam cleaning stand: 1 – pump, 2 – retractable reel, 3 – stationary terminal, 4 – lance with appropriate nozzle, 5 – compressor 6 – cleaner

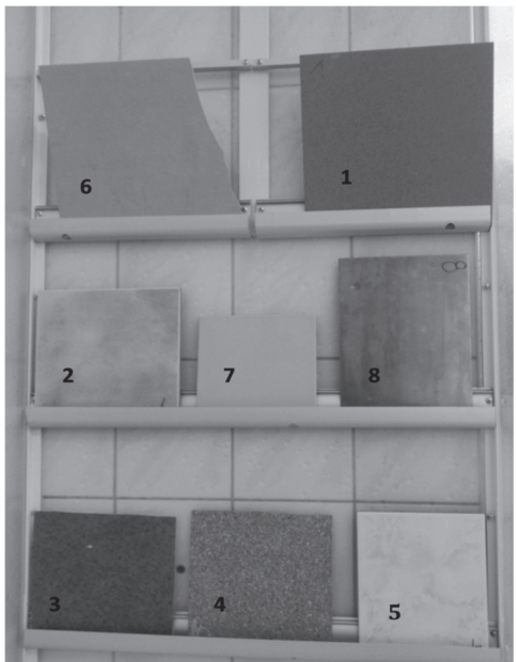

Figure 2. Surfaces subject to contamination and cleaning: stone tiles (1, 2), linoleum (3, 4), ceramic tiles (5), anti-bacterial tile (6), attested anti-bacterial tile (7), stainless steel (8)

A foam generator consisted of a base station equipped with: a pump (1) increasing the water pressure to 2.5 MPa and a compressor (5) delivering compressed air to the stationary terminal (3). Water, compressed air and the cleaning agent dosed in appropriate amounts, are applied as a foam on the cleaned surfaces with a lance equipped with a nozzle (4) adjusted to the process. In order to facilitate access to the cleaned surface the lance is mounted on a 25 m hose on a drum with a motor (2).

Surfaces subjected to the process of contamination and washing were placed in a specially adapted cabin, enabling the attachment of the washed items and preventing foam splashing.

Research methodology

The soiling and cleaning process was performed on 8 different surfaces: two types of tiles with different roughness, two types of linoleum, ceramic plate, the antibacterial plate, antimicrobial-approved plate and stainless steel. The tests were performed in triplicate. The study used two types of protein impurities, namely, impurities arising from pasteurized milk and 2% of chicken egg protein.

Impurities after being applied to the surfaces were fixed in a thermal chamber at 80ºC. The washing process was carried out in the foam technology by maintaining constant dispensing of chlorine detergent, at different pressure of compressed air (0.6, 0.8; 1.0 MPa) and for different contact times of foam with the cleaned surface (5; 10; 20 min).

Evaluation method of cleaning effectiveness

Cleaning efficacy was assessed in two ways: visualy according to standard BS EN 50242-2004 and with the use of rapid tests to detect protein residues Clean-Trace ™ Surface Protein Plus Protect (Diakun, 2011; BS EN 50242-2004). The scale of evaluation of those two methods and awarded points are presented in table 1.

Table 1

Numerical scale of the cleanliness surface evaluation

Visual assessment dirt area PN-EN 50242-2004	Clean-Trace™		Scoring
	Protein residue of	color reagent	
Lack	0-30 $\mu g \cdot \mu l^{-1}$	green liquid	5
Number of small point particles of dirt 1 to 4 and the area completely dirty ≤ 4mm²	30-60 $\mu g \cdot \mu l^{-1}$	liquid green-gray	4
Number of small point particles of dirt spot 5 to 10 and the area completely dirty ≤ 4mm²	60-80 $\mu g \cdot \mu l^{-1}$	liquid gray	3
Number of small point particles of dirt spot >10 area ≤ 4mm² or area completely dirty ≤50mm²	80-120 $\mu g \cdot \mu l^{-1}$	liquid gray-purple	2
50 mm²< Area completely dirty ≤ 200 mm²	120-300 $\mu g \cdot \mu l^{-1}$	purple liquid	1
Area completely dirty >200 mm²	300-500 $\mu g \cdot \mu l^{-1}$	deep purple liquid	0

Results and Discussion

Since equal effectiveness of removing protein impurities from milk and egg white was proved, the group test results for the removal of both types of impurities were presented. Foam produced at the pressure of 0.6 MPa was of poor quality, namely, was very moist and quickly ran down from the cleaned surface. Therefore, no studies have been conducted for the pressure of 0.6 MPa and the times of 10 and 20 minutes. Figure 3 shows the results of the protein removal efficiency for a pressure of 0.6 MPa and a time of 5 min. With the set parameters of the process no satisfactory cleaning performance was achieved. As many as 3 of the investigated areas received 0 pts., remaining ones received 2, 3 points, and they were still heavily contaminated. Increasing the air pressure to 0.8 MPa resulted in significant improvements in the quality and durability of foam and thus the efficient removal of protein impurities. Studies carried out after 10 and 20 minutes of the detergent contact with the surface of the test showed that only one surface (stainless steel) was still contaminated. Other areas have received 5 points, which means that the protein impurities have been completely removed from the test surface (fig. 4).

Increasing the air pressure to 1.0 MPa resulted in an improved removal efficiency even at the shortest contact time (5 min) (fig. 5). Still most contaminants remained on the surface of stainless steel. Extending the active foam cleaning surfaces to 10; 20 minutes resulted in the removal of all contaminants from all the tested surface.

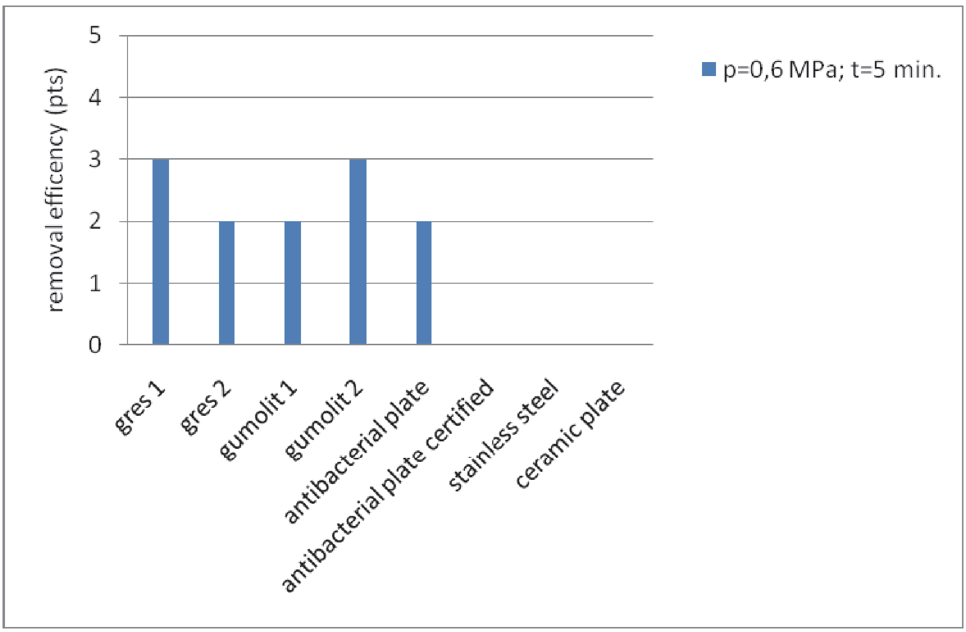

Figure 3. Effectiveness of removing protein impurities (p=0.6 MPa, t=5 min)

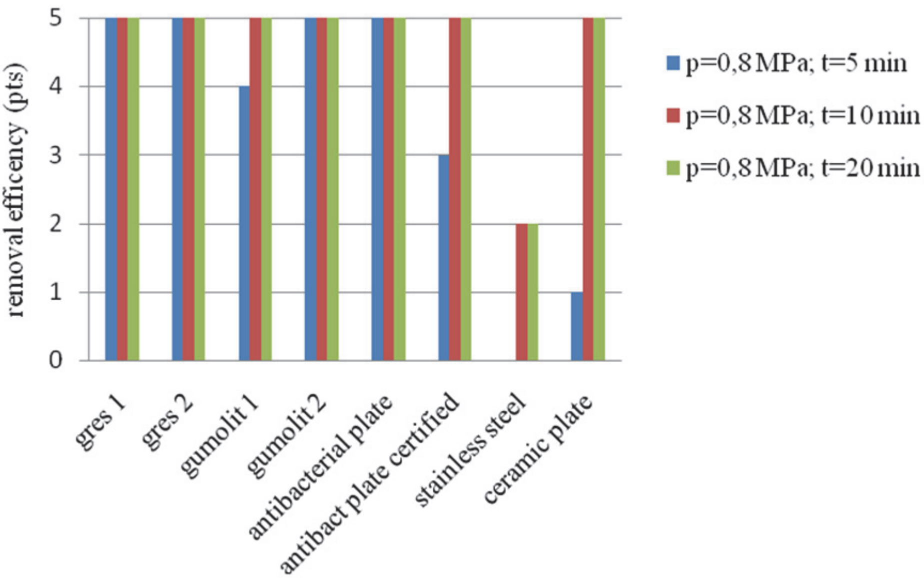

Figure 4. Effectiveness of removing protein impurities (p=0.8 MPa, t=5; 10; 20 min)

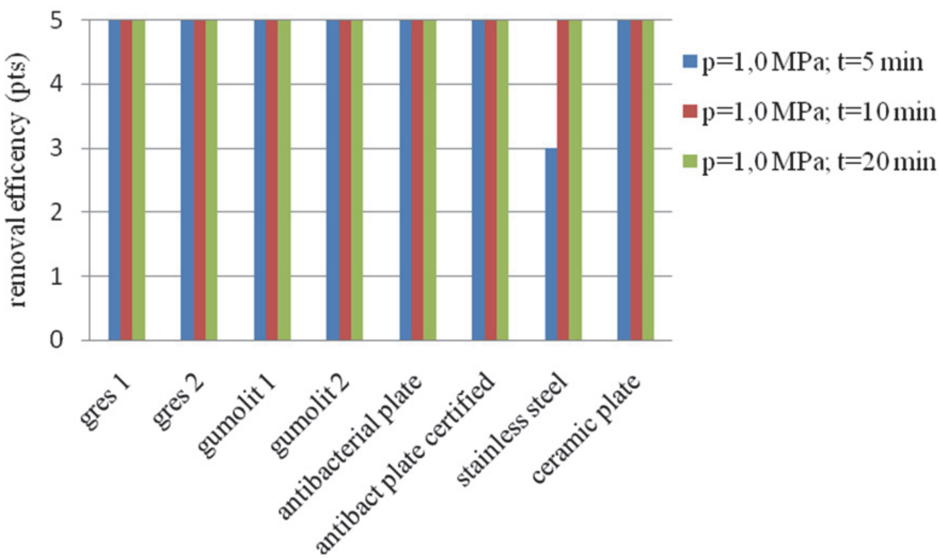

Figure 5. Effectiveness of removing protein impurities (p=1.0 MPa, t=5; 10; 20 min)

Statements and conclusions

Based on the survey the following statements and conclusions were formulated:

1. The parameters of the process are an important factor in determining the effectiveness of cleaning with the foam cleaning technique. The air pressure has the greatest impact on the cleaning process.
2. The foam produced at a pressure of 1.0 MPa, is the most persistnet foam which removes proteins from all test surfaces. Application of pressure of less than 0.8 MPa does not guarantee adequate quality of foam, which would remain on the surface for appropriate time.
3. Protein impurities are the most easily removed from surfaces such as tiles, antibacterial tiles, linoleum. Stainless steel is a surface, from which it is difficult to remove protein impurities.
4. The foam cleaning process parameters, in which all the protein impurities are removed is: 10 minutes of maintaining foam formed at the pressure of 1 MPa.

In food factories foam washing is widely used because of the simplicity and accuracy of the process. The ideal would be to use different cleaning instructions (different pressures, times, etc.) For different surfaces, but this results in the creation of many documents. The study shows that the development of the washing instructions for stainless steel surfaces with the appropriate parameters of the process ensures that any other surface (the surface of the respondents) will also be washed.

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BADANIE SKUTECZNOŚCI USUWANIA ZANIECZYSZCZEŃ BIAŁKOWYCH Z RÓŻNYCH POWIERZCHNI TECHNIKĄ MYCIA PIANOWEGO

Streszczenie. W pracy przedstawiono wyniki badań dotyczących skuteczności usuwania zanieczyszczeń białkowych metodą mycia pianowego z 8 różnych powierzchni wykorzystywanych w przemyśle spożywczym (gres, gumoleum, płytki antybakteryjne i tradycyjne, stal nierdzewna). Powierzchnie zanieczyszczano białkiem pochodzącym z mleka i białka jaja kurzego, a następnie poddawano procesowi mycia przy zmiennych parametrach ciśnienia sprężonego powietrza i czasu kontaktu środka myjącego z badaną powierzchnią. Na podstawie wyników badań stwierdzono, że największy wpływ na skuteczność usuwania zanieczyszczeń białkowych ma ciśnienie sprężonego powietrza.

Słowa kluczowe: higiena, mycie pianowe, zanieczyszczenia białkowe, skuteczność mycia

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ULTRASOUND APPLICATION FOR REMOVAL OF PROTEIN IMPURITIES FROM PIPING ELEMENTS[1]

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ABSTRACT

The paper presents results of the studies on the removal of protein impurities from the system components of a transmission installation in an ultrasonic cleaner. Contamination was removed from the places susceptible to insufficient washing in Clean In Place instalations, namely, from elbows, flap and ball valves and tees. The objective of this study was to evaluate the effectiveness of the cleaning process in an ultrasonic cleaner depending on the power of ultrasound, chemical agent (NaOH), temperature, and duration of the process. To evaluate the effectiveness of the method of cleaning Clean-Trace™ Surface Protein Plus visual tests were applied, which were based on the color reaction of copper and the protein complexes in the 5-point scale. Application of ultrasound and clean water does not completely remove protein contaminants from the cleaned surfaces. Application of chemical and high temperature improves the efficiency of the process. The fastest maximum cleaning efficiency was achieved in an ultrasonic cleaner at a full load and 40°C of ultrasound.

Introduction

Ultrasounds have been widely used in many industries such as mechanical engineering, printing, optics, jewelry, electronics and medicine and cosmetology. In the food industry by means of ultrasound, impurities are removed from the surface with complex structure and places difficult to reach. Due to their properties, the ultrasonic waves penetrate everywhere, removing impurities and destroying microorganisms. Ultrasonic waves are most commonly used in the cleaning devices called ultrasound washers. Another non-standard option is to include ultrasound generators near the measuring elements, which is intended to prevent deposition of mineral impurities. The use of such solutions in the system elements which are susceptible to insufficient cleaning could bring satisfactory results. Recent studies have shown that ultrasound can also be used for improving such processes as filtration, cutting, emulsification, drying or freezing (Chandrapala et al., 2012; Gallego-Juarez et al., 2007).

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Ultrasonic waves passing through liquid (cleaning solution), contribute to the phenomenon which removes sediment and contaminants. The most important phenomenon is cavitation, which consists in formation of gas bubbles in the lowest pressure and disappearance of the higher pressure zone. This phenomenon is very fast, and has an implosive nature and institutes detachment of pollutants from each, even the most complex element. The second phenomenon is the acoustic wind resulting from absorption of ultrasonic wave energy by liquid. The third important phenomenon in the ultrasonic cleaning process is the radiation pressure generated due to absorption of ultrasonic wave when meeting the obstacles (Sliwinski, 2001).

The effectiveness of ultrasonic cleaning in affected by:

– resistance of material of which cleaned items are made to cavitation;
– cleaning liquid, which determines the ability to create cavitation bubbles;
– cleaning temperature - is the most intense is cavitation for the temperature within 40-50ºC. A higher temperature is useful for distribution of impurities, but temperatures in the range of 70-80ºC will have a negative impact on the phenomenon of cavitation; The maximum temperature of the washing liquid should be approximately 10ºC lower than the boiling point of the washing liquid (Reidenbach, 1994);
– cleaning time - better cleaning results are achieved with a longer cleaning time, but its excessive extension can lead to corrosion and tarnishing of cleaning items.

Cleaning and disinfection of machinery and equipment for the food industry is a very important aspect of production of safe food for consumers. Well chosen parameters of the cleaning process and chemical agents should ensure that the cleaned items, piping instalations are properly cleaned and disinfected. Cleaning tests carried out in a closed circuit CIP in a laboratory, showed that not all elements of transmission pipelines are cleaned with the same efficiency. A simple design of a pipeline with a fixed cross section is relatively easy to clean, wheares all kinds of narrowings, arcs and structural components affecting the flow of the cleaning agent are problematic. Most dirt remains on elbows, small flap valves and tees with a blind end (Mierzejewska, 2013). Unsatisfactory cleaning results in the flow make it necessary to look for new solutions in the area of cleaning techniques. It was decided, therefore, to carry out preliminary studies on the possible use of ultrasound for the removal of protein impurities from the selected elements of the pipelines. The studies evaluated the efficacy of washing elbows, valves and blind ends of ultrasonic washers and analyzed the effect of ultrasound power, temperature, time, and addition of sodium hydroxide on the effectiveness of removing protein impurities.

Test stand, research material and test plan

The cleaning process was conducted in an ultrasonic washer by Intersonic IS-40S type (Fig. 1) with power of 1 kW. The washer is composed of a bath with a capacity of 40 liters, in which cleaned items were immersed in a special basket, and it has temperature control option of the cleaning liquid within 10ºC to 80ºC and the ultrasound power controller (0-(0 -100%). Two piezoceramic plates are a working element of the ultrasonic genererator. The transmitter is attached to the bottom of a bath and causes vibrations which are transferred to the cleaning liquid located in the bath. Washing is done by dipping the component in the respective cleaning solutions.

Figure 1. Ultrasound washer by InterSonic IS-40S

The research material included piping components that are uncleaned during CIP cleaning, as demonstrated in the paper by Mierzejewska et al. (2013). The test were carried out on: a butterfly and ball valve, tee with a blind ending and an elbow (fig. 2). Elements were contaminated with of milk three times thermally fixed at the temperature of 80ºC.

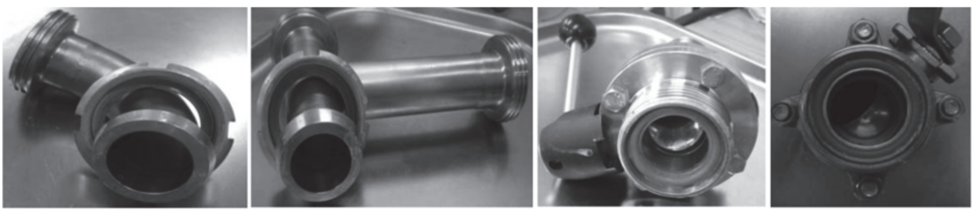

Figure 2. Elements of transmission system subjected to contamination and cleaning process

Tests were carried out on the ultrasonic washer under variable process parameters:

1. temperature of liquid (10; 30; 40ºC);
2. cleaning time (10; 20; 30 minutes);
3. ultrasound power (10; 50; 100%);
4. cleaning agent (water, soda lye).

Constant factors are: water with fixed parameters and dirty method.

Efficiency of removing protein impurities assessed visually and with Protect tests constitute Output parameters of the process. As part of the work performed 12 cycles of the tyree replicates for three different times according to the program presented in table 1.

Table 1
Plan of research

Lp.	Ultrasound power (%)	Time (min)	Temperature (ºC)	Cleaning agent
1.	10	10, 20, 30	10	H_2O
2.	10	10, 20, 30	40	H_2O
3.	50	10, 20, 30	10	H_2O
4.	50	10, 20, 30	40	H_2O
5.	100	10, 20, 30	10	H_2O
6.	100	10, 20, 30	40	H_2O
7.	10	10, 20, 30	10	NaOH 1%
8.	10	10, 20, 30	40	NaOH 1%
9.	50	10, 20, 30	10	NaOH 1%
10.	50	10, 20, 30	40	NaOH 1%
11.	100	10, 20, 30	10	NaOH 1%
12.	100	10, 20, 30	40	NaOH 1%

Evaluation method of protein impurities removal effectiveness

After the process of contamination and cleaning pipe elements, their purity and effectiveness of removing protein deposits was assessed. The assessment was carried out with the use of two methods: visual and rapid tests Clean-Trace ™ Surface Protein Plus. As a part of the tests points were awarded according to PN- EN 50242-2004 (PN-EN 50242-2004; Diakun, 2011; Diakun, 2013). Visual evaluation result may sometimes be unreliable, however it is the fastest way to assess purity. The second method, much more accurate, was based on the detection of protein and sugar residues, the presence of which caused color change of indicators, giving information about the state of purity of the surface. It is based on the color reaction of copper and protein complexes. Cleaning effectiveness in both methods was expressed in the scale of 0-5 where 0 is the initial state of dirt, and 5 completely clean surface (table 2).

Table 2
Digital scale of assessment of surface cleanness

Visual evaluation	Clean-Trace™		
Area contamination by PN-EN 50242-2004	Protein residue	Color of the reagent	Scoring
Absence	0-30 μg/μl	green	5
Number of small particles of contamination point 1 to 4 and the area completely contaminated ≤ 4mm²	30-60 μg/μl	green-gray	4
Number of small particles of contamination point 5 to 10 and the area completely contaminated ≤ 4mm²	60-80 μg/μl	gray	3
Number of small particles of contamination point >10 the area ≤ 4mm² or the area completely contaminated ≤50mm²	80-120 μg/μl	gray- violet	2
50 mm²< the area completely contaminated ≤ 200 mm²	120-300 μg/μl	violet	1
The area completely contaminated >200 mm²	300-500 μg/μl	intense purple	0

Research results

The research results of the mean from three iterations were presented in table 3. Since, protein impurities were equally removed of the tested elements, group results were presented.

The tests, which were carried out indicate that the impact of ultrasounds and the clean water environment, is not able to remove protein impurities from the washed items.For the the programs 1 to 6 within 10 minutes, the effectiveness of cleaning was at the level of 0 points. The longer the cleaning time, the higher temperature and higher ultrasound power efficiency of removing protein impurities. The highest efficiency level of 4 points without the chemical agent was achieved in the 6th program, using 100% power of ultrasounds at the temperature of 40 ° C and with the washing time of 30 minutes. The use of a chemical agent in the form of soda lye improved the efficiency of the process. Standard concentration of NaOH in industrial cleaning processes vary depending on the type and the amount of impurities at the level of 3-5%.

As a part of the study 1% solution of soda lye was applied, which was much lower than that the one used in the cleaning processes in food factories. In all programs where soda lye was the washing agent the purity level of 5 points was obtained after 30 minutes of the process. In the 10th program, with the raised temperature cleaning all protein impurities were removed after 20 minutes of washing and tested items obtained 5 points. The 12th program at the process parameters: power 100%, temperature 40ºC, total purity was obtained after 10 minutes of the process.

Table 3
Research results

Number of research program	The removal efficiency contamination protein of tested elements					
	time test 10 minutes		time test 20minutes		time test 30 minutes	
	valuation Clean- Trace™	visual valuation	valuation Clean-Trace™	visual valuation	valuation Clean-Trace™	visual valuation
1	0	0	0	2	2	2
2	0	0	1	1	2	3
3	0	0	0	2	2	2
4	0	0	2	2	2	4
5	0	0	1	2	3	3
6	0	0	3	3	4	4
7	1	1	2	3	5	5
8	2	2	3	3	5	5
9	1	1	3	4	5	5
10	3	4	5	5	5	5
11	3	2	4	4	5	5
12	5	5	5	5	5	5

Summary and conclusions

It can be concluded that:

1. The impact of ultrasound and clean water on the washed elements does not remove all protein impurities.
2. The use of 1% soda lye solution and raised temperatures improves the efficiency of washing in an ultrasonic washer.
3. Regardless of the applied temperature and ultrasonic power when using 1% soda lye solution after 30 minutes, the end result of the process was assessed at 5 points in both tests.
4. Surface cleanliness at 5 points was quickly obtained at full power ultrasound and 40ºC.

The use of ultrasounds to remove contaminants from the installation components susceptible to insufficient cleaning required their demounting. It is a laborious process and may cause secondary pollution of the washed items. Satisfactory results obtained at the use of 1% sod alye solution, and thus a lower concentration than the one used in industrial washing installation prompts reflection on the possibility of using stationary ultrasonic generators in places vulnerable to insufficient washing. However, this would require a far-reaching modernization of transmission pipelines and installation of multiple ultrasonic generators on the production line. Therefore, the opinion provided by Leighton et al. that the best solution would be to create an ultrasonic generator moving along with the cleaning liquid in the washed installation seems to be right (Leighton et al., 2013).

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ZASTOSOWANIE ULTRADŹWIĘKÓW DO USUWANIA ZANIECZYSZCZEŃ BIAŁKOWYCH Z ELEMENTÓW INSTALACJI RUROWYCH

Streszczenie. W pracy przedstawiono wyniki badań dotyczących usuwania zanieczyszczeń białkowych z elementów instalacji przesyłowych w myjce ultradźwiękowej. Zanieczyszczenia usuwano z miejsc podatnych na niedomycie w instalacjach Clean In Place, a więc z kolanek, zaworów klapowych i kulowych oraz z trójników. Celem pracy była ocena skuteczności procesu mycia w myjce ultradźwiękowej w/w elementów w zależności od mocy ultradźwięków, środka chemicznego (NaOH), temperatury i czasu trwania procesu. Do oceny skuteczności mycia zastosowano metodę wizualną i testy Clean-Trace™ Surface Protein Plus, opierające się na reakcji barwnej miedzi z kompleksami białkowymi w skali 5 punktowej. Wyniki badań wskazują, że zastosowanie ultradźwięków i czystej wody nie zapewniają całkowitego usunięcia zanieczyszczeń białkowych z mytych powierzchni. Dopiero zastosowanie środka chemicznego i podwyższenie temperatury wpływa na poprawę skuteczności mycia. Najlepszą skuteczność mycia w myjce ultradźwiękowej, w najkrótszym czasie uzyskano przy pełnej mocy ultradźwięków i temperaturze 40ºC.

Słowa kluczowe: higiena, mycie ultradźwiękowe, zanieczyszczenia białkowe, skuteczność usuwania zanieczyszczeń

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USEFULNESS OF THE SELECTED APPLE CULTIVARS FOR PRESSING IN FARM CONDITIONS

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ABSTRACT

The paper presents the research results concerning the impact of varietal properties of apples on the efficiency of pressing juice. The research was carried out on eight apple cultivars from the crop of 2011 and 2012 after three month storing in a cold store with controlled atmosphere. Pressing was carried out in one cycle with the use of a laboratory bucket press. It was reported that varietal properties significantly influence the pressing efficiency. The highest efficiency was obtained in case of Idared cultivar and the lowest for Elise and Boiken variety. Moreover, it was proved that the content of essence, pH value of juice, dynamic viscosity and the juice thickness depend on the varietal properties of apples. The obtained juice was characterised with the content of essence exceeding Brix 10º, which indicated usefulness of all the investigated cultivars for production of cloudy juices.

Introduction

Apples are a source of many valuable phenolic compounds having antioxidant, antibacterial, antiviral, anti-inflammatory, antiallergic, or even expected to have anti-cancer properties (Kalinowska, 2012). Poland is one of the largest producers of apples in the European Union. The assessment for polish farmers suggested the production of apples at 3.2 million tons in 2013. Modern techniques, used in Poland concerning apples storing in controlled atmosphere guarantee the availability of high-quality fruit almost throughout the year. On 1 December 2012, according to the WAPA, stocks of apples in Poland amounted to about 1.18 million tons, while in the first day of February 2013 – 819 thousand tons and was 2% higher compared to the same period in the previous year (AgroTydzień 2013). Successful harvesting and large inventory of fruits contributes to difficulties with sale, as well as reduction of their prices. According to the data of IERiGŻ [Institute of Agriculturla and Food Economics] presented in January 2013, the average price of dessert apples in the national procurement was 14% lower compared to January 2012. The procurement prices of apples for export in the same period fell by an average of 5% to PLN 1.09·kg^{-1} (E-sadownictwo, 2013). The low price of the fruit may cause the interest of orchard farmers to produce fresh juices in ta farm. In Western Europe, the market share of fresh juices ranges from several to several dozens of percent, while in Poland does not exceed 2%. They are often cloudy juices and juices produced from organic farms, and thus they have pro-health properties. The heat treatment has negative influence on the antioxidant properties and the content of bioactive compounds in cloudy apple juice (Rembiałkowska et al., 2006). In some countries (Austria, Germany) orchard farms are equipped with a complete line of pressing and gentle juices preservation. Lately the development of a service using the mobile pressing is observed. This fact justifies the need for investigation of national apple cultivars to assess their suitability for production of fresh juices. In the industry for juice extraction from fruits and vegetables basket presses are commonly used (Nadulski et al., 2006; Lewicki et al., 1989; Lewicki et al., 1984), while less frequently layer presses are used. For basket presses, two designs are used: presses with a perforated basket or a solid basket, where the juice flows out through drainage hoses. Under laboratory conditions for research on the pressing process, basket presses with perforated elements (Nadulski, 2012; Guillermin et al., 2006; Grochowicz and Kusińska, 1980) and layer presses (Gerard and Roberts 2004) are most often used.

Objective and scope of the work

The objective of the study was to evaluate selected national apples cultivar after storage in ULO conditions (ultra low oxygen), for their suitability to produce fresh juices by pressing. Pressing was performed in a single cycle using a laboratory basket press. The scope of work included determining the efficiency of pressing and quality of apple juice, such as extract content (^{o}Brix), acidity (pH), dynamic viscosity and density.

Materials and Methods

The study was conducted in the Department of Food Engineering and Machinery in Lublin on eight apple cultivars: Golden Delicious, Gloster, Ligol, Jonagored, Idared, Boiken, Elise and Pinova harvested in 2011 and 2012. Apples came from specialized farm orchard Witków located in the Lublin region. Fresh juices are naturally cloudy and should be produced from apples of maturity close to the consumer quality (ie. not containing starch) (Gasik et al., 2012). Maturity of fruit was determined by the starch test. The tests were performed on the material after three months of storage at refrigerated controlled atmosphere (temperature 1,6-2,2^{o}C, oxygen content of 1.6%, 2.2% carbon dioxide and 96.2% nitrogen). The raw material was ground using a shredding machine MKJ250 (Spomasz, Nakło, Poland) with the use of a standard shredding disc with a hole with a diameter of 8 mm. The shredding disc speed was 170 rpm · min^{-1}. Pressing was carried out in a laboratory basket press of own construction with a diameter of 120 mm and a working chamber volume of approximately 150 cm^{3} (Fig. 1). The ground material with a weight of 500 g was placed in special bags, which were inserted into the press cylinder and then loaded with the piston. After obtaining the value of the loading force of 40 ± 1 kN pressing process was stopped. Each measurement was performed in six replications.

Figure 1. A laboratory bucket press

After each procedure the amount of juice obtained (mass and volume) was determined, as well as its density, extract °Brix (PN-90 / A-75101/02), pH (according to BS EN 1132: 1999) and the dynamic viscosity. To determine the amount of juice extract refractometer, PAL-1 (Atago, Tokyo, Japan) was used; to determine the pH of the juice, a CP-411 pH meter (Elmetron, Zabrze, Poland) was used; and to determine dynamic viscosity, an LVDV-II + PRO machine (Brookfield Engineering Laboratories, Middleboro, MA, USA) was used. The dynamic viscosity of the juice was measured using a ULA spindle at a rotational speed of 20 rpm at 20±0.5ºC, controlled by a thermostat. Rheocalc V3.1 software (Brookfield Engineering Laboratories) was used to record the data and control the viscosity meter.

Efficiency of pressing was determined by the following formula:

$$W_j = \frac{M}{M_p}$$

where:

W_j – is the efficiency of pressing, (%)
M – is the mass of juice after pressing, kg (kg),
M_p – is the mass of input material, (kg)

Statistical analysis of results of tests carried out using factorial ANOVA. The significance of differences was tested using Fisher test

Results

Statistical analysis of the results showed the impact of the cultivar characteristics on the juice extraction process and showed differences in the physical properties of the juices obtained from different cultivars. Juice yield of the tested cultivar is from 38.67 to 52.33%. The obtained yield is less than the values obtained in industrial conditions, i.e. 72-83% (Kowalczyk, 2004). Under the conditions of the experiment only one pressing cycle have been used and the enzyme preparations have not been used. The highest yield was obtained in the case of Idared and the lowest in the case of a Boiken and Elise cultivars (fig. 2). Statistical analysis confirmed the significance differences in the yield of pressing for pulp obtained from different apple cultivars (table 1).

Table 1.
Significance of difference between amount obtained for particular cultivars (Fisher's test)

Variety	Significance of difference				
	Efficiency W	Extract °Brix	Acidity pH	Dynamic viscosity η	Dencity ρ
Jonagored	bc	d	a	a	a
Golden D.	b	a	b	b	a
Boiken	a	c	c	c	a
Idared	d	c	d	d	b
Pinova	bc	a	e	e	ab
Elise	a	a	f	f	a
Gloster	d	b	g	a	b
Ligol	c	b	h	g	d

a, b, c – average values marked with the same letter are not statistically significantly different (p>0.05)

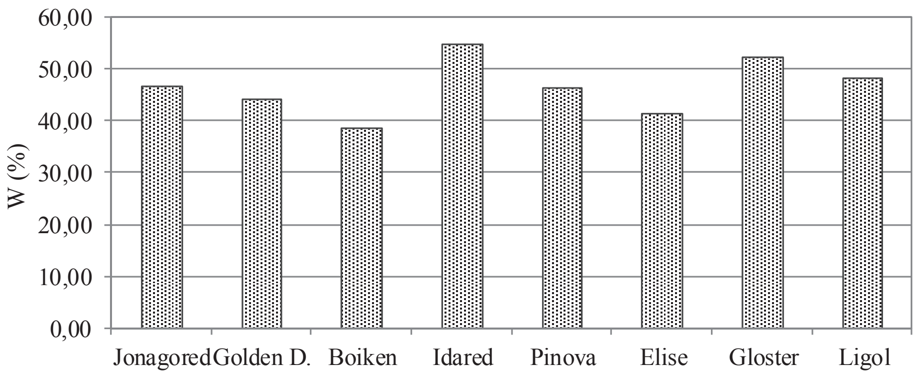

Figure 2. Pressing efficiency W (%) in relation to cultivar

Extract content in apples depends on the conditions during the growing season, harvest date and time of cool storage (Błaszczak, 2006). In the investigated apple juice, the extract content ranged from 10.5 to 13.5 of °Brix and depended on the cultivars from which juice was extracted (Fig. 3). Extract had the highest content of juice obtained from Idared and the lowest from a Boiken cultivar. The extract content in apple juice pressed in the fruit and vegetable industry is at the level of 11.0-12.4 of °Brix (Kowalczyk, 2004).

Considerably statistically significant differences in the acidity of apple juice were presented (table 1). The lowest pH value of 2.51 was obtained for Boiken cultivar juice, and the highest value of 3.58 in the case of Ligol cultivar juice (fig. 4).

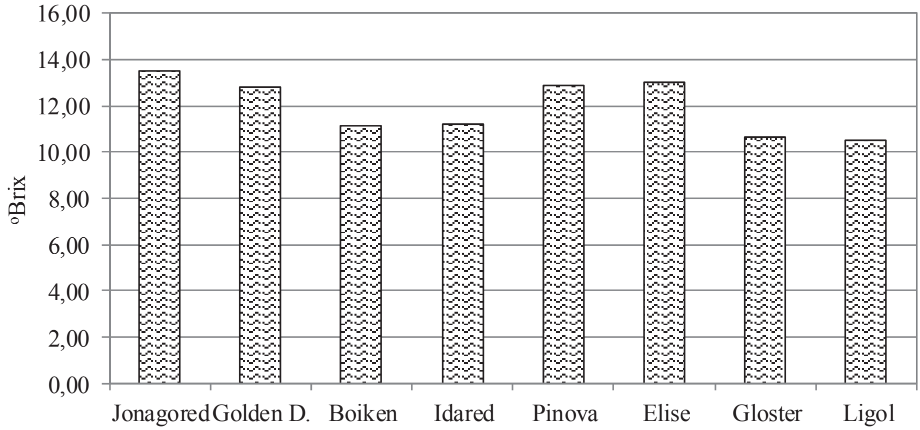

Figure 3. Extract content (ºBrix) in apple juice depending on cultivar

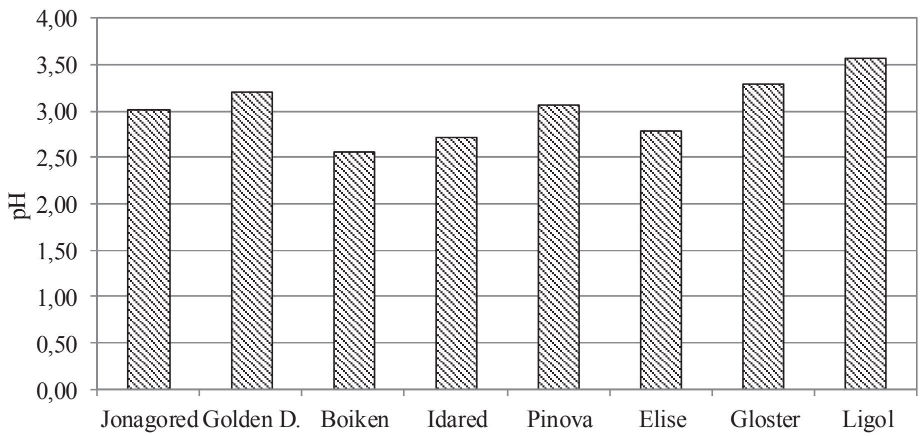

Figure 4. Acidity (pH) of apple juice depending on cultivar

Studies have shown clear differences in the dynamic viscosity of obtained apple juice (fig. 5). Dynamic viscosity of tested juices ranged from 4.3 m·Pa·s to 15.1 m·Pa·s. The highest value of dynamic viscosity was obtained in the case of apple juice from Boiken cultivar, whereas the lowest value in the case of juice from Idared and Pinova cultivars. Difference of dynamic viscosity is related to the fact that the tests were carried out on fresh cloudy juice. Particles included in the juice pulp may affect the dynamic viscosity of the obtained values. In contrast, apple juice is Newtonian fluid and has a lower dynamic viscosity value. The density of apple juice obtained from different cultivars is presented in figure 6. It was found that juice density is in the range of 1.028 to 1.052 kg·m^{-3}. No statistically significant difference was found between the Jonagored, Golden Delicious, Boiken, Pinova and Elise cultivars.

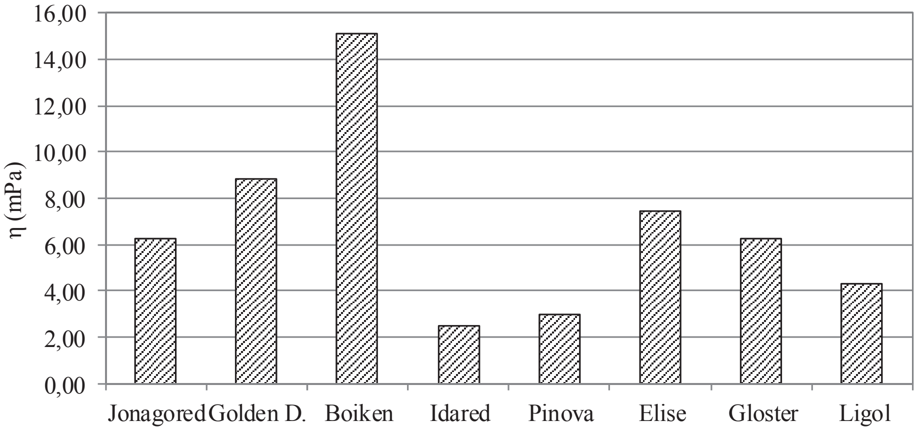

Figure 5. Dynamic viscosity η (m·Pa·s) of apple juice in relation to cultivar

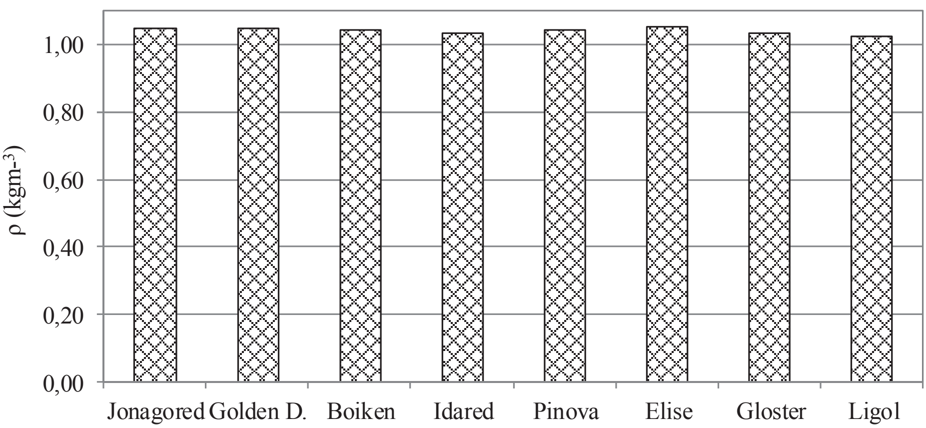

Figure 6. Density ρ (kg·m^{-3}) of apple juice in relation to cultivar

Research has indicated different yield of apple juice, depending on cultivars, the quality of juice depends on the cultivar, from which it is obtained. Obtained apple juices were characterized by the content of the extract above 10^{o}Brix, indicating the usefulness of all the examined cultivars for production of cloudy juices (Gasik et al., 2012).

Conclusions

The study allows formulation of the following conclusions:

1. The highest juice yield, during single pressing, was obtained for apple pulp from Idared cultivar whereas the lowest from Boiken cultivar.
2. Juice obtained from Gloster and Ligol cultivars characterized by the lowest content of the extract, whereas the highest obtained from Jonagored cultivar.
3. Taking into account the content of extract (10ºBrix) in juice all investigated cultivars of apples are suitable for the production of cloudy juices.
4. The highest acidity of juice obtained from Boiken cultivar, and the lowest from Ligol cultivar.
5. Dynamic viscosity of apple juice is highly diverse, the highest value obtained in the case of Boiken cultivar and the lowest in the case of Idared variety.
6. Minor, but in some cases substantial, statistically significant differences were recorded during measurement of density of the obtained juices.

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PRZYDATNOŚCI WYBRANYCH ODMIAN JABŁEK DO TŁOCZENIA W WARUNKACH GOSPODARSKICH

Streszczenie. W pracy przedstawiono wyniki badań dotyczące wpływu cech odmianowych jabłek na wydajność tłoczenia soku. Badania wykonano na ośmiu odmianach jabłek ze zbioru w 2011 i 2012 roku po trzymiesięcznym przechowywaniu w chłodni z kontrolowaną atmosferą. Tłoczenie prowadzono w jednym cyklu przy użyciu laboratoryjnej prasy koszowej. Stwierdzono, że cechy odmianowe owoców mają istotny wpływ na wydajność tłoczenia. Najwyższą wydajność uzyskano w przypadku odmiany Idared a najniższą odmian Elise i Boiken. Ponadto wykazano, że zawartość ekstraktu, wartość pH soku, lepkość dynamiczna i gęstość soku zależą od cech odmianowych jabłek. Otrzymane soki charakteryzowały się zawartością ekstraktu powyżej 10oBrix'a, co wskazuje na przydatność wszystkich badanych odmian do produkcji soków mętnych.

Słowa kluczowe: sok jabłkowy, odmiany jabłek, wydajność tłoczenia

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POSSIBILITIES OF USING BIOMASS FOR ENERGY PURPOSES[1]

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ABSTRACT

Energy consumption demand, which is constantly growing along with civilization development facing depletion of traditional resources - mainly fossil fuels (coal, petroleum, natural gas), and accompanying increase of pollution of natural environment have resulted in the increase of interest in the use of energy from renewable sources. This paper presents the significance of renewable energy sources in the domestic energy balance. Special attention has been paid to the basic source of renewable energy in Poland, that is to biomass. Types of biomass are described and general energy properties as well as physical and chemical features of the basic plant materials obtained for energy purposes. Possibilities of using biomass for production of electric energy and heat as well as the applied methods of its conversion into biofuels are discussed. The advantages and threats related to the use of plant biomass for energy purposes are pointed out.

Introduction

The term biomass is used for solid or liquid substances of plant and animal origin derived from products, waste and residues from agriculture, forestry and related industries as well as, partially, other types of biodegradable waste. Biomass resources for energy purposes, estimated in different scenarios and strategic documents, are the highest among all the available renewable energy sources in Poland. Their use, compared to other RES, is dominant in all the energy sectors of our country (Janowicz, 2006).

In recent years, the resources of fossil fuels have been rapidly diminishing. The conventional energy uses of these fuels have contributed significantly to the pollution of the environment. For these reasons, the use of renewable energy sources has become an indispensable solution. They provide an alternative to traditional non-renewable energy sources. Their resources are complementary in natural processes, which practically allows treating them as inexhaustible. Moreover, obtaining energy from these sources is more

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environmentally friendly compared to the conventional sources. The use of renewable energy sources significantly reduces the harmful impact of energy on the environment, notably by reducing emissions, especially greenhouse gases (Grzybek, 2003).

Plant biomass is rather difficult to use as a fuel and it requires suitable treatment. First of all, it is a fuel of local importance, which is a heterogeneous material, often damp and with low energy potential relatively to the unit volume. Therefore, in comparison to other commonly used energy carriers, biomass may seem a troublesome energy source. However, due to the universality of its occurrence and general availability, it enjoys constant interest of the agricultural producers, potential consumers of electricity and heat as well as environmentalists. It is also an opportunity for the creation and development of local businesses that can use raw materials from local farmers and allocate them for energy purposes (Frączek, 2010; Kuś and Matyka, 2008; Piotrowski et al., 2004; Terlikowski, 2012).

Plant biomass in its natural form is characterized by a relatively low density, hindering the transport, storage and use in practice. Hence, it has to be thickened, for example as pellets or briquettes. They are prepared from dry particulate biomass under high pressure at elevated temperature, usually without the addition of binders. During the agglomeration the forces and temperatures cause the concentration of a large quantity of material into a small volume. This results in a decrease of water content, at the same time increasing the concentration of mass and energy and thus the distribution and use of this biofuel is facilitated (Hejft, 2013; Kołodziej and Matyka, 2012; Szyszlak-Bargłowicz and Piekarski, 2009).

The energy value of plant biomass depends on both the type and condition of raw material, and especially its moisture content. A high water content causes reduction in the calorific value and hence the amount of heat obtained during the biomass combustion. The largest item in the balance sheet of renewable energy in Poland is the energy of solid biofuels. The share of other renewable energy carriers has been changing, showing a clear upward trend for energy from liquid biofuels, wind, biogas and solar. The share of renewable energy carriers in the total energy from renewable sources is presented in Table 1 (GUS, 2013).

Table 1

Participation of particular renewable energy carriers in the total energy production from renewable sources in 2012 (GUS, 2013)

Type of RES	Participation (%)
Solid biofuels	82.16
Fluid biofuels	7.97
Wind energy	4.80
Water energy	2.06
Biogas	1.98
Municipal waste	0.38
Heat pumps	0.31
Geothermal energy	0.19
Solar energy	0.15

Solid biofuels accounted for the highest share (56.45%) in total electricity production from renewable energy sources in 2012. Further energy carriers used to produce electricity were wind, water and biogas (fig. 1). Electricity generated from biogas was derived mainly from landfill biogas (41.8%) and wastewater treatment plants biogas (34.3%). In contrast, liquid biofuels and solar power accounted for a small share in the total electricity production (GUS, 2013).

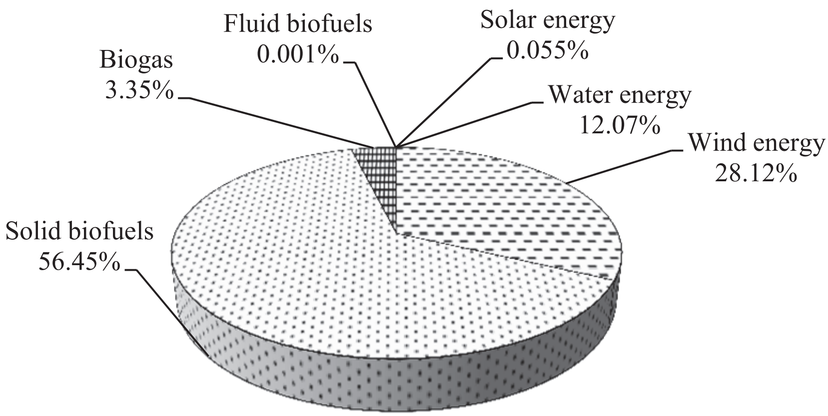

Figure 1. Participation of renewable energy in production of electricity in 2012 (GUS, 2013)

Types of biomass

Plant biomass is formed as a result of photosynthesis, in which the energy of solar radiation converts CO_2 and H_2O into organic compounds. It is considered a major renewable energy source because its resources reproduce in a short time. Biomass for biofuel use is extracted from various sources such as: forestry, agriculture, industry (mainly agri-food), public utilities and other sources. The energy contained in biomass can be processed into other, very convenient, forms of biofuels. The main components of plant biomass energy are: cellulose, hemicellulose and lignin, which are multi-particulate biopolymers. The contents of these ingredients in the selected types of biomass are presented in table 2.

Solid biofuels include organic, non-fossil substances of biological origin, which can be used as fuels to produce heat or electricity. The main solid biofuels are: firewood occurring in various forms, briquettes or pellets produced from plant waste materials and waste from timber and paper industries. A separate group of fuels are those from energy crops plantations (fast-growing trees, perennial dicotyledonous plants, perennial grasses, energy crops) as well as organic residues from agriculture and horticulture (Denisiuk, 2006; Kościk, 2007; Kołodziej and Matyka, 2012).

The following types of biomass can be mentioned according to their origin:

1. Wood biomass (dendromass):
   - Shrub biomass,
   - Deciduous and coniferous fast-growing trees biomass,
   - Residues and waste from wood biomass processing industry.
2. Agricultural biomass (agrimass):
   - Biomass from crop production waste and residues,
   - Biomass from energy crops,
   - Biomass from agri-food production waste,
   - Biomass coming from other biodegradable waste.
3. Biomass of animal origin (zoomass):
   - Animal manure, solid and liquid (manure, slurry),
   - Side waste of slaughtering animals (e.g. stomach content),
   - Products from animal processing (e.g. fats).

Table 2
Composition of polymers in the selected types of plant biomass (Klimiuk et al., 2012)

Type of biomass	Cellulose (%)	Hemicelluloses (%)	Lignin (%)
Wheat straw	38.0	30.0	16.5
Rye straw	28.8	27.6	2.8
Maize stover	12.4	30.8	1.4
Grasses	39.7	16.9	17.6
Energy plants	45.0	30.0	15.0
Soft timber	35-40	25-30	27-30
Wood waste	50.0	23.0	22.0
Municipal waste	45.0	9.0	10.0

The primary source of biomass obtained from crop production is straw from cereals and other crops. An important role of potential biomass resource is also played by energy plants, which include: fast-growing shrubs and trees (*willow*, *Rosa multiflora*, *Robinia pseudoacacia*, *poplar*, *Acer negundo*), long-lasting perennials (*Virginia mallow*, *Jerusalem artichokes*, *Silphium-perfoliatum*, *Sakhalin knotweed*), perennial grasses (*reed canarygrass*, *Miscanthus giganteus* and *Miscanthus sacchariflorus*, *Andropogon gerardi*, *Spartina pectinata*, *Panicum virgatum*), annuals (energy crops: maize, beet, rape, rye) and others (Majtkowski, 2007; Stolarski et al., 2008; Terlikowski, 2012).

Methods of biomass conversion

Plant biomass obtained in varying weather conditions is usually characterized by increased moisture and it needs drying. The drying process of biomass is carried out prior to its storage in order to get rid of water contained in the material and to avoid the problems associated with:

– Decay of plant material (loss of dry weight and energy),
– Processes that cause mold growth and cause risk to human health and the environment,
– Risks arising from self-ignition (self-heating),

– Microbiological processes resulting in emissions of greenhouse gases,
– Reduction of calorific value.

A commonly used method of mechanical biomass processing is its grinding (cutting, chipping) and pressing, briquetting or pelleting (fig. 2). Shredding is usually used before transporting biomass, to increase its bulk density and reduce transport costs. In turn, pressing, briquetting and pelleting of biomass is the process of fuel densification in order to improve its physical and energy properties. Densification most commonly applies to solid biomass, i.e. sawdust, wood chips, straw, hay, husks etc. This type of biomass conversion increases its energy density, defined as the ratio of calorific value per unit volume ($GJ \cdot m^{-3}$), reduces moisture content and also causes standardized sizes and shapes of the derived biofuels, so that they can both be used in the power industry and distributed. Table 3 shows some of the energy, physical and chemical properties of solid biofuels produced from selected types of straw.

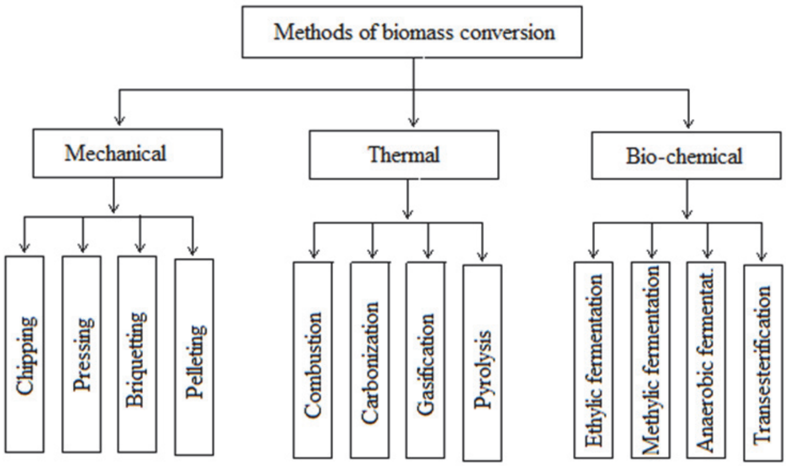

Figure 2. Methods of biomass conversion into biofuels

Table 3
Energy, physical and chemical properties of solid biofuels produced from straw (Lewandowski and Ryms, 2013)

Specification	Measure unit	Briquettes		Pellets	
		Wheat straw	Rape straw	Wheat straw	Rye straw
Calorific value	($MJ \cdot kg^{-1}$)	15.2	20.1	18.2	19.2
Moisture	(% mass)	15.1	9.6	8.3	6.6
Bulk density	($kg \cdot m^{-3}$)	320	310	540	580
Diameter	(mm)	50.0	50.0	9.0	9.0
Chloride content (Cl)	(% mass)	0.047	0.013	0.270	0.263
Sulfur content (S)	(% mass)	0.160	0.592	0.130	0.390
Carbon content (C)	(% mass)	45.5	50.0	45.5	40.1

Thermal biomass conversion methods, in addition to combustion, include carbonization, gasification and pyrolysis. The biomass used as a fuel in power industry can be burnt in different ways. The most common way is direct combustion in special fluidized bed boilers that are characterized by a very high efficiency of the combustion process and stable working conditions. Another way is the biomass co-incineration with coal in power boilers designed for the combustion of coal or charcoal

Direct co-incineration of biomass is carried out in the combustion chamber into which the biomass and coal are supplied either separately or as a previously prepared mixture of biomass and coal. Indirect co-incineration is carried out after the biomass gasification in a special gasifier, when the resulting gas is transported to the combustion chamber where it is burnt in special burners. And in the parallel incineration the coal and biomass are burnt in separate combustion chambers in which both the combustion processes are individually prepared and controlled.

The thermal carbonization of biomass is carried out under anaerobic conditions, at the temperature of 200 to 300ºC under the near atmospheric pressure. It is actually the process of high-temperature drying of biomass for processing into biofuel with properties similar to carbon.

As a result of biomass carbonization the obtained fuel is characterized by:
– Similar physical and energy properties,
– Higher calorific value,
– Hydrophobic nature,
– High resistance to biological processes,
– Increased milling properties,
– Higher melting temperature of ashes.

Pellets made from char are characterized by high energy density, they are resistant to moisture absorption and do not require special equipment for storage, as is the case with conventional pellets. The combination of biomass pelletizing with carbonization process gives good results for these biofuels which in the future may become a substitute for coal. After this process the lignocellulosic biomass becomes more carbon-like. Milling properties are improved, whereby there is a reduction in energy expenditure for grinding. Also the hydrophobic properties are upgraded, which make storage of biomass safer as the risk of its biological degradation is lower.

Pyrolysis is a process of thermal decomposition of biomass occurring in oxygen-free atmosphere or in the presence of a small amount of oxygen relatively to the amount of oxygen needed for combustion. The main products of pyrolysis are pyrolysis gas, bio-oil (called pyrolytic oil) and char (solid form with a high degree of oxidation). Pyrolysis can be fast or slow. During the fast pyrolysis biomass is decomposed under the influence of elevated temperature (approx. 500ºC) to form a vapor and an amount of the char. Upon cooling some of the products are condensed to generate a dark brown oily liquid with a high calorific value. The slow pyrolysis is traditionally used in the production of charcoal by wood de-oxidation (dry distillation). Currently, the slow pyrolysis is used for the production of char characterized by greater stability and energy density as well as very low moisture.

Gasification of biomass includes a series of thermal processes, wherein the treated solid fuel is delivered to a device called a gas generator, reactor or gasifier. This method of converting biomass is appropriate when it is to be used in dispersed, small or medium-sized cogeneration systems. During biomass gasification the wood gas (holzgas) is produced. In the gasification process the following steps can be identified: the biomass drying at the temperature of approx. 150ºC, the isolating from the fuel of volatiles at the temperature of 200-600ºC, i.e. oxidation, in other words formation of oxide and carbon dioxide and water vapor at the temperature above 600ºC and the reduction of carbon dioxide and steam to carbon monoxide and hydrogen. In the process of biomass gasification the following types of products are obtained: gas, liquid (condensing ones, steam, alcohols, acids), tar (heavy hydrocarbons condensing to a solid form) and solid (ash).

Among the biochemical methods of biomass conversion there are anaerobic fermentation, during which alcohols or biogas are obtained, as well as vegetable oils and animal fats transesterification for the production of biodiesel. Biomass which is composed of cellulose, hemicelluloses and lignin is biochemically conversed to liquid biofuels. After hydrolysis it becomes a material rich in sugars, from which in the process of the subsequent biochemical process ethanol or biogas is produced. Virtually each of biomass types is a potential raw material for the production of first-generation biofuels. There are the following processes of biomass hydrolysis: thermal hydrolysis, wherein the long chains of cellulose and hemicellulose molecules are reduced in an aqueous medium by the input of thermal energy, and anaerobic digestion, during which the cellulose is converted to sugars, and these in turn are converted to liquid biofuels.

Benefits and risks associated with the use of biomass

The use of biomass for energy purposes has both a lot of advantages and numerous disadvantages. First of all, its application as a biofuel is fairly harmless to the environment. This is due to the fact that during the combustion of biomass the CO_2 emissions are balanced with the CO_2 amount absorbed by plants in the process of photosynthesis. In some cases, for example, perennials can take from the atmosphere more CO_2 than they emit during combustion in boilers. In addition, biomass contains significantly lower amounts of sulfur, so there is no need for flue gas desulfurization which takes place during coal combustion. Also, the use of biomass for heating is very cost-effective because its prices are lower than those of other fuels. Another advantage is finding use for uncultivated land and waste (Romanowska-Słomka, 2009).

Among the benefits associated with the use of biomass there are, e.g.:

- Protection of the environment,
- Management of degraded land unsuitable for agriculture,
- Increasing the share of renewables in the overall balance of raw materials,
- Ensuring the energy security of the country,
- Management of surplus food on the market,
- Ensuring revenues from agricultural production carried out for non-food purposes,
- Creating conditions for the restructuring of the Polish countryside and agriculture,
- Development of the industry in terms of resources for the production and processing of biomass,
- Providing a cheap source of heat for industrial and municipal customers.

In contrast, the physical and biological hazards are associated primarily with the way the preparation and storage of biomass are performed. Storage of wet plant biomass is associated with the growth of microorganisms whose metabolic activity increases its temperature. In extreme cases, the temperature rise may lead to self-ignition. Biomass exposed to adverse weather conditions quickly becomes damp. Such an action leads to an intensive growth of microorganisms. The resulting fungi and bacteria may be a serious threat to the health of workers and can cause allergic reactions. Harmful micro-organisms include the toxin-producing fungi as well as viruses and parasites that can promote cancers, and even cause death. The most exposed to infections and allergies are people serving boilers because they do the loading and unloading work. Also, people employed in waste incineration are additionally exposed to contact with microorganisms carried by rodents (mice and rats), and even with parasites (Romanowska-Słomka, 2009).

In addition, the risks associated with the use of biomass include e.g.:

– Greater demand for large energy plants plantations and thus reduction or even elimination of biodiversity,
– Formation of large-scale monocultures and soil exhaustion,
– Possibility of a fire hazard in the accumulated biomass resources,
– Reducing the performance and efficiency of boilers,
– Destruction of heating devices associated with the so-called high-temperature corrosion,
– Sintering and agglomeration of ash (defluidization of the fluidized bed),
– Formation of deposits on the convection surfaces.

Conclusion

Environmental protection issues related to the operation and depletion of conventional fuels, as well as the growth of polluting emissions, contribute to the wider use of renewable energy sources. It results from the growing environmental awareness in societies and the desire to counteract the greenhouse effect and global warming. A significant reduction in the amount of emitted substances believed to be particularly harmful to the environment can be achieved by the use of biomass for energy purposes. However, energy production from biomass should be done without any risk to the acquisition of adequate resources for human food and animal feed.

Given the trends in new technologies concerning the use of biomass for energy purposes (relatively low conversion efficiency), it can be assumed that in the future the solutions applied on a larger scale will be cogeneration (production of electricity and heat in a single process) and trigeneration (production of electricity, heat and cooling in a single process). These solutions can significantly upgrade the management and use of available biomass resources in Poland and greatly contribute to the achievement of desired objectives in the field of climate and energy policy of this country.

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MOŻLIWOŚCI WYKORZYSTANIA BIOMASY NA CELE ENERGETYCZNE

Streszczenie. Stale rosnące wraz z rozwojem cywilizacyjnym zapotrzebowanie na energię, przy wyczerpywaniu się jej tradycyjnych zasobów – głównie paliw kopalnych (węgiel, ropa naftowa, gaz ziemny) oraz towarzyszący ich zużyciu wzrost zanieczyszczenia środowiska naturalnego, powodują zwiększenie zainteresowania wykorzystaniem energii ze źródeł odnawialnych. W pracy przedstawiono znaczenie odnawialnych źródeł energii w bilansie energetycznym kraju. Szczególną uwagę zwrócono na podstawowe źródło energii odnawialnej w Polsce, jakim jest biomasa. Opisano rodzaje biomasy oraz podano ogólne właściwości energetyczne i fizyczno-chemiczne podstawowych surowców roślinnych pozyskiwanych do celów energetycznych. Omówiono możliwości wykorzystania biomasy do produkcji energii elektrycznej i ciepła oraz stosowane sposoby jej konwersji na biopaliwa. Podkreślono także korzyści i zagrożenia związane z wykorzystaniem biomasy roślinnej na cele energetyczne.

Słowa kluczowe: biomasa, produkcja energii, sposoby konwersji, korzyści i zagrożenia

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INVESTIGATION OF THE IMPACT OF WATER CONTENT AND ACTIVITY ON ELECTRIC PROPERTIES OF HONEY WITH THE USE OF NEURAL NETWORKS

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ABSTRACT

The objective of this research was to determine how water content and water activity impact on the selected electrical honey parameters. Experimental data obtained for fifty samples of honey collected on the territory of Poland were used for research. These were nectar honeys, nectar-honeydew as well as honeydew honeys. Chemical and electrical parameters were determined for each sample: conductivity of 20 percentage water and honey solution, conductivity and impedance of liquid honey. Then, with the use of artificial neural networks, multi-dimensional mathematical models, describing relationships between electrical and chemical properties were constructed. Based on these models, with the use of knowledge on networks structure and values of synaptic weights, degree of the impact of particular input parameters on output parameters of the model was determined. The tests which were carried out proved that water activity and content influence impedance more than conductivity of liquid honey and solution.

Introduction and objective of the research

Water content and water activity are of great importance for food quality and food storage. There is a connection between these two parameters and their values have a great impact on preservation of food products of biological origin. Honey is that type of food therefore water as well as monosaccharides content determine its physical properties. Water content influences the honey fermentation phenomenon, which deteriorates the product quality (Lazaridou et al., 2004). There is a correlation between water content and water activity, however water activity provides more information on the product. During honey storage, crystallization process is observed, what influences the water-binding characteristics in honey and causes increase in water activity (Iurlina and Fritz, 2005; Wojtacki, 1989).

Measurement of honey water activity requires specialised equipment therefore it can be performed only in specialized laboratories. Electrical features of biological materials are seldom used for food quality assessment, however one can find some publications on this subject (Skierucha et al., 2012; Łuczycka et al., 2011). Electrical properties such as conductivity and impedance can be used for assessment of honey quality. Therefore it is appropriate to establish the effect of water content and water activity on certain electrical features of honey.

The determination of relations between chemical and electrical honey properties based on the measurement data is difficult with the use of analytical methods. In publications on the agricultural engineering subject one can find many reports describing the use of artificial neural networks for modeling of complex nonlinear relationships (Langman, 1999; Hebda and Francik, 2006; Górski et al., 2008; Łapczyńska-Kordon et al., 2008). A multilayer perceptron with quite a simple structure can be used for these tasks (Pentoś et al., 2008; Łuczycka and Pentoś, 2010).

When sufficiently extensive measurement data set is used for network training, the network can be used as a mathematical model of complex, multidimensional and nonlinear relationships (Rutkowska et al., 1999; Osowski, 2006; Rutkowski, 2011). The network structure is empirically selected as to obtain a model with high accuracy for both, training and testing data set.

The aim of the research was to use neural models obtained from simulation tests for determination of the influence level of water content and water activity on certain honey electrical properties.

Methodology

Chemical and electrical parameters were determined for fifty honey samples. Among these fifty samples were nectar honeys (39 samples), nectar-honeydew honeys (4 samples) and honeydew honeys (7 samples). All honey samples were harvested in year 2011 directly from producers located on the area of Poland. The following honey parameters were measured: water content, water activity, the content of glucose, fructose and proline, pH, diastase, strained honey conductivity, conductivity of aqueous solution of honey at 20%, strained honey impedance.

Water activity measurement was conducted at the Department of Agriculture and Food Technology at Bialystok University of Technology. For water activity determination liquid honey was used. Samples were heated up to the temperature of 55ºC and afterwards cooled down to the temperature of 25ºC. The measurements were taken in the temperature of 25ºC by the use of AQUA LAB CX-2 device with a climate chamber. The measurements were taken by five repeated tests (using five different samples) and afterwards average value was calculated. Water content determination was conducted with the use of refractometric method by refractive index measurement (with Abbe-type refractometer). Other chemical parameters were measured in Bee Product Quality Testing Laboratory, the Research Institute of Horticulture, Apicultural Division in Pulawy. For glucose and fructose content measurement, HPLC method was used, for proline content – a calorimetric (A) method, for diastase – Phadebas (A) method.

Electrical parameters measurement was conducted in the Institute of Agricultural Engineering, Wroclaw University of Environmental and Life Sciences. All parameters were measured in the temperature of 25ºC. Impedance was measured by means of ATLAS 0441 apparatus. The impedance analyzer enabled the complex impedance measurement. The real part of impedance and imaginary part of impedance were used separately in neural models. For the conductivity determination by direct method, aqueous solution of honey at 20% was used. The measurement was taken by means of AZ 8361 Cond./TDS apparatus. Before measurement, a liquid form of honey was obtained by samples heating up to the temperature of 40ºC. Electrical honey features measurements were taken four times.

The values of experimental data were of the wide range (e.g. conductivity of aqueous solution of honey at 20% – from 165 to 1222, water activity from 0.52 to 0.65). This kind of values high spread can cause difficulties during neural network training process and can lead to mistakes in determination of the influence level of certain input parameters on output parameters. Therefore, training data were normalized into a new range of <0.1–1> using the equation (Eq. 1):

$$ZN = \frac{ZN_{\max} - ZN_{\min}}{Z_{\max} - Z_{\min}} \cdot (Z - Z_{\min}) + ZN_{\min} \quad (1)$$

where:

ZN – normalized value of z variable,
$ZN_{\min}$ – minimum value of a normalized range,
$ZN_{\max}$ – maximum value of a normalized range,
Z – experimental value of z variable,
$Z_{\min}$ – minimum experimental value of z variable,
$Z_{\max}$ – maximum experimental value of z variable.

Based on the data obtained during the experiment, a neural model was performed. The following honey features were suggested as input model parameters:

– water content, (%)
– water activity, (-)
– glucose content ($g \cdot 100g^{-1}$)/fructose content ($g \cdot 100g^{-1}$) ratio
– proline content, ($mg \cdot 100g^{-1}$)
– pH, (-)
– diastase, (-).

As output model parameters the following honey electrical features were suggested:

– strained honey conductivity, ($S \cdot m^{-1}$)
– conductivity of aqueous solution of honey at 20%, ($S \cdot m^{-1}$)
– impedance, (Ω) .

Input as well as output model parameters were proposed on the basis of authors experience.

Two independent network models were used for the determination of water content and water activity influence on honey electrical parameters. In the first model the input parameters were as follows: water content, glucose content /fructose content ratio, proline content, pH and diastase. In the second model water activity was used instead of water content.

The aim of neural models development was to determine the influence of water content and water activity on certain honey electrical parameters. Therefore neural networks containing five input nodes and four neurons in the output layer were used. The scientific reports of other authors (Ślipek et al., 2003) show that the experimental data set should be divided into a training and testing set in appropriate proportions e.g. 70% patterns for the training set and 30% patterns for the testing set. During the training process, the training set of 150 patterns and the testing set of 50 patterns were used. Simulations were executed using *Matlab* environment. The feed-forward neural networks (a multilayer perceptron) with one hidden layer were used. The initial weights values were selected randomly. The training process was executed using some different training algorithms (selected backpropagation algorithm modifications). Several dozen network configurations were tested. The number of neurons in the hidden layer was changed from 3 to 50. The best network architecture was chosen on the basis of the error value for the training set (the error value for the testing set was also calculated in order to avoid the overfitting effect). The mean relative error calculated as follows was used:

$$\varepsilon = \frac{\sum_{i=1}^{n} \frac{|(x_i^{\exp} - x_i^{calc})|}{x_i^{calc}} \cdot 100\%}{n} \tag{2}$$

where:

$x_i^{\exp}$ – the output expected value for *i*th pattern from training or testing set,

x_i^{calc} – the output value for *i*th pattern from training or testing set calculated by neural model,

n – the number of patterns in the training or testing set.

On the basis of the network structure and connection weights values after learning process, the algebraic expression describing relations between output and input parameters can be developed (Pentoś, 2009). Each connection between two neurons is described by the connection weight value *w*. For each neuron the activation function *f* is defined (in this work the sigmoid activation function for neurons in the hidden layer and linear activation function for neurons in the output layer were defined). The general expression describing the output signal of *i*th neuron in the output layer is as follows:

$$y_i = f_{wi}\left(\sum_{j=1}^{n} w_{ij}^{(2)} v_j\right), \tag{3}$$

where:

$$v_j = f_{uj}\left(\sum_{k=1}^{m} x_k w_{kj}^{(1)}\right). \tag{4}$$

In the expressions 3 and 4 x_k is the *k*th element of the input vector, y_i is the *i*th element of the output vector, f_{wi} is the activation function of *i*th neuron in the output layer, f_{ui} is the activation function of *j*th neuron in the hidden layer, $w_{kj}^{(1)}$ is the connection weight between *k*th input node and *j*th neuron in the hidden layer, $w_{ji}^{(2)}$ is the connection weight between *j*th neuron in the hidden layer and *i*th neuron in the output layer, v_j is the output signal of *j*th neuron in the hidden layer, *n* is the number of neurons in the hidden layer, *m* – is the number of input nodes.

On the basis of connection weights values in the neural network built of neurons with a sigmoid activation function in the hidden layer and a linear activation function in the output layer, for each network output the expression describing relationship between input and output model parameters can be developed. The expression is the sum of components as follows:

$$\frac{a}{1+\exp(b_1x_1+b_2x_2+...+b_nx_n)} \tag{5}$$

where the value of component a depends on the connection weights of neurons in the output layer values and values of components b_1, b_2, ..., b_n depend on the connection weights of neurons in the hidden layer. The expression describing the output signal of ith neuron in the output layer can be approximated by the following expression:

$$y_i = \chi_{i1}x_1 + \chi_{i2}x_2 + ... + \chi_{in}x_n \tag{6}$$

where values of components χ can be calculated or estimated using numerical methods. In this case, the multiple regression method was used. The data set representing the relationship between y_i and input parameters was generated (points must be located evenly in the parameters hyperspace across the parameters variability range). Based on the generated data set, the multiple regression was conducted (with the control of correlation coefficient R and determination coefficient R^2).

Test results

In order to verify the neural model accuracy, the preliminary tests were conducted. The aim of preliminary tests was to determine if all input model variables influence significantly on output model parameters. The four independent neural models were developed using *Statistica* environment. In each neural model six input nodes were used for six input variables mentioned above. Each neural model contained one output neuron for output variable (for four consecutive output parameters mentioned above). For each model, 150 feed-forward networks with different architecture were investigated using *Automated Neural Networks* in order to find the best network architecture. For the best networks found during this investigation, the sensitivity analysis was conducted. The results of the sensitivity analysis proved that all input variables influence significantly all output variables (the errors ratio value ≥1). The most significant influence on strained honey conductivity was observed for diastase and the least for the glucose content /fructose content ratio. In case of conductivity of aqueous solution of honey at 20%, the most important input variable is diastase and the least – proline content. In case of real part of impedance – proline content and pH respectively, in case of imaginary part of impedance – diastase (the most important) and water content (the least important).

Afterwards, two independent neural models were developed and used for determination of the influence of water content and water activity on honey electrical parameters. As a model used for determination of water content on honey electrical parameters, the network with the architecture 5-9-4 (nine neurons in the hidden layer) was used. The mean relative error calculated for training data set was equal to 2% (for the testing data set it was 5%).

On the basis of the connection weights values the expression describing relationship between each output variable and input variable was determined. Afterwards, each expression was approximated by polynomial and the following algebraic expressions were obtained:

$$y_1 = -27x_1 + 4{,}24x_2 + 0{,}79x_3 - 6{,}17x_4 + 32{,}77x_5 \quad (7)$$

$$y_2 = -9{,}28x_1 + 15{,}25x_2 + 0{,}49x_3 - 15{,}54x_4 + 11{,}16x_5 \quad (8)$$

$$y_3 = 58{,}45x_1 + 11{,}96x_2 - 21{,}93x_3 + 20x_4 - 108x_5 \quad (9)$$

$$y_4 = 41x_1 - 7{,}6x_2 - 14{,}77x_3 + 8{,}7x_4 - 89x_5 \quad (10)$$

where the follow-up y_i mean strained honey conductivity, conductivity of aqueous solution of honey at 20%, real part of impedance and imaginary part of impedance respectively and the follow-up x_i mean water content, glucose content /fructose content ratio, proline content, pH and diastase respectively.

In the fig.1. the absolute values of polynomial components describing the influence of water content on honey electrical parameters (output model variables) are shown.

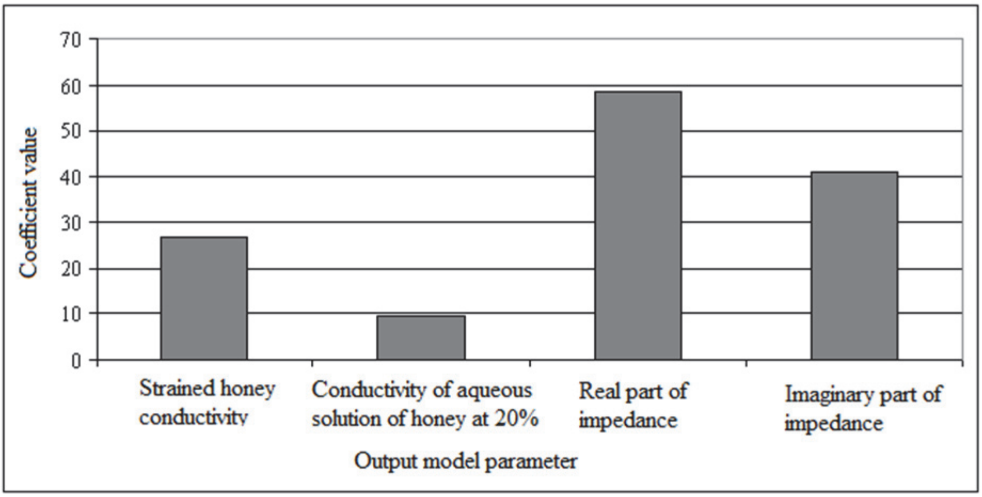

Figure 1. Absolute values of coefficients which picture the impact of water content on input parameters of the model

As a model used for determination of water activity on honey electrical parameters, the network with ten neurons in the hidden layer (the architecture 5-10-4) was used. The mean relative error calculated for training data set was equal to 2.5% (for testing data set 5.1%). On the basis of a neural model, the following polynomial expressions were obtained.

$$y_1 = 10{,}5x_1 + 14{,}5x_2 - 6x_3 + 11{,}6x_4 - 12{,}6x_5 \quad (11)$$

$$y_2 = -8{,}7x_1 - 9{,}6x_2 - 28{,}5x_3 + 24x_4 - 27x_5 \quad (12)$$

$$y_3 = 31{,}45x_1 - 17{,}3x_2 + 59x_3 + 15{,}3x_4 + 50x_5 \tag{13}$$

$$y_4 = 36{,}23x_1 - 44x_2 + 50x_3 - 12x_4 + 51{,}5x_5 \tag{14}$$

where the follow-up y_i mean strained honey conductivity, conductivity of aqueous solution of honey at 20%, real part of impedance and imaginary part of impedance respectively and the follow-up x_i mean glucose content /fructose content ratio, proline content, pH, diastase and water activity respectively.

In the fig.2. the absolute values of polynomial components describing the influence of water activity on honey electrical parameters (output model variables) are shown.

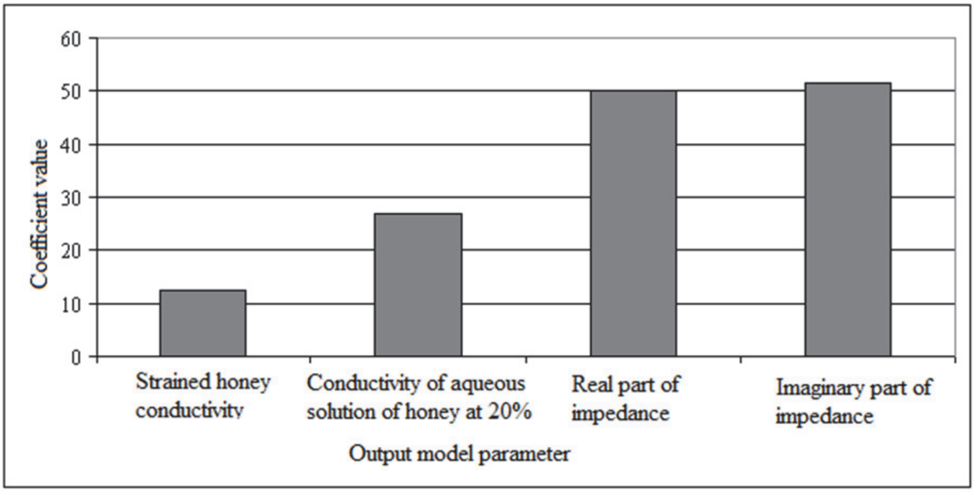

Figure 2. Absolute values of coefficients which picture the impact of water content on output parameters of the model

The polynomial expressions presented in this work are the approximation of relationships represented by a neural model obtained by the use of numerical methods. Therefore they mustn't be used as a model of relationships between chemical and electrical honey parameters. However, the contribution of input variables is not distorted. The differences between coefficients presented in Fig. 1 and Fig. 2 can not be properly interpreted because the coefficients calculation was performed using two independent neural models. Only differences of coefficients values calculated for one model can be properly interpreted.

Conclusion

Neural networks are a useful tool for the analysis of the influence of input variables on output model parameters. Particularly, when the number of parameters is high, relationships between parameters are nonlinear and the nature of relationships is difficult to describe using analytical methods. On the basis of the research results the following conclusions can be reached:

1. The water content influences the most the real and imaginary part of impedance and the least - strained honey conductivity.
2. The water activity has a significantly greater influence on the impedance (real and imaginary part) than on strained honey conductivity and conductivity of aqueous solution of honey at 20%.

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BADANIE WPŁYWU ZAWARTOŚCI WODY I AKTYWNOŚCI WODY NA CECHY ELEKTRYCZNE MIODU Z WYKORZYSTANIEM SIECI NEURONOWYCH

Streszczenie. Celem badań było ustalenie stopnia wpływu zawartości wody oraz aktywności wody na wybrane cechy elektryczne miodu. W badaniach wykorzystano dane doświadczalne uzyskane dla pięćdziesięciu próbek miodów zebranych na terenie całej Polski. Były to miody nektarowe, nektarowo-spadziowe oraz spadziowe. Dla próbek oznaczono parametry chemiczne oraz elektryczne: przewodność dwudziestoprocentowego roztworu wodnego miodu oraz przewodność i impedancję patoki. Następnie wykorzystując sztuczne sieci neuronowe, skonstruowano wielowymiarowe modele matematyczne, opisujące zależność cech elektrycznych od parametrów chemicznych. Na podstawie tych modeli, wykorzystując znajomość struktury sieci oraz wartości wag synaptycznych, określono stopień wpływu poszczególnych parametrów wejściowych na parametry wyjściowe modelu. Przeprowadzone badania wykazały, że aktywność i zawartość wody w znacznie większym stopniu wpływają na impedancję niż na przewodność patoki oraz roztworu.

Słowa kluczowe: miód, właściwości elektryczne, sztuczne sieci neuronowe, aktywność wody, zawartość wody

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SIMULATION TESTS OF FLUID FLOW IN THE PIPELINE ELEMENTS[1]

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ABSTRACT

The paper presents research results concerning the use of commercial software used for calculations in the fluid mechanics. With the use of numerical methods of CFD in the selected elements of pipe installations, pressure, speed and shear stress distribution on their walls were presented and analyzed in the aspect of cleaning conditions in the CIP system. The tests which were carried out constitute a part of the tests concerning conditions of cleaning installations of production installations funded with the research subsidy. The obtained research results have an interdisciplinary character whereas their interpretation with reference to the cleaning conditions confirms rightness of using the CFD method for forecasting and hygienic modeling of food industry devices.

Introduction

Cleaning in the CIP system (Clean In Place) is an automatized process, which does not require dismounting cleaned elements and consists in flowing through the cleaned installation suitable cleaning solutions, which during the flow moisten and tearing off post-production sediments. Devices and all production lines, which take part in production of liquid and semi-solid food along with pipelines for transportation of raw material in order to carry out another technological operation, are subject to cleaning in the CIP system (Diakun, 2013). The structure of pipelines can cause secondary infection of the produced food, particularly when it is equipped with many elbows, tees, dead ends and extra valves (Lelievre et al., 2002b, Jensen et al., 2005; Mierzejewska et al., 2013). These are the elements with variable cross-sections of flow channels, which affect flow conditions. These, on the other hand, are the most important factor in the process of cleaning within the flow, which is crucial for obtaining clean surfaces. The hydro-mechanical fluid impact on walls during the cleaning process provides mechanical cleaning effect and favors breaking off sediment particles from the cleaned surfaces, their dispersion in the entire fluid volume, their transport and

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removal. It was also shown that these impacts affect the reduction of the amount of microorganisms as early as during the cleaning process (Grasshoff, 1992; Lelievre et al., 2002a) and that the detachment of bacterial cell from the surface which isbeing cleaned, occurs when the wall shear stresses are greater than adhesive forces responsible for the bacterial adhesion (Hermanowicz et al., 1989; de Jong et al., 2002).). Many authors show, that the kinetic removal of contaminations is a function of fluid flow cleaning solutions, Reynolds number (1) and shear stresses forming on the wall (2) (Lelievre et al., 2002a; Jensen et al., 2005; Blel et al., 2007; Diakun et al., 2010), where wall shear stresses τ_w are defined as a product of dynamic viscosity μ and the flow velocity at a certain distance from the wall of element y (2).

$$Re = \frac{\rho \cdot u \cdot d}{\mu} \tag{1}$$

where:
- Re – Reynolds number,
- ρ – density, ($kg \cdot s^{-3}$)
- u – fluid flow, ($m \cdot s^{-1}$)
- d – characteristic dimension (diameter), (m)
- μ – dynamic viscosity coefficient, ($kg \cdot m^{-1} \cdot s^{-1}$)

$$\tau_w = \mu \left(\frac{\partial u}{\partial y} \right)_{y=0} \tag{2}$$

where:
- τ_w – shear stresses, (Pa)
- μ – dynamic viscosity coefficient, ($kg \cdot m^{-1} \cdot s^{-1}$)
- u – fluid flow, ($m \cdot s^{-1}$)
- y – fluid distance from the wall of the element, (m)

Velocity and flow turbulence (Re>10000) and complete moistening of all surfaces which are in contact with the product have a huge impact on the conditions of deposits removal and they are basic prerequisite in obtaining clean surface of pipelines (Bansal & Chen, 2005; Piepiórka & Mierzejewska, 2009). In order to determine the flow conditions occurring in some parts of pipelines, the numerical calculations with the CFD code were used (Lelievre et al., 2002a; Lelievre et al., 2002b; Jensen et al., 2005; Rahaman et al., 2007). It is a tool widely used for modeling and predicts flow conditions in the closed industrial installations, mainly when it is difficult to carry it out in laboratory conditions.

The objective, material and methods of the research

The objective of the research was to:

– Determine the conditions of fluid flow in the selected elements of pipelines: elbows, T-connectors, dead ends, using numerical calculations basing on the CFD code;

– Indicate, on the basis of numerical tests, in the above mentioned elements, the areas which are hard to clean within the flow.

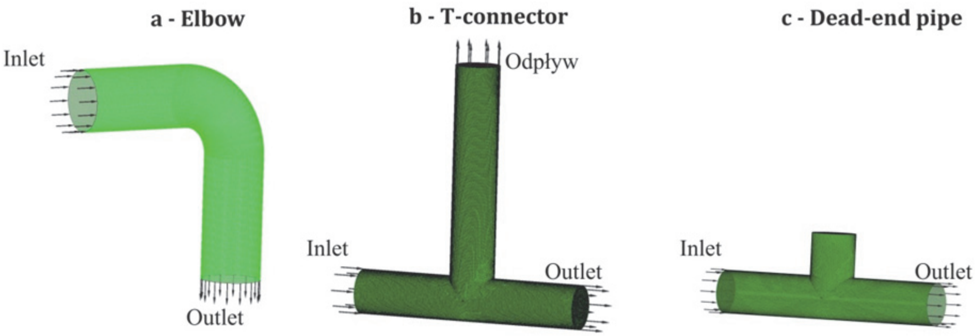

Figure 1. Boundary conditions for flow a – in the pipeline elbow; b – in the T-connector, c – in dead ends

$$u_x = 0; u_y = 0; u_z = 0; \tag{3}$$

$$\dot{m}_{in} \geq 0; \dot{m}_{out} \geq 0; \tag{4}$$

A half-empirical model of turbulence $\kappa - \varepsilon$ was used for analysis of the fluid flow in a pipeline. This model is properly adapted for the flows with high turbulence. Thus, the turbulent kinetic energy is cascade-transferred from large scale whirls to the small scale ones, where it is dissipated. In the concept of this model, the system of equations (N-S) is closed with two additional differential equations: the kinetic energy transport "κ" and the dissipation rate of turbulent kinetic energy "ε" (Elsner, 1987; Kazimierski, 2004; Bogusławski et al., 2008).

The equation for kinetic energy κ

$$\rho u_x \frac{\partial \kappa}{\partial x} + \rho u_y \frac{\partial \kappa}{\partial y} + \rho u_z \frac{\partial \kappa}{\partial z} = \frac{\partial}{\partial x}(\frac{\mu_e}{\sigma_\kappa}\frac{\partial_\kappa}{\partial x}) + \frac{\partial}{\partial y}(\frac{\mu_e}{\sigma_\kappa}\frac{\partial_\kappa}{\partial y}) + \frac{\partial}{\partial z}(\frac{\mu_e}{\sigma_\kappa}\frac{\partial_\kappa}{\partial z}) + G - \rho\varepsilon \tag{5}$$

The equation for the dissipation rate ε

$$\rho u_x \frac{\partial \varepsilon}{\partial x} + \rho u_y \frac{\partial \varepsilon}{\partial y} + \rho u_z \frac{\partial \varepsilon}{\partial z} = \frac{\partial}{\partial x}(\frac{\mu_e}{\sigma_\varepsilon}\frac{\partial_\varepsilon}{\partial x}) + \frac{\partial}{\partial y}(\frac{\mu_e}{\sigma_\varepsilon}\frac{\partial_\varepsilon}{\partial y}) + \frac{\partial}{\partial z}(\frac{\mu_e}{\sigma_\varepsilon}\frac{\partial_\varepsilon}{\partial z}) + C_1\frac{\varepsilon}{\kappa}G - C_2\rho\frac{\varepsilon^2}{\kappa} \tag{6}$$

where:
κ – turbulence kinetic energy, ($m^2 \cdot s^{-2}$)
ε – turbulence dissipation rate, ($m^2 \cdot s^{-3}$)
G – generation of the turbulence kinetic energy
μ_e – turbulent viscosity, (Pa·s)

Equations in the adopted turbulence model $\kappa - \varepsilon$, show the evolution of parameters which determine the turbulence (Jones & Launder, 1972; Wilcox, 1998). It was assumed that the constant of the model for turbulence is $C\mu$=0.09 while constant values of the coefficients are σ_κ=1.0; σ_ε=1.3; C_1=1.44; C_2=1.92.

The numeric calculations have been carried out by means of the Finite Volume Method (FVM), with the use of Ansys CFX 12 software. The idea of this method is to split computational domain into small cells – the finite volumes – and to enforce conservation by prescribing fluxes at the cells interfaces. In this way the evolution of the conserved quantities can be approximated if the fluxes are suitable approximations of the fluxes given by the conservation laws. From the pipeline elements with a diameter of d=0.038 m, spaces, which were forming the flow channels, were isolated. A numerical grid with the size of an element of 0.001m was used for discretization of each model. For this size of cells, there was no significant effect on the final simulation result. The numerical grid had tetrahedral-shaped cells, which constituted areas of computation. Boundary and initial conditions at the first step of the first iteration, were defined as a zero velocity value on the walls of the tested models, zero values of turbulent kinetic energy coefficients κ and the dissipation of turbulence ε, mass flow rate at the inlet and the outlet of the tested models at $\dot{m}$=1.95 kg·s^{-1} level. Surface roughness was assumed at the level of R_a=0.4 μm. The adopted flow rate was determined on the basis of experimental measurements of the flow velocity in the real channel pipe, for which the average flow velocity was u=1.5 m·s^{-1}. The flow was determined as turbulent, while water was the flowing liquid with viscosity and density corresponding to water at the temperature of T=45ºC. The flow conditions were established as isothermal and the flow was described as stable. On the basis of the maps of flow velocity, streamlines, velocity vectors and pressure distribution areas were determined where the flow may be advantageous or disadvantageous for the cleaning processes in the flow of t-connectors, elbows and dead ends in pipelines.

Research results

For numerical calculations the geometric models were developed (fig. 1) and the flow conditions in the selected elements of pipelines were modeled. The results of the research were shown in figures below. The first part presents the results of numerical tests for piping elbows, T-connectors and dead ends (fig. 2, 3, 4, 5). Then, in the above elements the areas which could be difficult to clean in the standard CIP method were presented (fig. 6).

Pipeline elbows

Streamlines and velocity vectors | Pressure | Wall shear stress

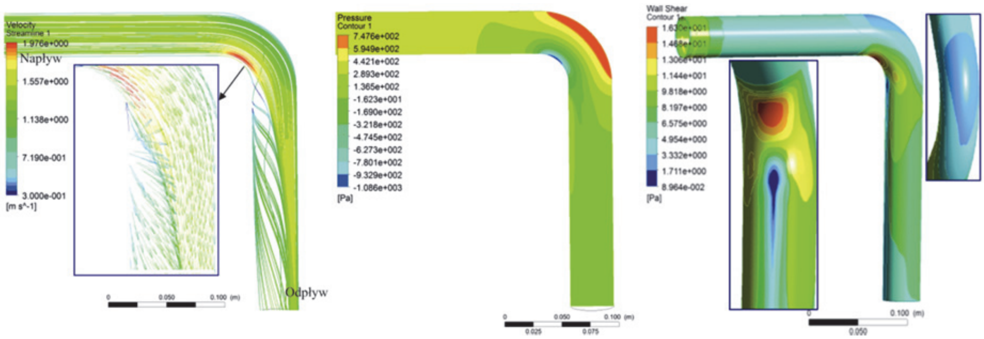

Figure 2. Results of numerical tests for pipeline elbows

The conducted numerical analyses indicate that the largest flow velocity and a large velocity gradient are present at the internal radius of the elbow. The lowest flows occur below the curve and on the external radius. In these areas small velocity gradients are present, too. The analysis of velocity vectors and streamlines leads to the conclusion that the most unfavorable area is the pipe surface below the internal curve. In these areas separation of fluid flow, as well as changes in the flow direction, occur. Whirls of fluid flow are formed here which is disadvantageous for the cleaning processes. The flow velocities in these places dropped to the value close to 0 $m \cdot s^{-1}$ and the wall shear stress dropped as well to the value of ≈0.009 Pa. The pressure distribution in the tested model indicates that the greatest pressure values occur on the outer edge of the elbow and decrease with the reduction of distance to the inner edge of the elbow. Pressures should be read as gradients for the reference pressure of P_r=1 atm.

Subsequent studies were carried out for elbows with a diameter of d=0.051 m and d=0.076 m. The numerical results were presented in figure 3.

The results of numerical calculations of fluid flow, as a distribution of velocity fields in tested models illustrate that the greatest velocities occur on the internal edges of the pipeline elbow. With the assumed values of the flow rate of fluid you can see a change of velocity due to the increased diameter. For pipeline elbow with a diameter of d=0.038 m the maximum flow velocity which occurs on the outer edge obtains u=1.97 $m \cdot s^{-1}$ while for diameter d=0.051 m it obtained u=1.15 $m \cdot s^{-1}$ and for diameter d=0.076 m it obtained only u=0.54 $m \cdot s^{-1}$.

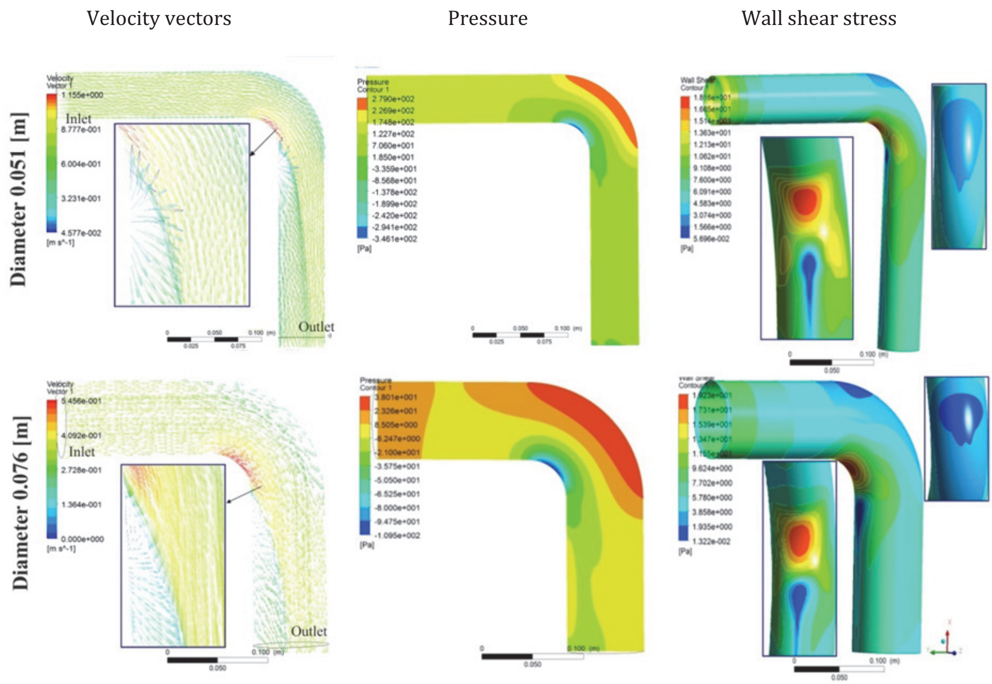

Figure 3. Results of numerical tests for pipeline elbows of various diameter

For the same models the numerical simulations with higher mass flow rate (m=3 kg·s^{-1} m=6 kg·s^{-1}) were made. The results, however, did not bring anything new. There were no significant changes in the flow character in the tested models except for the resulting flow velocity values. Relatively higher values of mass flow achieved a higher flow velocity - for smaller ones, lower values. Therefore, further studies have not taken into account this factor and focus only on the geometry of the tested elements.

Based on the results of numerical analyses, two areas with difficult cleaning conditions were identified in the elbow; these are the areas below the internal arc of the elbow and the area on the external arc (fig. 6).

T-connectors

The results of numerical calculations for tees show that the largest flow rate is obtained on the external wall, located perpendicularly to the fluid flow direction. A sudden change in the flow direction of the flowing fluid causes adverse whirls on the wall of the T-connector at the inflow. The reduced values of the flow velocity in these areas (u≈0.4 m·s^{-1}), could result in forming and growing the sediment layers and disadvantageous cleaning conditions. The lower flow velocities occur also on the outlet of the analyzed T-connector. From the initial value of u=1.5 m·s^{-1}, the flow velocity drops to u=0.1÷0.3 m·s^{-1}. This is due to liquid separation. There are no whirls of liquid in these areas, but the basic requirement for cleaning in place, which is a turbulent flow, is fulfilled only in the minimal degree. For the flow velocity at the outlet of the Reynolds number is obtained and it is $Re \approx 6000 \div 19\,000$ and therefore the flow has a laminar character. For this reason the wall shears stress are lowered.

The highest values of wall shear stresses for a tee were achieved in areas where the greatest values of flow velocity occur. That is, on the right wall of branching. On this basis, three areas in tees which could be difficult to be cleaned during cleaning in the flow were determined. That is the left wall of tees branching and the upper surface of the pipe per branching (fig. 6).

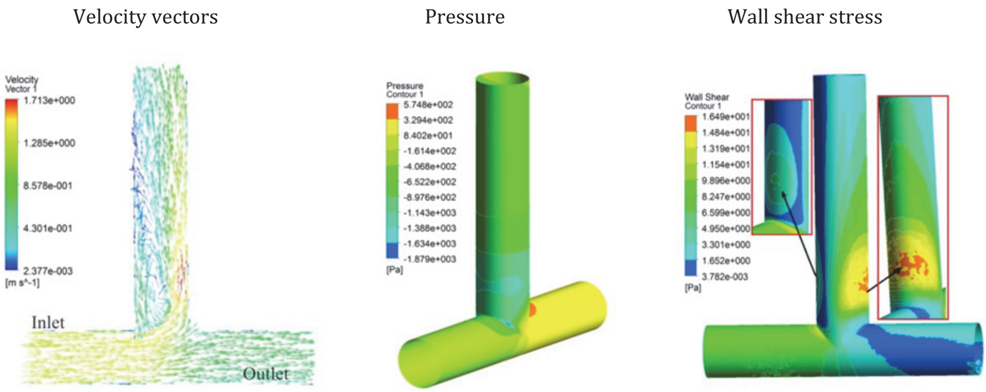

Figure 4. Distribution of flow tracks and flow velocity, pressures and shear stress vectors in a T-connector

Dead ends

In case of dead ends, liquid whirls occur as a result of the inflow in empty zones. Numerical analyses show that in long dead pipelines stasis can be also observed. The decrease in the media flow velocity in the pockets causes both product and cleaning media retention, particularly if they are directed downwards. Therefore, such solutions should be particularly avoided. However, in tees directed upwards one should expect difficult access for cleaning agents. The sediments which accumulated there will not be cleaned and these will be a great area for growth of microflora. The presence of a dead end also causes a 50% decrease in the flow velocity, to the value of u=0.5÷0.7 $m \cdot s^{-1}$ in the extension of the pipeline (right tube), on its upper edge. This area also cannot be cleaned properly.

The highest values of wall shear stresses in dead ends are at the inflow of liquid. Numerical test results also show that it is more preferable to use short blind ends. The areas considered as a potential hazard in the cleaning process were shown in figure 6.

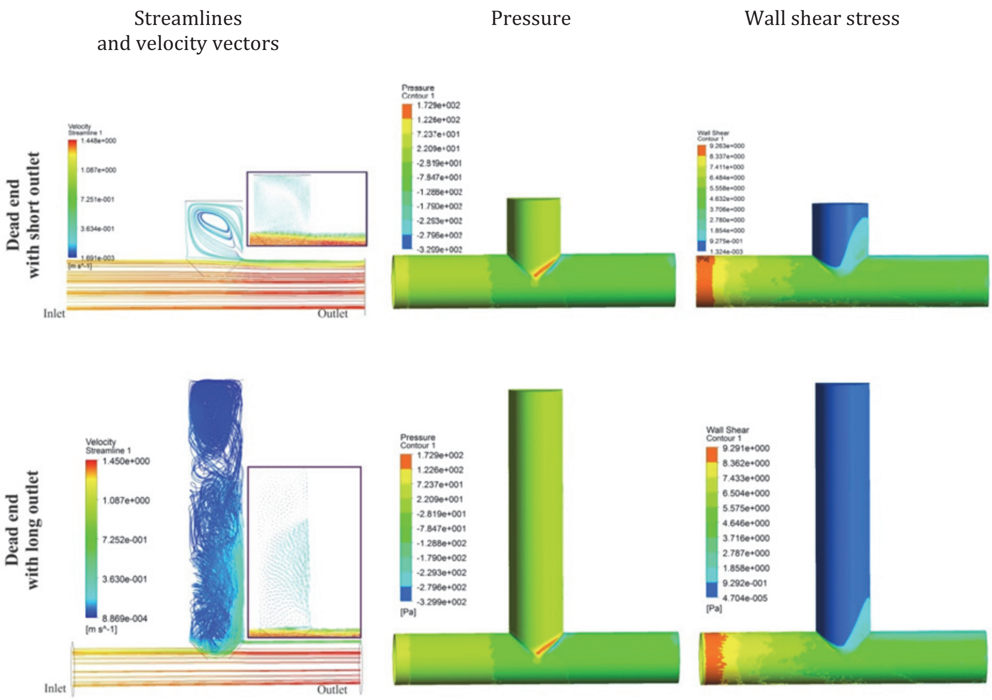

Figure 5. Distribution of flow tracks and flow velocity, pressures and shear stress vectors in dead ends of pipelines

On the basis of the CFD calculation, based on hydro-mechanical flow interactions on the walls of an item being cleaned, it was possible to identify zones in which favorable and unfavorable conditions for cleaning may occur. The identified areas were presented in figure 6.

The areas in pipeline elements which are identified as difficult to be cleaned in the flow

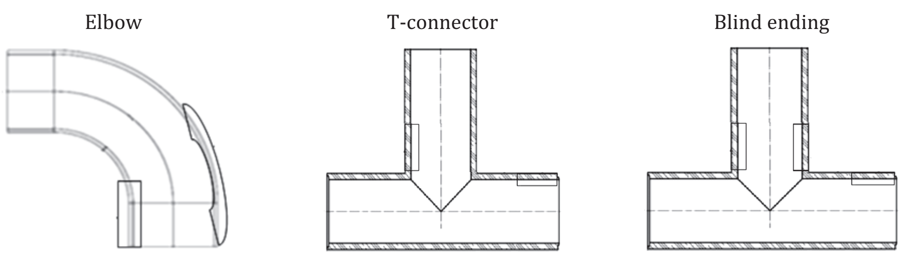

Figure 6. Areas in the tested elements of pipelines exposed to insufficient cleaning

Conclusion

The nature of the flow channel of a given device or installation has a significant impact on the hydrodynamic conditions of the liquid flow and, thus, on the conditions of the CIP cleaning. Depending on the shape of the channel, the variable velocity profiles and distribution of pressure and consequently of local variable shear stresses were observed. With respect to the cleaning conditions this may affect the varying degree of cleanliness in different areas of the tested elements in the standard procedure of the CIP.

The liquid flow in industrial transporting systems in the closed arrangement prevents finding the areas in pipes which may suffer from insufficient cleaning. This was, however, possible by conducting simulated computer calculations using different computer methods. The resulting velocity distributions indicate that there are significant differences of the flow velocity values in the analyzed models as well as differences in the flow velocity in the specified areas of piping elements. Taking into account the initial value of the fluid flow, the differences in the flow rates reach 0.7 $m \cdot s^{-1}$ in the case of elbows, or even close to 1.5 $m \cdot s^{-1}$, in case of blind ends. On the basis of the presented results it was shown that the areas of elbows and T-connectors are the most difficult to clean on internal curves. On the other hand blind ends are pockets where stagnant liquid may occur and if there is a need to use them, short blind ends should be used if possible. Furthermore, the amount of this type of elements in transporting pipeline installations should be minimal.

The CFD calculations are an innovative tool used for solving engineering problems. The research allowed obtaining information on the fluid flow velocity distributions in the pipe elements with different shapes. The velocity distributions, pressure and wall shear stress, show the changing nature of the flow in these elements, as a result of which in flow channels uneven distribution of liquid occurs.

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BADANIA SYMULACYJNE PRZEPŁYWU CIECZY W ELEMENTACH RUROCIĄGÓW

Streszczenie. W pracy przedstawiono wyniki badań dotyczące wykorzystania komercyjnych aplikacji komputerowych stosowanych do obliczeń w mechanice płynów. Za pomocą numerycznych metod CFD, w wybranych elementach instalacji rurowych, przedstawiono rozkłady ciśnienia, prędkości i naprężeń ścinających na ich ścianach i poddano je analizie w aspekcie warunków mycia w systemie CIP (czyszczenie na miejscu). Przeprowadzone badania stanowią cześć badań dotyczących warunków mycia instalacji produkcyjnych finansowanych w ramach grantu badawczego. Uzyskane wyniki badań mają charakter interdyscyplinarny, natomiast ich interpretacja w odniesieniu do warunków mycia potwierdza słuszność stosowania metod CFD do prognozowania i higienicznego modelowania urządzeń przemysłu spożywczego.

Słowa kluczowe: rurociągi, mycie w systemie CIP, obliczenia CFD

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HEAT AND MASS EXCHANGE MODEL IN THE AIR INSIDE A GREENHOUSE

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ABSTRACT

The objective of the paper was to draw up a mathematical model of heat and mass exchange in the air inside a big-size greenhouse, where commodity cultivation of plants is carried out. During formulation of the model, inter alia, models described in literature and results of experimental research were used. A developed mathematical model was implemented in MATLAB/Simulink software and simulations carried out with a computer model were used for carrying out graphical and statistical validation of a model. Analysis of simulation results allows making statement of logical correctness of the developed model and makes it possible to determine critical points of failure to adjust the model. A simplification degree of the developed heat exchange model influences its precision. In order to use the developed model e.g. for the control purposes, it requires to be more detailed.

Introduction

The interest in the greenhouse climate modeling dates back to the commodity crops under cover. Greenhouse climate models are the main tool helping to control thermal and humidity parameters inside the greenhouse. Knowledge of them supports decision-making related to cultivation, and also allows the use of modern, complex microclimate control algorithms. In the literature we can find many greenhouse climate models, they are both static and dynamic mathematical models, as well as „black box" models based on artificial intelligence methods. A review of these models can be found in the works (Boaventura Cunha, 2003; Raczek, 2012). Among the most important in this respect are the works of Bot (1983) and Jong (1990). Most greenhouse climate models are formulated for the experimental facilities, equipped with many additional sensors. Often these models are deliberately simplified. Some processes are omitted in the description in order to investigate a phenomenon which is interesting for the researchers (e.g. studies on ventilation are carried out in the facility without plants). The greenhouse climate models are formulated and validated taking into account: the crop type and development phase of crops, region and weather conditions; the structure and type of a greenhouse, and the operation of ventilation equipment as well. Therefore, it is not easy to directly extrapolate these models to differently built greenhouses located elsewhere.

The object of the research in this paper was modern Venlo type greenhouse located in Różanki in Lubuskie Voivodeshop, where on 5.9 hectares tomato cultivation was carried out. For the greenhouse a mathematical model of heat and mass transfer processes in the indoor air was developed which is presented below. In March and April 2011 temperature and relative humidity of air inside the greenhouse was recorded by a climate computer every 15 minutes, which in the model constitute the output signals, and control signals (input in the model): in the form of the heating pipe temperature and the degree of opening vents. Environmental parameters of the greenhouse constituted interference: temperature and humidity of the outside air, radiation and wind speed. The weather data were recorded by a weather station.

The objective of the paper was to draw up a dynamic, mathematical model of heat and mass exchange in air inside a big-size greenhouse, where a commodity cultivation of plants is carried out when we are provided with data on the climate parameters normally collected by a climate computer and a weather station.

The scope of work related to the greenhouse climate modeling included:

- adaptation of literature models to the test object, by taking into account characteristic dimensions of the tested greenhouse and its technical equipment,
- draw up a computer model and perform simulations,
- graphical and statistical validation of the resulting model of the process of heat exchange and mass transfer in the air inside the greenhouse using the results of experimental studies.

Mathematical model of greenhouse microclimate

Microclimate in the greenhouse is the result of combination of complex mechanisms involving processes of heat and mass transfer occurring in the greenhouse, and the processes between the interior of the greenhouse and the surroundings. Processes occurring in the greenhouse are highly non-linear, related to each other. During the formulation of a mathematical model of these processes, equations of heat and mass balances for the air inside the greenhouse should be formulated. (Wachowicz, 2006).

To develop a model the following simplifying assumptions were made:

- a greenhouse is treated as a perfectly mixed tank, i.e. the analyzed air parameters have the same value in the entire volume of the greenhouse,
- due to the lack of empirical data no effect of energy screens was taken into account,
- impact of the ground on the heat and mass transfer was neglected, because in the tested facility, cultivation was carried out on coconut fiber mats covered with white foil,
- evaporation from the greenhouse cover and crops was neglected, because in modern greenhouses a condensate is drained from the cover, and when cultivation is maintained properly, retting on plants should not take place.

Heat transfer model

Considering the equipment of the object, changes in air temperature inside the greenhouse can be presented in the form of the heat balance equation:

$$\frac{dT_{wew}}{d\tau} = \frac{1}{\rho_{wew} c_{wew} V_{sz}} \left(Q_{oslona} + Q_{s.grzewczy} + Q_{radiacja} - Q_{went} - Q_{transp} + Q_{kond} \right) \quad (\mathrm{K \cdot s^{-1}}) \quad (1)$$

where:

T_{wew} – air temperature inside the greenhouse, (K)
ρ_{wew} – air density inside the greenhouse, (kg·m^{-3})
c_{wew} – specific heat of air inside the greenhouse, (Jkg^{-1}·K^{-1})
V_{sz} – greenhouse volume, (m^3)
$Q_{osłona}$ – heat flux exchanged between the interior and the cover, (J·s^{-1})
$Q_{s.grzewcz}$ – heat flux from heating pipes, (J·s^{-1})
$Q_{radiacja}$ – heat flux supplied from solar radiation, (J·s^{-1})
Q_{went} – heat flux exchanged through the ventilation, (J·s^{-1})
Q_{transp} – heat flux exchanged by plant transpiration, (J·s^{-1})
Q_{kond} – heat flux supplied by condensation, (J·s^{-1})

Heat balance components are heat fluxes supplied to the greenhouse: due to condensation of water vapor on the cover, from heating pipes, from solar radiation and heat fluxes exchanged during ventilation, and as a result of plant transpiration. Heat transfer through the cover may take place in both directions.

Most of convective heat fluxes exchanging between different parts of the greenhouse and the air inside the greenhouse depend on the heat transfer coefficients and the temperature difference between the elements surface and the air. These fluxes describe the following equations:

– for convective heat exchange between the air inside the greenhouse and the cover:

$$Q_{oslona} = \alpha_{oslona} A_{oslona} \left(T_{oslona} - T_{wew} \right) \quad (\mathrm{J \cdot s^{-1}}) \quad (2)$$

where:

α_{oslona} – heat transfer coefficient through the cover, (W·m^{-2}·K^{-1})
A_{oslona} – cover surface, (m^2)
T_{oslona} – cover temperature, (K)

– for convective heat exchange between the air and the heating pipes:

$$Q_{s.grzewczy} = \alpha_{s.grzewczy} A_{s.grzewczy} \left(T_{s.grzewczy} - T_{wew} \right) \quad (\mathrm{J \cdot s^{-1}}) \quad (3)$$

where:

$\alpha_{s.grzewczy}$ – heat transfer coefficient of heating pipes, (W·m^{-2}·K^{-1})
$A_{s.grzewczy}$ – heating pipes surface, (m^2)
$T_{s.grzewczy}$ – heating pipes temperature, (K)

– for convective heat exchange through ventilation:

$$Q_{went} = \alpha_{went} A_{went} \left(T_{zew} - T_{wew}\right) \quad (\mathrm{J \cdot s^{-1}}) \tag{4}$$

where:

α_{went} – heat transfer coefficient between the air inside the greenhouse and its environment, ($\mathrm{W \cdot m^{-2} \cdot K^{-1}}$)

A_{went} – vent sufrace, ($\mathrm{m^2}$)

T_{zew} – outside air temperature, (K)

Heat flux supplied from solar radiation is expressed by following simplified relation (Tap, 2000):

$$Q_{radiacja} = A_{sz}\, 0{,}7\, Rad \quad (\mathrm{J \cdot s^{-1}}) \tag{5}$$

where:

Rad – solar radiation density, ($\mathrm{W \cdot m^{-2}}$)

From analysis of the results of simulation studies of the greenhouse follows that, in this case value 0.7 in the equation (5) is too high and was lowered to the level of 0.55.

Determination of the heat transfer coefficients α is a complex task. The reason for this is primarily a large number of time-varying factors that affect the value of coefficients. In this study, the heat transfer coefficients are calculated on the basis reported in the literature information models (Bot, 1983; Zwart, 1996), i.e. experimentally determined relationship between the temperature difference of the elements and the air temperature in the greenhouse and characteristic values. These coefficients are expressed by the following formulas:

– heat transfer coefficient between the air and the inner side of the cover (Zwart, 1996):

$$\alpha_{oslona} = 1{,}7 \left(\cos\varphi\right)^{0,33} \cdot \left(T_{wew} - T_{oslona}\right)^{0,33} \quad (\mathrm{W \cdot m^{-2} \cdot K^{-1}}) \tag{6}$$

where:

φ – slope of the roof, (º)

– heat transfer coefficient between the air and the upper heating pipes, which are located above the plants (Bot, 1983):

$$\alpha_{s.grzewczy\ 1} = 1{,}28\, A_{s.grzewczy\ 1}^{-0,25} \cdot \left(T_{s.grzewczy\ 1} - T_{wew}\right)^{0,25} \quad (\mathrm{W \cdot m^{-2} \cdot K^{-1}}) \tag{7}$$

– heat transfer coefficient between the air and the lower and vegetative heating pipes, when the pipes have a diameter of 51 mm and are located in the area of plants growth and under the cultivation gutters (Bot, 1983):

$$\alpha_{s.grzewczy\ 2} = 1{,}99\, A_{s.grzewczy\ 2} \cdot \left(T_{s.grzewczy\ 2} - T_{wew}\right)^{0{,}32} \quad (\mathrm{W \cdot m^{-2} \cdot K^{-1}}) \tag{8}$$

– heat transfer coefficient between the air inside the greenhouse and its surroundings through natural ventilation (Kurpaska, 2007):

$$\alpha_{went} = \rho_{wew} \cdot c_{wew} \cdot \Phi_{went} \quad (\mathrm{W \cdot m^{-2} \cdot K^{-1}}) \tag{9}$$

where:
Φ_{went} – air flow rate through ventilators, ($\mathrm{m \cdot s^{-1}}$)

taking into account density and specific heat of the air inside the greenhouse, and air flow rate through ventilators. The simplified relation presented in the work by Tap (2000) is used in the present work to calculate the air flow rate through ventilators

$$\Phi_{went} = \left(\frac{\sigma \cdot K_z}{1 + \chi \cdot K_z} + \zeta + \xi \cdot K_n \right) \cdot v_{zew} + \psi \quad (\mathrm{m \cdot s^{-1}}) \tag{10}$$

where:
K_n – opening degree of ventilators on the windward side, (%)
K_z – opening degree of ventilators on the leeward side, (%)
v_{zew} – outside wind speed, ($\mathrm{m \cdot s^{-1}}$)
σ,χ,ζ,ξ,ψ – constants, the value of which amounts to: σ=7.1708·10^{-5}($\%^{-1}$), χ=0.0156($\%^{-1}$), ζ=2.7060·10^{-5}(-), ξ=6.3233·10^{-5}($\%^{-1}$), ψ=7.4·10^{-5} ($\mathrm{m \cdot s^{-1}}$)

Air flow rate depends on the degree of opening vents on the windward side K_n and lee side K_z as well as on the outside wind speed v_{zew}.

The last two heat fluxes Q_{transp} and Q_{kond} included in the heat balance are latent heat. One of them is heat Q_{transp} lost through transpiration of plants (11), when due to plant metabolism the water passes from the liquid phase into the gaseous one.

$$Q_{transp} = r_0 A_{liscie} M_{transp} \quad (\mathrm{J \cdot kg^{-1}}) \tag{11}$$

where:
r_0 – heat of vaporization or condensation, ($\mathrm{J \cdot kg^{-1}}$)
$A_{liście}$ – leaf area, ($\mathrm{m^{-2}}$)
M_{transp} – mass flux absorbed by plants through transpiration referred to m^2 of the greenhouse area ($\mathrm{kg_{pary} \cdot m^{-2} \cdot s^{-1}}$)

The second source of the latent heat is the condensation on the cover. By condensation of water vapor, heat is released to the environment:

$$Q_{kond} = r_0 A_{oslona} M_{kond} \quad (\mathrm{J \cdot kg^{-1}}) \tag{12}$$

where:
M_{kond} – mass flux from the condensation ($\mathrm{kg_{pary} \cdot m^{-2} \cdot s^{-1}}$)

Mass exchange model

Water vapor content of the air inside the greenhouse is an important environmental parameter, which determines the proper development of a crop. It is also used to assess the risk of diseases and undesirable pest development.

A model describing the changes in the water vapor content of the air inside the greenhouse is based on the mass balance equation. The primary source of water vapor in the balance equation is plant transpiration. Water vapor in the air inside the greenhouse is reduced as a result of condensation on the inner side of the cover. Mass transfer due to ventilation can take place in both directions depending on the conditions inside and outside the greenhouse. Mass balance equation takes the following form:

$$\frac{V_{sz}}{A_{sz}}\frac{df_{wew}}{d\tau} = M_{transp} - M_{kond} - M_{went} \quad (13)$$

where:
A_{sz} – greenhouse area, (m^{-2})
f_{wew} – water content of the air inside the greenhouse, ($g \cdot m^{-3}$)
M_{went} – mass flux due to ventilation, ($kg_{pary} \cdot m^{-2} \cdot s^{-1}$)

In this study to determine the transpiration of the plants a regression model presented in the work (Kurpaska, 2006) was applied. It was developed to determine the water demand of greenhouse tomatoes, taking into account controllable factors of the surrounding climate, i.e. solar radiation *Rad*, air temperature inside the greenhouse T_{wew} and vapor pressure deficiency *VPD*.

$$M_{transp} = \frac{1}{120}\left(0{,}0025 \cdot Rad + 0{,}098 \cdot T_{wew} - 0{,}143 \cdot VPD + 0{,}05\right)\ (g \cdot m^{-2} \cdot s) \quad (14)$$

where:
VPD – vapor pressure deficit, (Pa)

In order to simplify the developed mass exchange model it was assumed that the temperature of inner side of the cover is calculated according to the following equation (Kurpaska, 2007):

$$T_{oslona} = 0{,}4T_{zew} + 0{,}6T_{wew}\ (K) \quad (15)$$

where:
T_{oslona} – cover temperature, (K)

Whereas condensation of water vapor on the inner side of the cover is expressed by the relation (Tap, 2000):

$$\begin{cases} M_{kond} = m_1 \left| T_{wew} - T_{oslona} \right|^{m_2} \left(f_{wew} - f_{\max wew} \right) & \text{gdy} \quad f_{wew} > f_{\max wew} \\ M_{kond} = 0 & \text{gdy} \quad f_{wew} \le f_{\max wew} \end{cases} \quad (\text{g}\cdot\text{m}^{-2}\cdot\text{s}) \qquad (16)$$

where:

$m_1 \left| T_{wew} - T_{oslona} \right|^{m_2}$ – mass transfer coefficient,
m_1 i m_2 – fixed parameters of the mass transfer coefficient,
$f_{max.wew}$ – the maximum water content of the air inside the greenhouse ($\text{g}\cdot\text{m}^{-3}$).

Reducing or increasing (to a lesser degree) the water vapor content of the air inside the greenhouse is also carried out through ventilation. The amount of water vapor removed from the greenhouse is described by the following formula:

$$M_{went} = \Phi_{went} \left(f_{wew} - f_{zew} \right) \quad (\text{g}\cdot\text{m}^{-2}\cdot\text{s}) \qquad (17)$$

where:
f_{zew} – water content in the outside air, ($\text{g}\cdot\text{m}^{-3}$)

The air flow rate through ventilators is calculated from the relationship (10) presented in the part of the work on heat balance.

Computer model and simulation results

Models of heat and mass transfer in the air inside the greenhouse, which were described earlier, were implemented in MATLAB/Simulink software. Figure 1 shows a schematic representation of the developed computer model of heat and mass transfer in the air inside the greenhouse.

The developed computer model was used to perform simulations, which led to the conduct of daily changes in temperature and humidity inside the greenhouse. Waveforms of input variables of the simulation model shown in Figure 1 were determined by experimental investigations. Figure 2 and figure 3 show exemplary results of these simulations for four consecutive days, as well as the values of the analyzed parameters obtained in the course of experimental tests in the greenhouse. The simulations carried out with a computer model were used for carrying out graphical and statistical validation of the model.

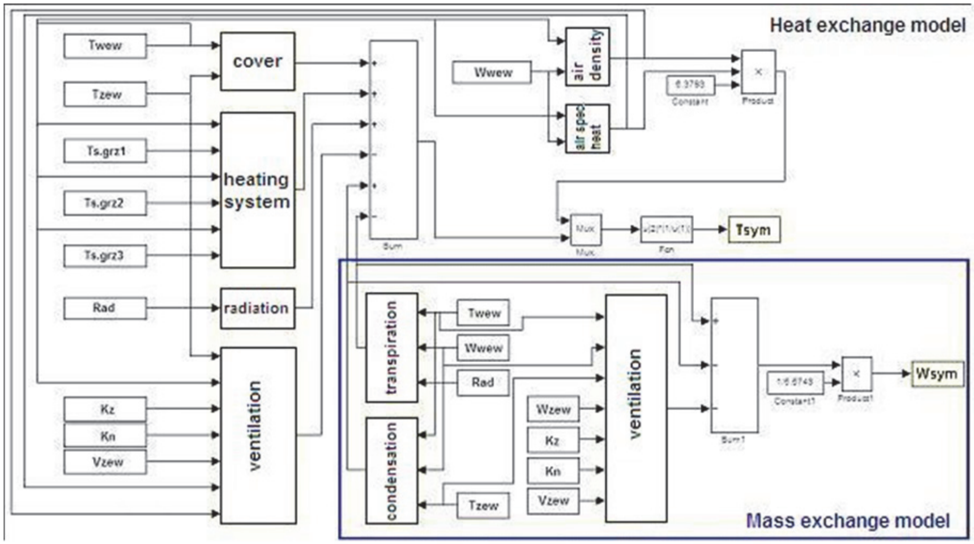

Figure 1. Schematic representation of the computer model of heat and mass exchange in air inside greenhouse. Symbols: W_{wew} *– relative humidity of air inside greenhouse (%),* W_{zew} *– relative humidity of air inside greenhouse (%),* T_{sym} *– air temperature inside greenhouse obtained as a result of computer simulations (°C),* W_{sym} *– humidity of air inside greenhouse obtained as a result of computer simulations ($kg_{pary}\cdot m^{-3}_{powietrza}$)*

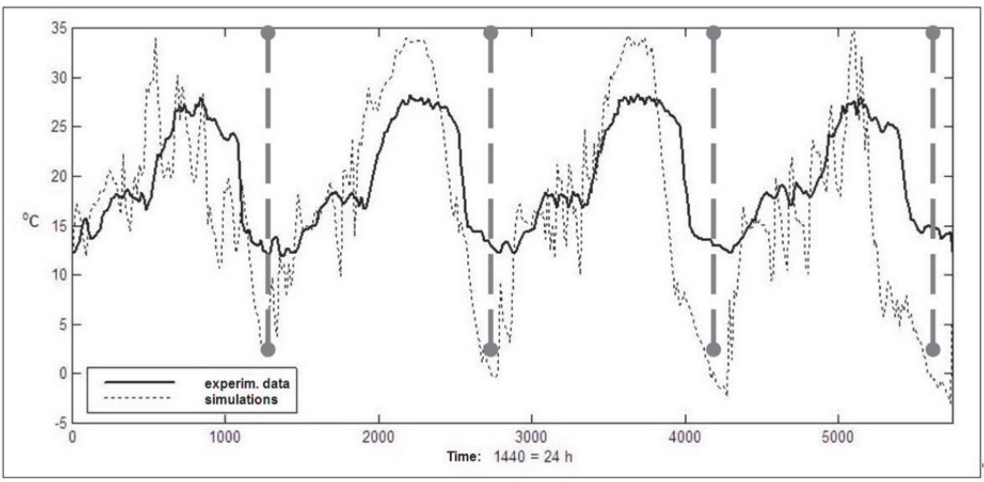

Figure 2. Air temperature changes inside greenhouse obtained during measurements and simulation research

Analysis of simulation results allows statement of logical correctness of the developed model. It also enables the identification of critical points of failure to adjust the model. It was found out that in this case the moment is the sunset, marked on the charts with a vertical line ●▬ ▬●. This indicates the strong correlation and sensitivity of microclimate inside the greenhouse on the amount of heat supplied to the object due to sun radiation.

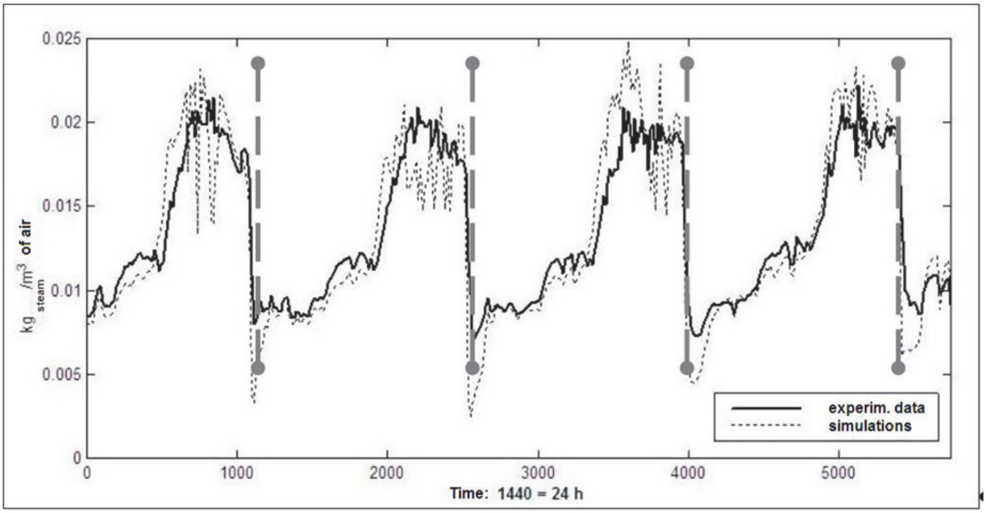

Figure 3. Changes of air humidity inside greenhouse obtained as a result of measurements and computer simulations

For statistical verification of the developed model a determination rate was used (Makać and Urbanek, 2010):

$$R^2 = \frac{\sum_{i=1}^{n}(y_i - \bar{y})^2 - \sum_{i=1}^{n}(y_i - Y_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}; \quad R^2 \leq 1 \tag{18}$$

where:

y_i – are the values of the selected features obtained from measurements,

Y_i – the corresponding values determined from the model.

If the value of determination rate is closer to 1, the better is consistency of data from the model with empirical data. For the heat exchange model the determination rate (for example four days presented in fig. 2 and 3) was 0.87. Whereas for mass exchange model the determination rate was 0.97.

Conclusions

The accuracy of the heat transfer model is mainly affected by the simplification degree and by omitting other heat fluxes in the model. This applies in particular to the heat exchanged between solid elements of the greenhouse and the air inside the greenhouse by radiation. None of these heat fluxes in the developed model may explain the discrepancy between the data obtained during the simulation and data obtained from experimental investigations in the period just after sunset. Whereas a better fit of the mass transfer model may result, inter alia, from smaller number of process variables, compared to the amount of variables involved in the heat exchange process. The developed mathematical model and a computer model created on this basis provide valuable information about the complex system, which is a greenhouse. The ability to perform a variety of simulation enables, among others, to analyze the sensitivity of the system to individual parameters changes. In order to use the developed model e.g. for control purposes, it requires to be more detailed.

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MODEL PROCESU WYMIANY CIEPŁA I MASY W POWIETRZU WEWNĄTRZ SZKLARNI

Streszczenie. Celem pracy było opracowanie matematycznego modelu wymiany ciepła i masy w powietrzu wewnątrz wielkogabarytowej szklarni, w której prowadzona jest towarowa uprawa roślin. Podczas formułowania modelu wykorzystano m.in. modele opisane w literaturze i wyniki badań eksperymentalnych. Opracowany model matematyczny został zaimplementowany do programu MATLAB/Simulink, a symulacje przeprowadzone z udziałem modelu komputerowego wykorzystano do przeprowadzenia graficznej i statystycznej walidacji modelu. Analiza wyników symulacji pozwala na stwierdzenie logicznej poprawności opracowanego modelu, a także umożliwia określenie punktów krytycznych niedopasowania modelu. Na dokładność opracowanego modelu wymiany ciepła wpływa przede wszystkim stopień jego uproszczenia. Aby opracowany model mógł być wykorzystany, np. do celów sterowniczych, wymaga większego uszczegółowienia.

Słowa kluczowe: szklarnia, mikroklimat, model matematyczny, wymiana ciepła i masy

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ANALYSIS OF POTENTIAL OF HEAT RECOVERY AND STORAGE FROM THE COOLING SYSTEM OF A TUNNEL

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ABSTRACT

The paper presents analysis of potential of recovering and storing thermal energy from a cooling installation of a fluidization tunnel freezer and then its storing. A plate heat exchanger placed behind a section of compressors was used for heat recovery and heated water that leaves the exchanger transferred heat through a pipe coil to a heat accumualtor. The amount of heat possible to be recovered from a cooling installation in relation to burdening of the cooling tunnel and the change of water temperature in a dispenser during the process was determined.

List of abbreviations:

$C = exp\left(\frac{k \cdot F}{m_a \cdot c_a}\right)$ constant value,

Δt – temperature difference, (ºC)
c – specific heat of the liquid, (J·kg^{-1}K^{-1})
C, a, b – constants depending on the conditions of heat exchange,
c_a – specific heat of the heating fluid, (J·kg^{-1}K^{-1})
c_b – specific heat of the heated fluid, (J·kg^{-1}K^{-1})
d – double distance between the plates, - diameter of the coil (m),
F – heat transfer surface area, (m^2)
g – gravitational acceleration (g=9.81 m·s^{-2}),
Gr – Grashof number,
h_o – conventional size – 1 mm,
k – heat transfer coefficient, (W·m^{-2}·K^{-1})
l – replacement characteristic dimension, height of the tank, (m)
m_a – mass flow of the heating fluid,
m_b – heated liquid mass,
Nu – Nusselt number,

Pr – Prandtl number,
Re – Reynolds number,
t – temperature of the heating fluid, (90ºC)
t_k – temperature of water in the tank heat when heated by a predetermined step, (t_p+ 5ºC)
t_p – the initial temperature of the water in the water tank, (ºC)
u – factor speed, ($m \cdot s^{-1}$)
α – heat transfer coefficient, ($W \cdot m^{-2} \cdot K^{-1}$)
β – the attenuation factor of turbulence at the surface of the wall,
β_1 – liquid volumetric expansion,
βt – ratio of forced turbulence,
ΔT_{ln} – logarithmic temperature difference,
ζ –coefficient of flow resistance in the smooth channels,
η – agent dynamic viscosity, (Pa·s)
λ – thermal conductivity, ($W \cdot m^{-1} \cdot K^{-1}$)
ν – kinematic viscosity, ($m^2 \cdot s^{-1}$)
ρ – density of medium, ($kg \cdot m^{-3}$)
τ – tank heating time, (s)

Introduction

The issues related to energy savings, in addition to the alternative energy sources are in recent years, one of the cornerstones of the European energy policy strategy. Taking into account the increase in the price of conventional energy sources, environmental protection and financial benefits resulting from reduction of manufacturing costs, reducing energy consumption are of particular importance in case of production facilities (Staniszewski and Bonca, 2006; Wojdalski et al., 2008a; 2008b; Łapczyńska-Kordon et al., 2013). There is also work being carried out concerning analysis of energy effects of installations, including storage of excess heat in different objects (Kurpaska, 2003; 2007; Rutkowski 2008).

The plants using refrigeration systems may recover from condensers waste heat energy, which must be cooled, and originally the heat is transferred to the cooling medium (air, water) and eventually lost. Superheat of the refrigerant vapor and condensation heat can be used as needed, for example: for production of hot water for technological purposes - processing of raw materials, cleaning equipment and premises in the production process, and heating the ground under the cold chambers. If the plant is not connected to the district heating the hot water can be used for sanitary purposes and for heating of buildings (Oberg, 2005; Targański, 2011).

However, given the asynchronous availability and demand for waste heat the additional conventional heat source or heat storage accumulators must be installed.It is advisable to analyze the recoverable amount of thermal energy with reference to the existing energy needs (Gazda, 2002; Targański, 2009).

The objective of the study was to analyze the possibility of recovery and storage of the waste heat from the selected cooling system receiving heat from the tunnel, intended for pre-freezing of fruit and vegetables. The amount of recoverable heat from the refrigeration system in relation to loading of the cooling tunnel in a plate heat exchanger arranged behind the compressor system was determined. In the process of the heat storage tank temperature changes depending on the duration of the process were also determined.

Research facility

A fluidized freezing tunnel is used to freeze any whole or sliced fruit and vegetables. High-quality products are obtained through their individual freezing, and then the temperature is still reduced in two zones using cold air blast, due to the effect of fluidization. The research was conducted on a device located at the production plant Producers Group "Class" company based in Klementowice. Technical data concerning a fluidized cooling tunnel were presented in table 1.

Table 1.
Basic technical data of fluidized tunnel freezer

Specification	Technical parameters
Base performance, ($kg \cdot h^{-1}$)	1000
Cold demand for strawberries, (kW)	175
Refrigerant agent	R404
Refrigerant circuit (R404 , R407)	Expansion valves & distributor of Freon
The boiling point of the medium, (ºC)	- 40
The internal volume of coolers ammonia / Freon, (dm^3)	1x548 / 3x198
Defrosting coolers for Freon	Spraying water
Defrost time, (min)	25÷30
Re-cooling time, (min)	15÷20
Freezing time adjustment of the product, (min)	7÷35
The total installed electric power, (kW)	52
Normal power consumption during operation, (kW)	44
Electric power	3x400/50Hz
Compressed air for UDS – dried air	1 $m^3 \cdot min^{-1}$, 7.5 bar
Working width of the strip, (mm)	900
Width of the tunnel housing with Freon, (m)	4.4
Height of the housing tunnel, (m)	4.4
Length of the tunnel lining, (m)	5.12
Total length of the tunnel, (m)	6.67

A cooling tunnel is equipped with a system of three screw compressors with a capacity of 15 kW each, connected in parallel. Compressors, depending on the demand for cooling power, turn on automatically. A condenser of a freezing tunnel with a capacity of 100 kW is placed on the outside of the building and it is cooled by outside air, circulation of which is forced by a fan.

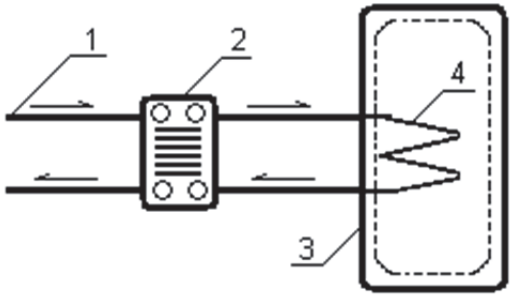

Figure 1. Schematic representation of the heat recovery installation, 1 – factor flowing from the compressor system, 2 – plate heat exchanger, 3 – water tank, 4 – pipe coil

Fans causing air fluidization in the tunnel have total performance of 30 $m^3 \cdot s^{-1}$. A schematic representation of heat recovery from a refrigerant was shown in Figure 1. A plate heat exchanger (soldered, made of stainless steel) which recovers heat from the tunnel freezing system was embodied in the cooling system behind the section of compressors. In the exchanger operating in the countercurrent, superheated vapor of refrigerant leaving the system of compressors is the cooled medium, while deionizer water is the heated medium. Table 2 summarizes the basic technical and structural parameters of the plate heat exchanger.

Table 2.
Technical parameters of the plate heat exchanger

Design data	Medium 1	Medium 2	Unit
Medium	Superheated vapour R- 407 C	Water	
Flow rate	0.85	0.5	$kg \cdot s^{-1}$
Speed of the flow	16.8	0.78	$m \cdot s^{-1}$
Temperature input	97	10	ºC
Temperature output	50	90	ºC
Density	55.6	999.6	$kg \cdot m^{-3}$
Specific heat	829	4215	$J \cdot kg^{-1}K^{-1}$
Thermal conductivity	0.0112	0.573	$W \cdot m^{-1}K^{-1}$
Dynamic viscosity	$0.0128 \cdot 10^{-3}$	$1.304 \cdot 10^{-3}$	Pa·s
Kinematic viscosity	$0.23 \cdot 10^{-6}$	$1.3 \cdot 10^{-6}$	$m^2 \cdot s^{-1}$
Operating pressure	1.8	0.7	MPa
Distance of plates	0.01	0.01	m
Prandtl number	0.947	9.56	
Surface of the plate	0.05	0.05	m^2
Number of plates all active	10/8	10/8	
Drop of pressure (max)	12	12	m H_2O

Table 3.
Technical parameters of the heat accumulator

Parameter	Unit	Value
Tank volume	(dm^3)	1500
Volume of heat exchanger	(dm^3)	22.8
Surface op pipe coil	(m^2)	3.6
Length of pipe coil	(m)	45
Diameter of pipe coil	(m)	0.0254
Diameter of cylinder without insulation	(mm)	1200
Diameter of tank with insulation	(mm)	1400
Width	(mm)	1210
Heat circulation	($kWh \cdot 24\ h^{-1}$)	5.3
Maximum operating pressure	(bar)	8
Maximum operating overpressure	(bar)	3
Maximum temperature	(ºC)	95

The constant temperature of water leaving the heat exchanger plate of 90°C was adopted and the water flow rate of 0.78 $m \cdot s^{-1}$ was assumed, which corresponds to the flow rate of 0.5 $kg \cdot s^{-1}$. The heated water leaving the plate heat exchanger is fed by thermally insulated wires to the heat storage, the operating parameters and design parameters of which are presented in table 3.

Due to the fact that the temperature of hot water in the heat storage increases with the duration of the heat exchange process, the heat transfer coefficients and heat penetration coefficient were determined using the temperature jump at 5°C within the range of 10°C to 90°C.

Results

Heat transfer coefficient of the plate heat exchanger between the heat exchanging agents was calculated using the equation-criteria given by (Zander and Zander, 2003). This equation takes the following form:

$$Nu = 0{,}022 \cdot \sqrt{\zeta_0} \cdot \beta \cdot \beta_t \cdot \mathrm{Re}^{0{,}825} \cdot \mathrm{Pr}^{0{,}54} \quad (1)$$

Determination of the Nusselt number, which allows determination of heat transfer coefficients of water and superheated vapour to the surface of the heat exchanger is possible after determination of factors included in the equation (1). The Reynolds number and parameters necessary to determine the Nusselt number, as well as the transfer coefficients and heat transfer coefficients and the heat penetration coefficients were determined on the basis of the data included in table 2. Calculated parameters for superheated refrigerant vapor and the water heated in the heat exchanger are summarized in table 4.

Table 4
Numbers indispensable for determination of Nusselt number from equation (1), coefficients of heat transmission and penetration

Parameter	Method of determination	Superheated steam	Water
Reynolds number	$\mathrm{Re} = \frac{u \cdot l}{\nu}$	$1.46 \cdot 10^6$	12000
Flow resistance coefficient	$\zeta_0 = \frac{0.3164}{\mathrm{Re}^{0.25}}$	0.0091	0.03
Turbulence damping factor	$\beta = 4 - \frac{1.65 \cdot h_0}{d}$	3.9175	
Coefficient of forced turbulence	$\beta_t = 1 + \left(0.33 - \frac{0.66 \cdot h_0}{d}\right) \cdot \ln \frac{4.23 \cdot \left(0.65 + 1.07 \cdot \lg \frac{h}{h_0}\right)}{0.3164}$	1.9312	
Nusselt number	$Nu = 0.022 \cdot \sqrt{\zeta_0} \cdot \beta \cdot \beta_t \cdot \mathrm{Re}^{0.825} \cdot \mathrm{Pr}^{0.54}$	1877.6	226.25
Heat transfer coefficient	$\alpha = \frac{Nu \cdot \lambda}{h} \quad \left[\frac{W}{m^2 \cdot K}\right]$	2102.9	12964.1
Heat penetration coefficient	$k = \frac{1}{\frac{1}{\alpha_s} + \frac{\delta}{\lambda} + \frac{1}{\alpha_w}} \quad \left[\frac{W}{m^2 \cdot K}\right]$	4018.88	

The logarithmic temperature difference needed to determine the heat exchanger capacity was determined on the basis of the temperature factors contained in Table 2.

$$\Delta T_{\ln} = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}} = \frac{(97-90)K - (50-10)K}{\ln \frac{7K}{40K}} = 18.93K \cdot \tag{2}$$

Thermal power of the plate heat exchanger is:

$$\dot{Q} = F \cdot k \cdot \Delta T_{\ln} = 0.4\, m^2 \cdot 4018.88 \frac{W}{m^2 \cdot K} \cdot 18.93K = 30431W \tag{3}$$

The maximum heat output of the heat exchanger is slightly higher than the value of 30 kW. Achieving this thermal power is possible during operation of all compressors, assuming that the temperature of condensing agent is 40°C.

It was assumed that the process of heat exchange between the coil pipe and the water in the tank can occur by natural unlimited convection, while the heat transfer coefficient between the water and the heating coil pipe in accordance with forced convection with the laminar flow. Nusselt number, which is used to determine the coefficient of heat transfer from the heated water to the surface of the coil, can be determined from the following relation:

$$Nu = C \cdot (Gr \cdot \Pr)^n \tag{4}$$

Based on the obtained values of the Grashoff and Prandtl criterion numbers the constants C and n are 0.54 and 0.25, respectively. Since the fluid flow is an intermediate flow, it appears from the values of the criterion numbers, the equation becomes:

$$Nu = 0.54 \cdot (Gr \cdot \Pr)^{0,25} \tag{5}$$

Table 5.
Coefficients indispensable for determination of characteristic numbers of equation (4) for heat exchange between a pipe coil and water in an accumulator and the value of coefficient of heat penetration

Coefficients										
T (°C)	ρ ($kg \cdot m^{-3}$)	c ($J \cdot kg^{-1}K^{-1}$)	λ ($W \cdot m^{-1}K^{-1}$)	$\beta_1 \times 10^4$ (K^{-1})	$\eta \cdot 10^3$ (Pa·s)	$v \cdot 10^6$ ($m^2 \cdot s^{-1}$)	Pr -	Gr -	Nu -	α_1 ($W \cdot m^{-2}K^{-1}$)
10-15	999.6	4215	0.57	88.00	1.30	1.30	9.56	9411404	52.59	24.9
15-20	998.9	4211	0.59	156.00	1.13	1.10	8.15	18484951	59.83	28.93
20-25	998.2	4207	0.60	207.00	1.00	1.00	7.06	25182190	62.35	30.76
25-30	996.9	4207	0.61	248.00	0.90	0.91	6.20	30785681	63.47	31.84
30-35	995.6	4203	0.62	304.00	0.80	0.81	5.50	39378038	65.51	33.35
35-40	993.9	4203	0.62	342.00	0.72	0.72	4.85	45402673	65.78	33.92
40-45	992.2	4203	0.63	390.00	0.65	0.66	4.30	51425002	65.85	34.39
45-50	990.1	4203	0.64	105.00	0.60	0.62	3.90	13352169	45.87	24.22
50-55	988	4203	0.65	46.00	0.55	0.56	3.56	5751328	36.32	19.39
55-60	985.6	4203	0.65	50.00	0.51	0.52	3.25	5905490	35.74	19.26
60-65	983.2	4207	0.66	53.00	0.47	0.48	3.00	5768817	34.83	18.94
65-70	980.5	4211	0.66	56.00	0.44	0.45	2.75	5467555	33.63	18.4
70-75	977.7	4215	0.67	58.00	0.41	0.42	2.56	4857748	32.07	17.65
75-80	974.8	4215	0.67	60.00	0.38	0.39	2.35	4062627	30.02	16.6
80-85	971.8	4219	0.67	63.00	0.36	0.37	2.23	2991470	27.44	15.26
85-90	968.5	4224	0.68	66.00	0.34	0.35	2.10	1652759	23.31	13.02

The values of the heat transfer coefficient from the outer surface of a coil pipe to heated water in the water tank increases slightly in the temperature range from 10ºC to 40ºC. Above this temperature range the values of the heat transfer coefficient are reduced. The coefficient of heat penetration into the water heated in the tank has a small value in the whole considered temperature range.

The coefficient of heat transfer from the heating fluid to the inner surface of the coil pipe can be determined from the criterial equation:

$$Nu = C \cdot \mathrm{Re}^a \cdot \Pr^b \cdot \frac{d}{L} \tag{6}$$

Coefficients C, a, b are determined after previous determination of the Reynolds number, in order to determine the type of flow in the coil pipe. The Reynolds number included in Table 6 is greater than 3,000, on this basis, we conclude that the flow in the coil pipe is turbulent. The coefficient d/L is skipped because its value is less than 1/50. After being simplied the criterial equation takes the following form:

$$Nu = C \cdot \mathrm{Re}^a \cdot \mathrm{Pr}^b \tag{7}$$

Constants included in the equation for turbulent flow are respectively: C=0.023, a=0.8, b=0.4. Criterial numbers of Reynolds, Prandtl and, determined on the basis of these numbers, the Nusselt number and the heat transfer coefficient for the heat transfer process between the heating water and the inner surface of the coil pipe are presented in Table 6.

The coefficients of heat transfer from the heating fluid to the inner surface of the coil pipe have a much higher values than in the case of the plate heat exchanger, which is a consequence of forced convection and turbulent flow of the heating fluid.

The heat penetration coefficient for the considered ranges of temperature, was determined according to the formula presented in table 2.

The value of heat transfer coefficient, thermal conductivity coefficient of the coil pipe wall, the heat penetration coefficient and the coil pipe wall are listed in table 7.

Table 6.
Value of characteristic numbers and coefficient of heat transmission concerning heat permission between heating water and internal surface of pipe coil

Temperature (ºC)	Kinematic viscosity ($m^2 \cdot s^{-1}$)	Reynolds number	Prandtl number	Nusselt number	α_2 ($W \cdot m^{-2} K^{-1}$)
10-15	1.30	15240.00	9.56	125.98	6447.8
15-20	1.10	18010.91	8.15	135.09	5850.35
20-25	1.00	19812.00	7.06	137.66	5419.69
25-30	0.91	21771.43	6.20	140.93	5049.07
30-35	0.81	24611.18	5.50	148.18	4696.26
35-40	0.72	27516.67	4.85	154.06	4367.06
40-45	0.66	30063.73	4.30	157.6	4088.91
45-50	0.62	32214.63	3.90	160.18	3878.37
50-55	0.56	35633.09	3.56	167.41	3664.57
55-60	0.52	38469.90	3.25	171.62	3479.7
60-65	0.48	41361.17	3.00	176.14	3321.7
65-70	0.45	44521.35	2.75	180.43	3161.08
70-75	0.42	47739.76	2.56	185.41	3029.34
75-80	0.39	51459.74	2.35	190.25	2883.71
80-85	0.37	54131.15	2.23	194	2795.43
85-90	0.35	57095.10	2.10	197.65	2700.18
90	0.33	60773.01	1.95	201.7	2588.75

The determined values of heat transfer coefficients in the considered range of measurement are low, this is due to the specificity of the relation which defines this coefficient and mainly due to the lowest sum of components.

The heating time of liquid in the heat accumulator to the desired temperature can be determined by balancing the heat transfer equation and the equations of heat collected by the heated water and the equation of the heat given by heating water:

$$\tau = \frac{c}{c-1} \cdot \frac{m_b \cdot c_b}{m_a \cdot c_a} \cdot \ln \frac{t - t_p}{t - t_k} \qquad (8)$$

The constant C used for determination of the duration of the process of heating water in the heat accumulator for each temperature ranges were presented in table 7.

Table 7.
Numbers indispensable for determination of the value of heat transmission coefficient and determined value of heat permission (k) and time of heating a tank(τ)

Temperature (ºC)	α_l ($W \cdot m^{-2}K^{-1}$)	α_l ($W \cdot m^{-2}K^{-1}$)	δ (m)	λ ($W \cdot m^{-1} \cdot K^{-1}$),	k ($W \cdot m^{-2} \cdot K^{-1}$),	C	τ (s)
10-15	24.9	6447.8	0.002	25	24.755	1.043193	1833
15-20	28.93	5850.35	0.002	25	28.721	1.12447	1868
20-25	30.76	5419.69	0.002	25	30.512	1.132861	1896
25-30	31.84	5049.07	0.002	25	31.561	1.13773	1982
30-35	33.35	4696.26	0.002	25	33.027	1.144716	2065
35-40	33.92	4367.06	0.002	25	33.568	1.147254	2228
40-45	34.39	4088.91	0.002	25	34.01	1.149331	2433
45-50	24.22	3878.37	0.002	25	24.023	1.103304	3774
50-55	19.39	3664.57	0.002	25	19.258	1.081999	5286
55-60	19.26	3479.7	0.002	25	19.125	1.08141	6149
60-65	18.94	3321.7	0.002	25	18.804	1.079911	7399
65-70	18.4	3161.08	0.002	25	18.267	1.077466	9320
70-75	17.65	3029.34	0.002	25	17.523	1.074124	12506
75-80	16.6	2883.71	0.002	25	16.483	1.069575	18717
80-85	15.26	2795.43	0.002	25	15.159	1.06375	34739
85-90	13.02	2700.18	0.002	25	12.944	1.054121	64254

Heating time of the heat accumualtor increases with the increase of temperature. Extending the heating time at higher levels of temperature is caused by lower temperature difference between the heat exchanging factors. Water heating to the temperature above 80ºC, due to duration of the process, is pointless. Typically, sufficient water temperature stored in the tank is at the level of 65-70ºC. This range of temperature allows its use both for central heating, hot water, as well as to thawing of cooling tunnel and other processes.

Conclusions

1. The process of heat exchange between the superheated vapour of refrigerant and water, taking place in the heat exchanger, has considerable values of the heat transfer coefficients, because of its turbulent nature. Much greater values (about 6 times) are obtained for the coefficient of heat transfer penetration from the liquid to the inner surface of the heat exchanger.

2. The maximum heat output of the heat exchanger is slightly higher than the value of 30 kW. Obtaining such power is possible when all compressors work and the refrigerant condensing temperature of 40ºC. Actual thermal power of the exchanger is usually smaller and depends primarily on the condensation temperature depending on ambient temperature conditioned and instantaneous loads of freezing tunnel.
3. The heat penetration coefficients determined in case of natural convection have low values in the range within aaproximately 13 to 35 $W \cdot m^{-2} \cdot K^{-1}$. The values of these coefficients in the analyzed temperature range initially increase with increasing temperature, and then decrease.
4. In the investigated temperature range the values of heat transfer coefficients from the heating liquid to the inner surface of the coil pipe decrease with increasing temperature.
5. Determined heat penetration coefficients in the analyzed exchanger, take small values. Improving the conditions of heat transfer in this case would be possible by applying a mixer in the heat accumualtor
6. The heating time of the heat accumulator increases with the temperature increase. In this case heating water to the temperature above 80ºC, is not justified from the energetic point of view.

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ANALIZA MOŻLIWOŚCI ODZYSKIWANIA I MAGAZYNOWANIA CIEPŁA Z INSTALACJI CHŁODNICZEJ TUNELU

Streszczenie. W pracy przeprowadzono analizę możliwości odzyskiwania i maga-zynowania energii cieplnej z instalacji chłodniczej fluidyzacyjnego tunelu zamrażalniczego a następnie jej magazynowania. Do odzysku ciepła wykorzystano płytowy wymiennik ciepła umieszczony za sekcją sprężarek a podgrzana woda opuszczająca wymiennik przekazywała ciepło poprzez wężownicę do zasobnika ciepła. Wyznaczono ilość ciepła możliwego do odzyskania z instalacji chłodniczej w zależności od obciążenia tunelu chłodniczego i zmiany temperatury wody w zasobniku w trakcie trwania procesu.

Key words: odzysk ciepła z instalacji chłodniczych, tunel zamrażalniczy, ciepło odpadowe

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DISTRIBUTION OF SURFACE PRESSURES WITH REGARD TO AVOCADO FRUIT AT THE CONSTANT LOAD VALUE

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ABSTRACT

Researches, which were carried out, present results of measurements of surface pressure of Avocado Fuerte cultivar in the radial compression test between flat panels at the constant load value including time factor. The test was carried out with the use of Instron 5566 testing machine. On the bottom panel, under the compressed Avocado fruit a sensor of Tekscan system number 5076 was placed. It allowed a constant observation of contour lines of surface pressures on the contact surface and determination of distribution of surface pressures between Avocado and a bottom panel of the testing machine. Contour layers and distribution of surface pressures in different stages of the creep test were determined. It was proved that maximum and average values of the surface pressures are subject to minimum changes during the entire test. Distribution of surface pressures has a shape typical for contact issues in the elastic scope of deformation, where maximum values are in the central zone of contact and are distributed similarly to the even number curve. At the end of the test, distribution of thrusts on the contact surface of Avocado with a working element of the testing machine took place at the end of the test.

Introduction

Avocado from the Lauraceae family occurs in the tropical and subtropical climate of America. In South America it has been known for thousand years. Avocado spread fast from North America through Central America as far as South America. The main exporters are Peru, Chile and Mexico, New Zealand and South Africa. In the USA plantations are located in California and in Florida. Orchards produce at the average seven tonnes per hectare annually and some even reach 20 tonnes per hectare. An avocado tree does not tolerate low temperatures and may be cultivated only in the subtropical and tropical climate. There are several cultivars, which are cold resistant and they are planted in the region of Gainesville in Florida and are able to survive temperatures even up to -6ºC.

Avocado fruit is pear shaped. A thick green exocarp surrounds thick, cream-green pulp (mezocarp) and an inedible seed. Avocado is a calorific fruit. It contains 160 kcal in 100 g. Its fat profile is a unique feature. It contains 15.3 g of fat in 100 g. However, these are monounsaturated fats and omega 3 acids. Avocado may be used interchangeably with butter or margarine. It is a plant product thus it does not contain cholesterol and has a lower content of calories compared to fat products. Nutritive value of avocado comprises vitamins A, B1, B2, C, PP, K and, pantothenic acid, carotenes, protein and mineral substances: calcium, potassium and phosphorus.

Although there are over 500 cultivars of avocado fruit, cultivars are focused in three basic groups:

– Mexican breed - (Central Mexico) with small fruit (2.5-7.5 cm of length), pulp has a walnut taste and anise smell; it contains 29% of fat. It is a cultivar which is frost-resistant, of pink and brown colour.
– Antilles breed with bigger fruit (Antilles) (7-25 cm of length). Requires warmth and moisture. It has green and yellow-coloured fruit
– A guatemala breed - (Guatemala), a fruit with a similar size but with a lower content of fat (5-14%) with a water taste, yellow to brown-mahogany colour (www.itum.com.pl).

On account of nutritive values, avocado has become an important raw material in the food industry. During transport and storing fruit are exposed to mechanical damages, which may lead to the lowering of their quality and may cause losses to growers and exporters. Knowing the behaviour of Avocado fruit influenced by external forces may lead to new solutions which aim at improvement of the products quality. Care for raw material may decrease losses on the domestic market which translates into a higher profitability of production (Nadulski, 2009; Płocharski et al., 2000).

On account of the Avocado fruit shape, a significant role in carrying loads in harvesting, transport and storing processes is played by surface pressures. The contact issues are one of the most complex problems related to resistance of not only biological materials. One of the methods used in practice in calculation of surface pressures is based on Hertz formulas. Using these formulas for plant materials has no theoretical justification. Despite this, some authors' research proved that the use of Hertz's theory may in many cases lead to formulation of trustworthy indexes which describe surface pressures or the time of contact, although errors may reach as much as 20% (Rabelo, 2001; Siyami et al., 1988). Model research, which cover the issue of surface pressures of carrot roots constructed with the use of MES show that the model tests results correspond well to real values (Stopa, 2011).

Tests on the strength properties of avocado fruit were carried out by Edward A. Baryeh (2002) who showed that directly at harvesting they are very high but get worse as soon as after 7 days. Impact tests were carried out and they proved that at the test of free falling from 0.5 m height directly after harvesting – 25% of fruit were damaged, whereas after 15 days of storing – 90% were damaged. He also stated that fresh fruit may be packed into wooden boxes up to 35 layers but as soon as after 15 days only two layers are recommended. In his paper Herold et al. (2001) used Tekscan system, which allows the measurement of the surface thrust distribution on the entire surface of contact of the loading element with the investigated object. Another method indispensable at determination of surface thrust was suggested by (Lewis, 2008). It consisted in the use of an ultrasound wave.

Van Zeebroeck (2003) prepared discreet models with the method of finite elements which allow determination of the transport conditions impacts on the losses due to damage to apples. Modelling with the finite elements method was also carried out by M. Valente et al. (1996) investigating the heat exchange during drying of avocado.

Objective of the research

The objective of the research was determination of contour layers and distributions of surface pressures of Fuerte avocado as a function of time in the radial compression test and determination of changes of the surface thrust values as a function of time in the central contact zone.

Methodology and object of the research

The research was carried out in the Laboratory of Agrophysics of the Institute of Agricultural Engineering of the Wroclaw University of Environmental and Life Sciences. A testing machine INSTRON 5566 equipped with a tensometric head with a measurement scope up to 1 kN was used in the research. It allowed measurement of power with precision up to 1 N and displacement with a precision up to 0.05 mm. The machine was controlled by a computer with the installed BlueHill programme allowing registration and analysis of the results of research. The speed of the head movement to the moment of reaching an assumed value of initial loading was 1.8 $mm \cdot min^{-1}$.

Fuerte cultivar of Avocado from Peru was used in the research. Fruit were bought in Poland. Healthy items were selected with similar dimensions and mass from 180 to 220 g. During measurement constant moisture of raw material was maintained.

Firstly, measurements aiming at determination of border values of loading in the compression test were carried out. The value of the destructive force F_{max} was determined. It was the basis for calculation of the value of the initial loading of avocado F_0 and a corresponding value of the initial movement of the element, which loads the testing machine Instron 5566.

From the point of view of the contact issues with reference to the biological materials the basic problem when determining the surface pressures, is a measurement of the surface area of contacting bodies and the value of the pressure force. The presented research applied a method based on the use of Tekscan system, which allows permanent observation of the changes of the contact surfaces of avocado and working elements of the loading device, the pressure force and surface pressures. Measurements were carried out at three values of initial loading in 5 repeats. After the initial research, the measurement time was assumed at the constant value of loading which was 1200 s. The increase of the measurement time over 1200 s did not affect the nature of changes of surface thrust values as a function of time.

Figure 1. Tekscan measuring system

The Tekscan system consists of the foil sensor, a grip, a distributor and the computational programme which allows registration of the research results carried out at the frequency of sampling of approx. 1000Hz. It also allows later analysis of the collected data. 5076 sensor (fig. 1 table 1) built of the system of parallel electrodes divided with a layer of polyester foil was used for the research. In the place where the electrodes were crossing, they formed sensors which allowed determination of the value of the loading force and the surface area of the contact of avocado fruit with a working element of the testing machine. During the measurement, changes of the surface area of the contact, values of the pressure force and contour layers of surface areas as a function of time, were registered.

Table 1
Technical data of plastic sensor 5076

Dimensions of a sensor		Lengthwise direction		Transverse direction		Number of sensors (item)	Density of sensors (item·cm^{-2})
Length (mm)	Width (mm)	Spacing (mm)	Numb er of (item)	Spacing (mm)	Numb er of (item)		
83.8	83.8	1.9	44	1.9	44	1936	27.6

Source: www.tekscan.com

Errors related to the shape of samples, measurement of the pressure force and determination of the contact surface constituted a part of the total error of experimental determination of the surface area of the contact of an avocado sample with the ground. 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 pressures was determined with the use of the Tekscan system of the following parameters: system precision $<\pm4\%$, blinearity error$<\pm3\%$, repeatability of results$<\pm3.5\%$, hysteresis$<\pm4.5\%$ and creeping: $<5\%$.

Research results and their analysis

Based on the compression test, values of the maximum force, which cause destruction of the tested fruit, were determined and on this basis initial loading of samples F_0 and the corresponding shift of the loading element Δl_0 were defined (tab. 2). The compression test was carried out for five repeats at the speed of movement of the measurement head which is 1.8 $mm\cdot min^{-1}$. The maximum force F_{max} which is 674 N and corresponding movement Δl_{max} which is 23.9 mm was obtained. Based on the obtained data, values of the initial loading of fruit were calculated (table 2).

Table 2
Initial parameters of the compression process

Initial parameters	Initial loading	Initial movement
10% F_{max}	F_{010} =67.4 N	Δl_{010} =2.39 mm
20% F_{max}	F_{020} =134.8 N	Δl_{020} =4.78 mm
30% F_{max}	F_{030} =202.2 N	Δl_{030} =7.07 mm

Exemplary results of research obtained in the compression test of Avocado fruit for the initial value of the loading force which is 20% F_{max} will be presented (table 2).

Figure 2 presents the course of changes of the measurement head of the testing machine instron as a function of time. The process of creeping started after 190 seconds from the moment of starting the measurement after reaching the complex loading F_{020} =134.8 N at the head movement Δl_{020} = 4.78 mm. In the final phase of test after 1,200 seconds the shift reached the value of Δl =5.58 mm, which means that the average speed of the creeping process is 4.7 10^{-2} $mm\cdot s^{-1}$.

The change of the value of mean surface pressures in the contact zone of avocado fruit with an element which loads the testing machine during the test is presented in figure 3. In the moment, the test started, mean surface pressures reached the value of p=0.328 MPa and afterwards were gradually reduced to the level of p=0.309 MPa after 500 seconds and p=0.295 in the end of the test. It means that within 190 to 500 seconds the surface pressures were decreasing in the rate of 612 10^{-6} $MPa \cdot s^{-1}$ whereas within 500 to 1200 seconds the rate was 20 10^{-6} $MPa \cdot s^{-1}$.

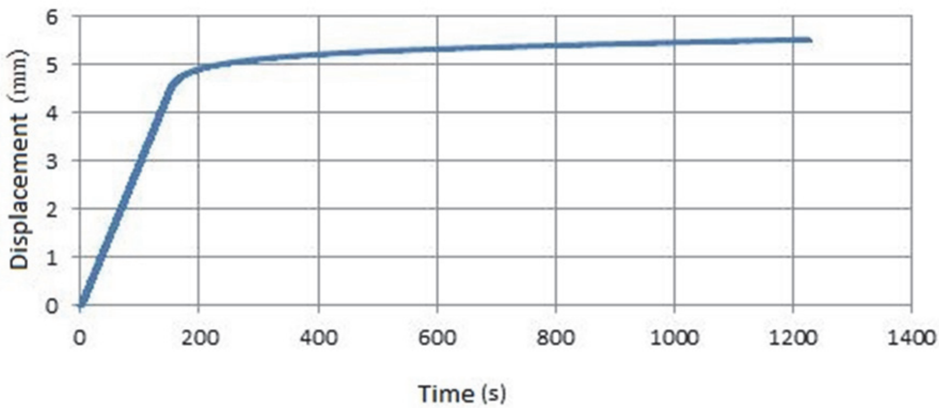

Figure 2. Course of the creeping process

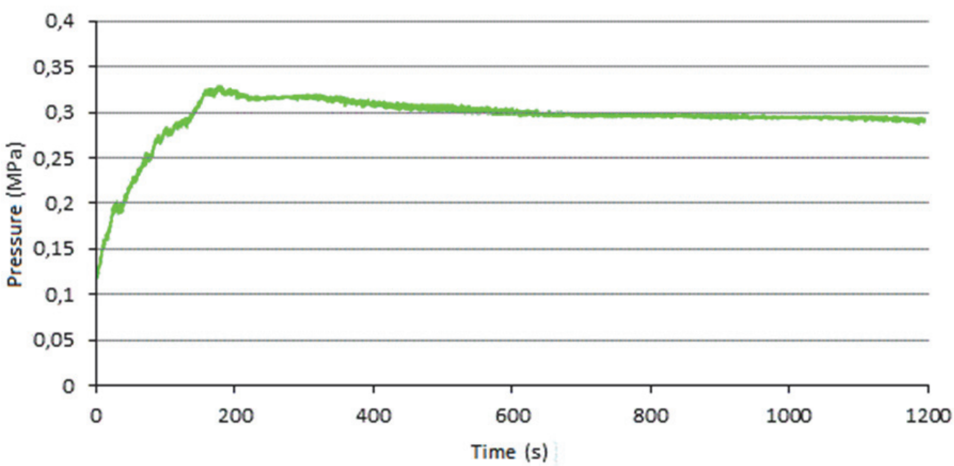

Figure 3. Average values of surface pressures as time function Δt=0 to 1200s

Figure 4 presents contour layers and distribution of surface pressures of avocado Fuerte cultivar after time of t=78 s from the moment the test begins, during reaching the assumed value of the initial loading F_{020} =134. N.

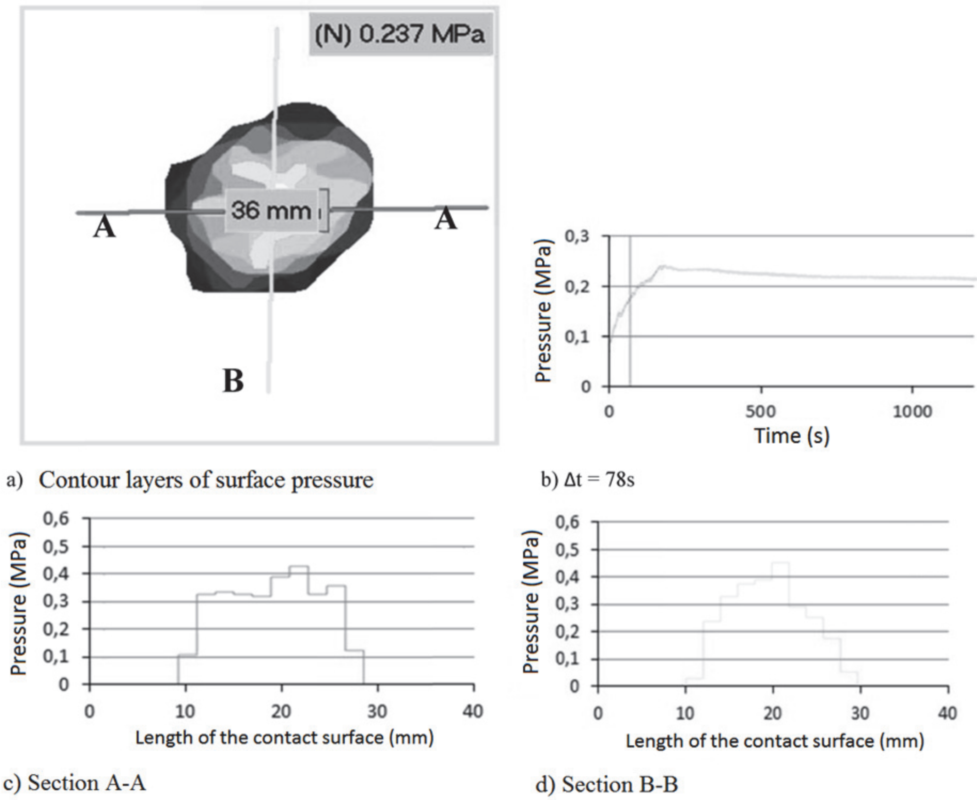

Figure 4. Contour layers and distribution of surface pressures in time Δt=78 s

Contour layers of the surface pressures indicate a point nature of the loading element impact on the avocado fruit (figure 4a). Average values of surface pressures are 0.237 MPa while the maximum values which are in the central point of contact are 0.451 MPa (fig. 4c,d).

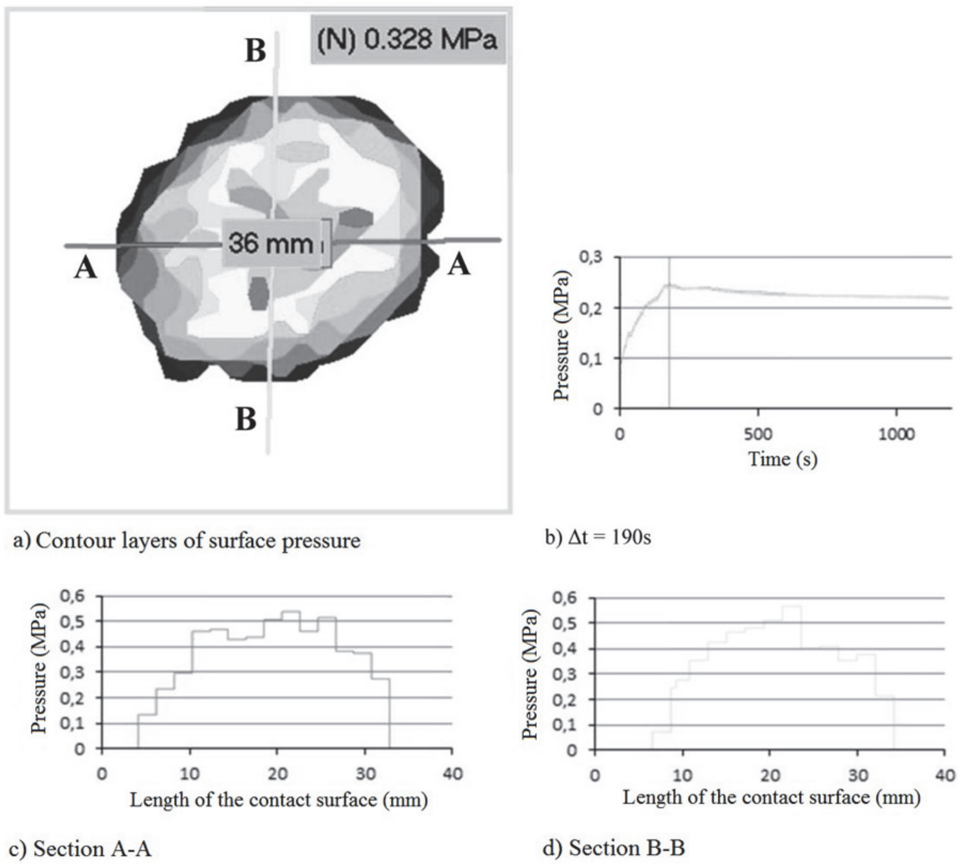

Figure 5. Contour layers and distribution of surface pressures in time Δt=190 s

With the beginning of the creeping process after 190 seconds from the moment the test begins and after the assumed value of loading F_{020}=134.8 N (fig. 5a) begins, the nature of impact of the working part of the testing machine on the Avocado fruit did not significantly change. The maximum surface pressures are in the central contact zone (fig. 5 c, d). Only their values increased to the level of 0.574 MPa at the average which was 0.328 MPa and an explicit increase of the contact surface. It proves that the Avocado cells were not destroyed in the contact zone. One should assume that this phenomenon is caused by a slow movement of liquids in the zone with a higher pressure to zones with still empty intercellular spaces without destruction of cell walls.

Figure 6 presents contour layers and distribution of surface pressures of avocado after t=500 s from the moment the test begins. The surface area of avocado contact with a testing machine did not undergo any explicit change. Distribution of surface pressures along the contact surface is of a shape of an even curve. The maximum values of surface pressures decreased and they are p=0.509 MPa (fig. 6 c,d) at average values p=0.309 MPa. Surface pressures on the contact surface were not levelled and the maximum thrusts are still in the central zone of contact (fig. 6a). Such distribution of thrusts proves an elastic nature of deformation of the avocado pulp tissue and shows no destruction of cell walls in the process of creeping.

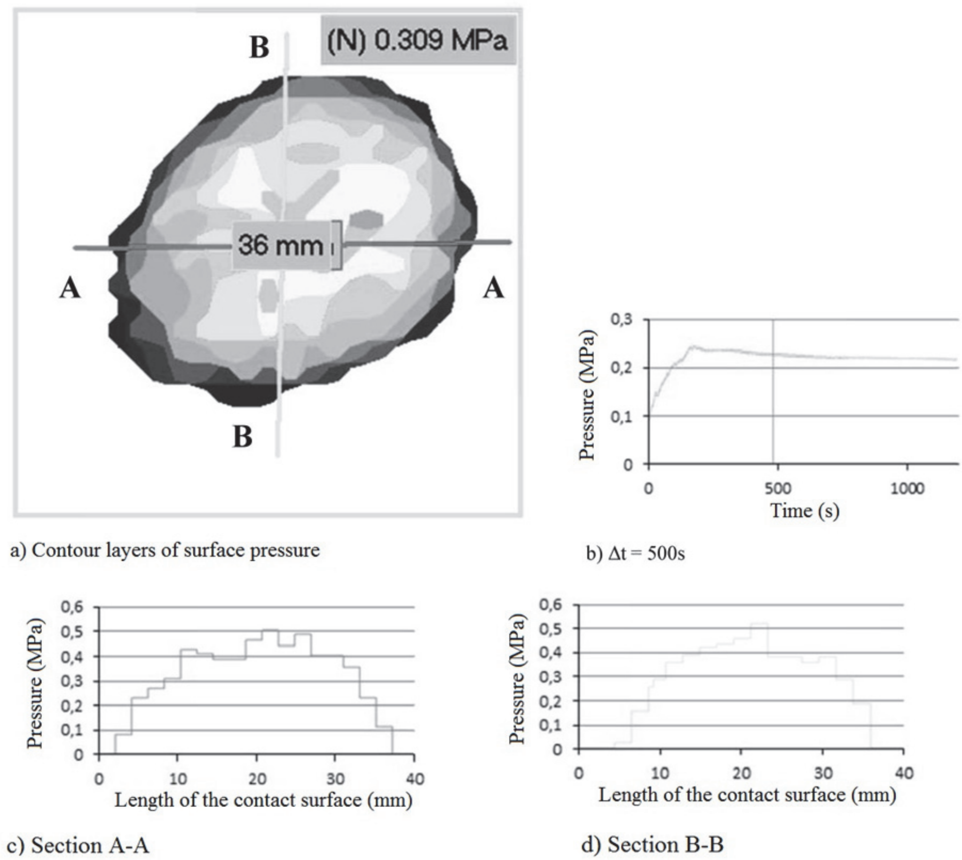

Figure 6. Contour layers and distribution of surface pressures in time Δt=500 s

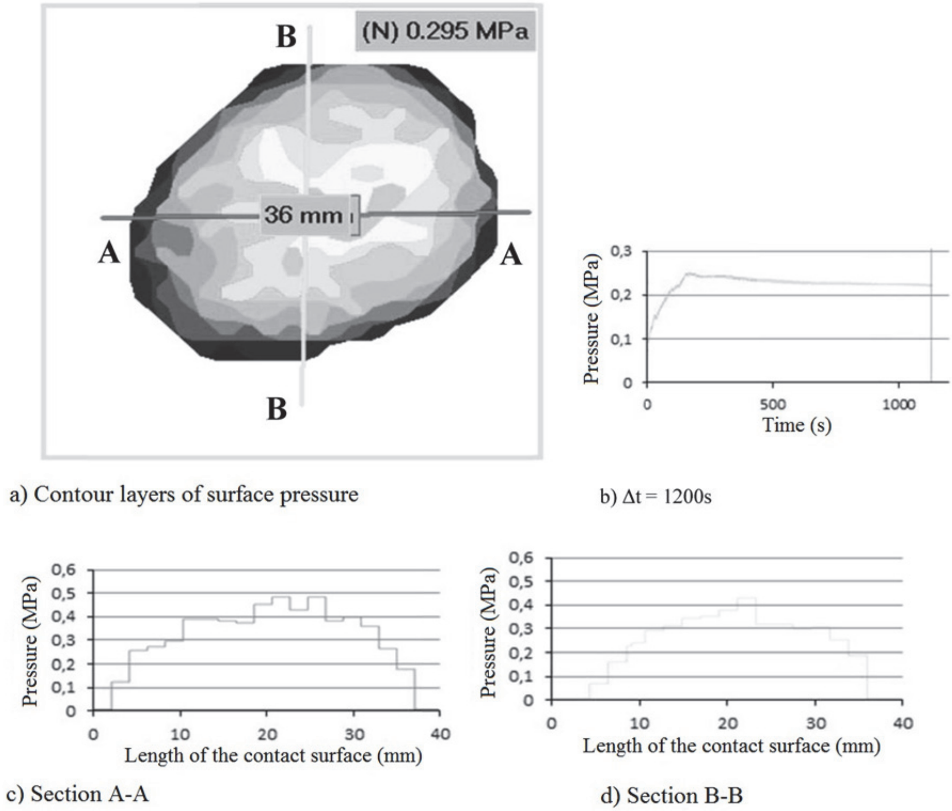

Figure 7. Contour layers and distribution of surface pressures in time Δt=1200 s

In the final phase of the creeping test, avocado fruit after 1200 seconds from the moment the test starts, the contour layers and surface pressures distribution did not explicitly change. Only a slight levelling of surface pressures took place in the contact zone of a fruit with a working element of the testing machine (fig. 7c,d) with maintaining an elyptic nature of distribution along the contact surface. The maximum values of the surface pressures were reduced to the value of p=0.475 MPa at the average pressures of p=0.295 MPa.

The change of the maximum values of surface pressures in the contact zone of avocado fruit with an element which loads the testing machine during the test is presented in figure 8. In the moment the test starts, average pressures obtained the value of p=0.574 MPa and afterwards gradually decreased to the level of p=0.509 MPa after 500 seconds and p=0.475 in the end of the test. It means that within 190 to 500 seconds the surface pressures were reducing in the rate of 209 10^{-}-6 MPa·s^{-1} whereas within 500 to 1200 seconds the rate was 49 10^{-}-6 MPa·s^{-1}.

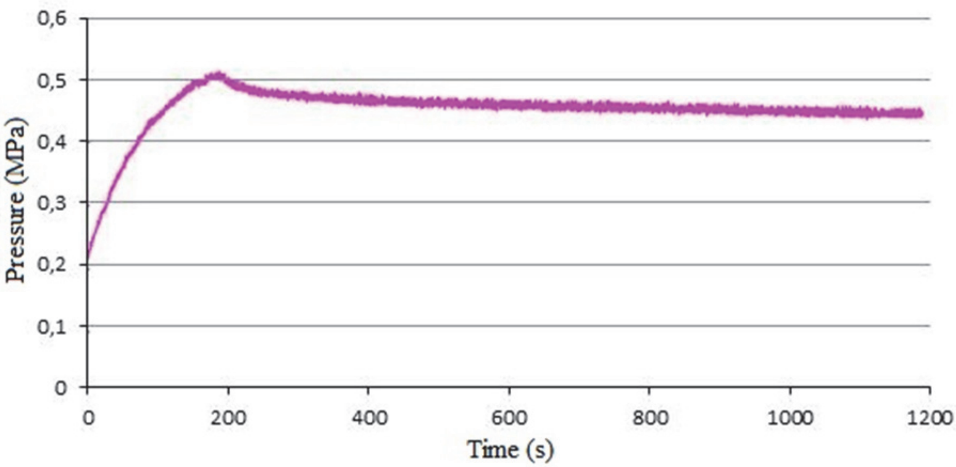

Figure 8. Maximum values of surface pressures as time function Δt=0 to 1200s

Conclusions

1. Value of the maximum surface pressures in the entire cycle of loading is reduced to the value of 0.574 MPa in the beginning of the test to 0.475 MPa in the end of the test, but in the initial stage of the test (190-500 seconds) the speed of thrusts reduction was four times higher than in the final stage.
2. The value of the average surface pressures in the entire cycle of loading is reduced from the value of 0.328 MPa to 0.295 MPa but in the initial stage of the test (190-500 seconds) the speed of thrusts reduction was thirty times higher than in the final stage.
3. Shift of the working element of the testing machine increases from the initial value l_0=478 mm to the value of l_1= 558 mm in the end of the cycle.
4. Distribution of thrusts on the contact surface of avocado with a loading element is not levelled during the creeping test.
5. The maximum values are in the central zone of the fruit contact with a loading element.

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ROZKŁADY NACISKÓW POWIERZCHNIOWYCH DLA AWOKADO PRZY STAŁEJ WARTOŚCI OBCIĄŻENIA

Streszczenie. W przeprowadzonych badaniach zaprezentowano wyniki pomiarów nacisków powierzchniowych awokado odmiany Fuerte w teście ściskania promieniowego pomiędzy płaskimi płytami przy stałej wartości obciążenia z uwzględnieniem czynnika czasu. Test przeprowadzono przy wykorzystaniu maszyny wytrzymałościowej Instron 5566. Na dolnej płycie pod ściskanym owocem Awocado umieszczony został czujnik systemu Tekscan o numerze 5076. Pozwoliło ta na ciągłą obserwację warstwic nacisków powierzchniowych na powierzchni styku oraz wyznaczenie rozkładu nacisków powierzchniowych pomiędzy awokado z płytą dolną maszyny wytrzymałościowej. Wyznaczono warstwice i rozkłady nacisków powierzchniowych w różanych etapach testu pełzania. Wykazano, że maksymalne i średnie wartości nacisków powierzchniowych ulegają wyraźnemu zmniejszeniu w trakcie całego testu. Rozkład nacisków powierzchniowych ma kształt typowy dla zagadnień kontaktowych w sprężystym zakresie odkształceń, gdzie maksymalne wartości znajdują się w centralnej strefie styku i mają rozkład zbliżony do krzywej parzystej. Pod koniec testu nastąpiło tylko nieznaczne wyrównanie rozkładu nacisków na powierzchni styku Awocado z elementem roboczym maszyny wytrzymałościowej.

Słowa kluczowe: naciski powierzchniowe, awokado, ściskanie, czynnik czasu, pełzanie

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ANNUAL USE AS A CRITERION FOR SELECTION OF A COMBINE HARVESTER UTILISATION FORM

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ABSTRACT

The objective of the study was to decide which alternative of using mechanization services by farms, namely the purchase of new or second-hand technical equipment on the example of grains combine harvesters should be taken into consideration. Two typological groups of grain combine harvesters were created. In the selected groups the following models responded to an average combine harvester: A – Bizon Z056; B – John Deere 1450 CWS. Limit points balancing the price of service in working hours and the surface area in hectares designed to be harvested were established. Investigations showed, that the purchase of a new combine harvester will be rational only in these farms, where minimum acreage of grains and technologically similar plants will be achievde: group A – 128 ha; group B – 173 ha. If these services are unavailable, farms can afford purchase of the second-hand equipment for an average price which does not exceed: 89,530 PLN for group A and 176,315 PLN for group B.

Introduction

Individual farms in Poland are diversely equiped with mechanization means. This applies to both the number as well as the type, age and technical condition of machines and equipment. A relatively small size of the average farm with a simplified structure, not of very high intensity, low level of services in the close neighbourhood, and thereby often with too many technically and technologically obsolete machinery influence a low level of annual use of the equipment. This situation generates high cost of mechanization, which raises the level of total production costs and consequently decreases the income (Pawlak, 2011). Taking into account insatisfactory condition of the machinery park some farms have already started its modernization with EU funding (Zając et al.,, 2012). The remaining units are at the stage of planning mechanization investments or consider termination (Szuk, 2009). Rationality of purchase and use of mechanization funds determines the level of costs and its impact on the final result of production (Komarnicki et al., 2012). Therefore, a problem of rational choice of the form of use of particularly high-value machines seems to be crucial (Muzalewki, 2007). The form of use determines the manner and extent of mechanization means, which may be limited to one or multiple farms. These forms are the most frequently distinguished: individual, team, service and mixed (Pawlak, 2011).

Objective, scope and methodology of research

Therefore, the objective of this study was to carry out a scientific attempt to decide which alternative for using farm mechanization services namely the purchase of a new or used technical equipment is more beneficial on the example of combine harvesters.

Tests were simualtive in nature and were based on the standards and norms concerning the organization of work in plant production, parameters of the most commonly exploited combine harvesters on individual farms, mechanization services prices and theoretical and practical knowledge of the author (Lorencowicz, 2007).

The research material came from 96 deliberately selected individual farms located in 44 communes of Lower Silesia Voivodeship. These farms co-operated with the Lower Silesian Agricultural Advisory Centre in Wroclaw and were significantly bigger than the average units of this type located in Lower Silesia. The study was conducted in 2008-2010. Data were obtained during a questionnaire interview with landowners.

On the basis of these data two typological groups of combine harvesters were formed. Group selection was carried out taking into account the brands and models of combines and their basic operating parameters,such as strength, width and bandwidth threshing.

In each group the following brands and models corresponded to an average combine: group A – Bizon Z056; Group B – John Deere 1450 CWS. The unit costs of their operation, depending on the annual mixed use were calculated. Cost calculation was carried out using the methodology proposed by Muzalewski (2009). Depreciation costs were calculated in relation to the adopted 15-year lifetime. It was assumed that the period of use , longer than than the accepted one, will result in significant technical and moral use, which may affect the efficiency of mechanization on farms. Storage costs are assumed to be 0.5% of the purchase price and insurance costs of 0.1%. The intrest from the capital costs were skiped. The costs of repair were established with the use of ther repair costs index over the life of a combine. This ratio is assumed to be 40%, which is half the size given in the methodology presented by Muzalewski (2007, 2009). This value is consistent with the level recommended in the world literature (Calcante et al., 2013) and administered by OKL, KTBL and ART-Berichte by Muzalewski (2009). Operator costs were skipped assuming that the farmer does the work himself. Prices included in the calculations: fuel, harvest services (with shredding straw) and the purchase of harvesters were gross average prices for the period of 2008-2010 in accordance with farmers' indications during the interviews. The limit points balancing price of the service during working hours and the surface of acres to be harvested has been established. The limit points are synonymous with so much work of a machine per one year, at which the unit cost of operation is equal to the price of service. In this situation, the purchase of equipment is justified if it can be guaranteed that it is used not less than the limit (Muzalewski, 2003; Skwarcz, 2006). The maximum purchase price of a second-hand combine was estimated by setting a purchasing price if the following were known: the actual annual use and the unit cost of exploitation on the level of the service price.

Research results

The investigated farms had 57 combine harvesters. An average age of a combine was 22 years, with a coefficient of variation of 30%. Among these, only 13% of machines were purchased as brand new. On average, there were 1.71 combine per 100 ha, which was comparable to the national average and research in other research centers (GSO, 2011a; GSO, 2011b; Lorencowicz and Figurski, 2009). Distinguishing between typological groups similar operating parameters of combines were taken into consideration. 51 combines were classified to two groups, 6 were rejected- they differed significantly from combines qualified to these groups and their parameters did not allow for creation of another homogeneous group. Division into typological groups with the basic parameters of combines was presented in table 1.

Table 1
Characteristics of typological groups of combine harvesters

Specification	Typological groups of combine harvesters	
	A Bizon Z056	B John Deere 1450 CWS
Number, (pieces)	46	5
Age, (years)	24	11
Work width, (m)	4.2	4.8
Power, (kW)	78	139
Performance W_{07}, ($ha \cdot h^{-1}$)	0.85	1.65

In order to calculate the border use a simulation of calculation of unit costs of operation at varying annual use was conducted. Actuarial calculation model was made in Excel, where according to the principle Ceteris Paribus, all parameters other than the annual use were maintained at aconstant level. This procedure is similar to the graphic method of determining the limit usage (Muzalewski, 2003). In order to calculate the unit costs of combines exploitation assumptions similar to those set out by Muzalewski were used in both groups (2009, 2010). Detailed assumptions are presented in Table 2.

Table 2
Assumptions for calculation of operating costs and limit points

Specification	Typological groups of combine harvesters	
	A	B
Life time, (years)	15	15
Fuel consumption, ($l \cdot h^{-1}$)	17	24
Ratio of repair costs, (%)	40	40
Parking costs, (% purchase price)	0.5	0.5
Fuel price, ($PLN \cdot l^{-1}$)	3.8	3.8
Costs of iunsurance, (% purchase price)	0.1	0.1
Purchase price, (PLN)	244, 000	402, 600
Harvesting service price, ($PLN \cdot ha^{-1}$)	300	300

Taking the combine service as a reference price it was proved that planning the purchase of a new combine, surface area for harvesting of cereals and plants which are technologically similar must be ensured at the following level: group A – 128 ha; Group B – 173 ha. Based on W_{07} combines operational efficiency in each group the limit number of hours of operation has been established (tab. 3, fig. 1 and 2).

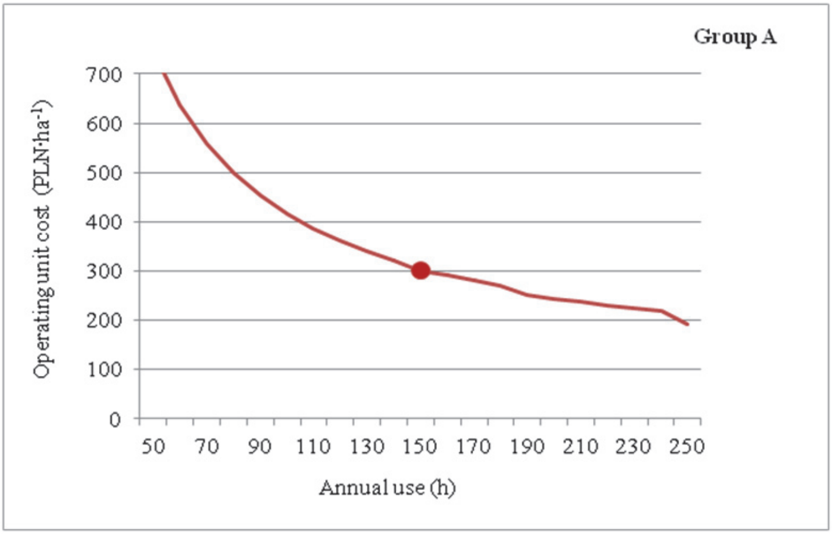

Figure 1.Limit point equalizing service price during working hours – group A

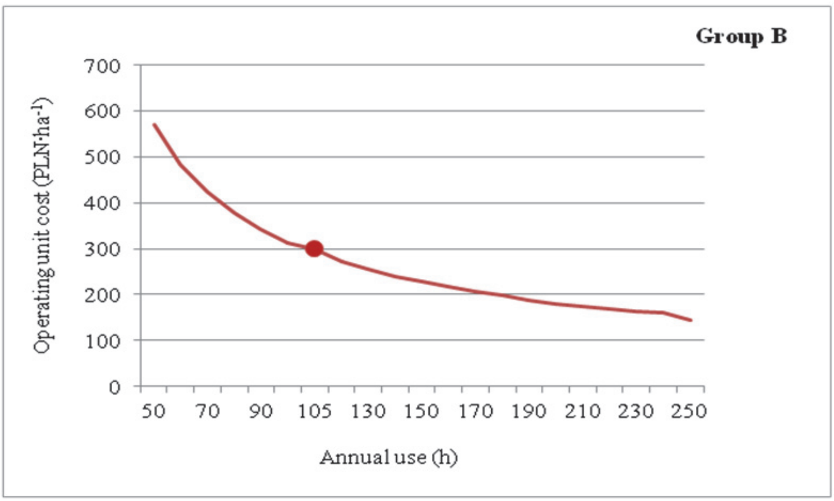

Figure 2. Limit point equalizing service price during working hours – group B

Table 3
Limit points equalizing service price during working hours and harvest acreage

Specification	Typological groups of combine harvesters	
	A	B
Hours, (h)	150	105
Area, (ha)	128	173

Limit values were compared to the surface area for harvesting in the farms under investigation. Only in five farms these values were exceeded approximately by 25% at the range of 4% to 59%. In four cases, farms owned harvesters from group A and in one case from group B. In the remaining 46 farms the harvesting surface was lower than the limited size at the average by 42% at the range of 9% to 92%. If this farms are planning to exchange existing combines while maintaining the current yield of production and the lack of activity in the form of a service of combine harvesting of cereals they should not decide to purchase a new machine. Much better solution would be for them to use the services. Similar conclusions are made by Muzalewski (2007) and Jablonka et al. (2010). In order to calculate the maximum purchase price of second-hand combines the simulation calculation of the purchase price at the following constant must be carried out: real annual use and operating unit cost price on the service price level. Time of utilization of the purchased combines has been set at 10 years. The remaining assumptions for calculations comply with data from table 2. Calculations show that if services are unavailable, farms can afford to buy used equipment for the average price, not exceeding for the farms posessing combines from group A – 89, 530 PLN, and for group B – 176, 315 PLN (tab. 4).

Table 4
Characteristics of use of combine harvesters in farms, limit points and limit prices

Specification	Typological groups of combine harvesters	
	A	B
Total harvested area, (ha)	53.00	104.16
Total services area, (ha)	10.24	10.20
Crop area – Total, (ha)	63.24	114.36
limit point, (ha)	128.00	173.00
% of yearly utilisation	49.41	66.10
Real annual use, (h)	74.40	69.31
Limit price of the used combine purchase, (PLN)	89, 530	176, 315

Conclusions

On the basis of the obtained results the following conclusions has been formulated:

1. The study showed that the purchase of a new combine will be rational only in those farms where there will be an area of cereal or technologically similar crops at the minimum level of 128 ha for group A and 173 ha for group B.

2. The established limit points based on the simulation were exceeded in four farms, which had harvesters from group A and in one from group B. In the remaining 46 farms the harvesting area was lower than the set limit size by an average of 42%.
3. The most rational form of mechanization in farms where the established points did not excede the limit points will be use of services or purchase of second-hand combine harvesters at a price not exceeding 89, 530 PLN for A group, and 176, 315 PLN for group B.

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WYKORZYSTANIE ROCZNE JAKO KRYTERIUM WYBORU FORMY UŻYTKOWANIA KOMBAJNU ZBOŻOWEGO

Streszczenie. Celem opracowania była próba naukowego rozstrzygnięcia alternatywy korzystania przez gospodarstwa z usług mechanizacyjnych w stosunku do zakupu nowego bądź używanego sprzętu technicznego na przykładzie kombajnów zbożowych. Utworzono 2 grupy typologiczne kombajnów zbożowych. W poszczególnych grupach odpowiednikami kombajnu przeciętnego były następujące marki i modele: A – Bizon Z056; B – John Deere 1450 CWS. Ustalono punkty graniczne równoważące cenę usługi w godzinach pracy i ha powierzchni przeznaczonej do zbioru. Badania wykazały, że zakup nowego kombajnu będzie racjonalny jedynie w tych gospodarstwach, gdzie zapewniony zostanie minimalny areał zbóż i roślin technologicznie podobnych na poziomie: grupa A – 128 ha; grupa B – 173 ha. W sytuacji braku dostępności do tych usług mogą sobie one pozwolić na zakup sprzętu używanego w przeciętnej cenie nie przekraczającej dla gospodarstw posiadających kombajny z grup A – 89530 PLN, i z grupy B – 176315 PLN.

Słowa kluczowe: gospodarstwo rolne, kombajn zbożowy, mechanizacja, usługa mechanizacyjna, województwo dolnośląskie

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SPRAY APPLICATION QUALITY AS AFFECTED BY SPRAY VOLUME, NOZZLES AND PHENOLOGICAL GROWTH STAGE OF APPLES

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ABSTRACT

The objective of studies was to determine the influence of spray volume and the nozzle type on product deposition and distribution in apple tree canopies, as well as spray coverage on leaves obtained in different phenological growth stages. The spray volumes 250, 500 and 750 $l \cdot ha^{-1}$ were applied with fine spray and coarse spray nozzles generating droplets of VMD around 150 µm and 400 µm respectively. Munckhof cross-flow sprayer was used at the driving velocity of 5.0 $km \cdot h^{-1}$ to apply fluorescent dye as spray liquid. During flowering the greatest deposition was obtained at the spray volume of 250 $l \cdot ha^{-1}$ applied with the coarse spray nozzles. The spray volume 750 $l \cdot ha^{-1}$ resulted in the best coverage in the tree centre. During development of fruit, deposition in the canopy centre was at a constant level irrespective of the spray volume and a droplet size. At the stage of fruit maturity the best coverage was observed for fine spray nozzles and spray volumes of 500 and 750 $l \cdot ha^{-1}$. The use of coarse spray nozzles resulted in the coverage reduction by 50%.

Introduction

The quality of the treatment in the apple tree orchard depends considerably on the even distribution of spray in the sprayed tree canopies. Variability of distribution in tree canopies is usually very high on account of a spacious nature of horticultural crops, dynamic increase of leaves in the vegetation season and the change of the wind direction and speed during the protection treatments. The spray volume and the type of applied nozzles may directly influence even distribution and the level of deposition of spray in particular phenological growth stages.

Labels of the crop protection chemicals include recommendations on the amount of spray volume to be applied for crops, for which these chemicals are registered. In case of the apple tree, these volumes are within 250 to 1000 litres per hectare. In relation to the tree size, doses may be differentiated with the TRV method (Tree Volume Method) (Buyers et al., 1971; Doruchowski et al., 2013). Along with the increase of the spray volume, evenness of the spray distribution in the tree canopies increases. However, due to the limited retention ability of a tree, excessive volumes may increase the spray losses as a result of dripping (Travis et al., 1987a; Doruchowski et al., 1997).

The droplet size depends on the type of applied nozzles. Standard hollow cone nozzles produce fine, fine and average droplets, which means that as much as a several percent of volume of the generated droplets are droplets with a diameter below 100 µm, the most susceptible to drift (Knewitz et al., 2002). Coarse air inclusion nozzles have a great potential of drift reduction (Wenneker et al., 2006). They produce coarse, aerated and less susceptible to drifting droplets and the share of droplets with a diameter lower than 100 µm in the total volume of emitted droplets is usually reduced to a few percent (Knewitz et al., 2002). Coarse spray nozzle treatments result, as a rule, in worse leaves coverage and reduce the spray retention on the sprayed objects (Brunskill, 1965) As a result the finest droplets are obtained in the spraying process and the higher degree of spray coverage of objects (Szewczyk et al., 2013).

A decisive majority of protection treatments in orchard is performed from May to the end of July, that is from the flowering stage to the stage of fruit maturity. In the early phenological growth stages a dynamic growth of leaves and densification of tree canopies takes place. Their retention ability increases considerably. During full leafage, trees retain 40-50% of the applied spray volume and before blossom up to 24% (Siegfried and Holliger, 1996). Therefore, evenness of deposition at full leaf stage is by 50% worse than at the blossom (Godyń et al., 2006), whereas the best uniformity of deposition is obtained in the loose tree canopies (Travis, 1987). Walklate et al. (2000) proved that the level of deposition is inversely proportional to the density of tree canopies.

Objectives

The objectives of the research was to determine the impact of the spray volume and the type of nozzles on the deposition and distribution of spray and leaves coverage in apple trees in various phenological stages.

Materials and Methods

The tests were carried out in 2011-2012 in the experimental orchard of the Research Institute of Horticulture on Jonagold apple trees. The orchard was divided into three blocks, which consisted of three rows. The trees were of 3.0 m height and 1.8 m wide, planted in the 4 m row spacing (volume of tree canopies TRV=13,500 $m^3 \cdot ha^{-1}$). The blocks were separated by the black alder row. Different spray volumes were applied in the form of the solution of fluorescent dye (BSF):

– 250 $l \cdot ha^{-1}$ (volume TRV – 50%), with BSF concentration of 0.05%,
– 500 $l \cdot ha^{-1}$ (volume TRV), with BSF concentration of 0.025%,
– 750 $l \cdot ha^{-1}$ (volume TRV + 50%), with BSF concentration of 0.017%.

Each block consisted of two fields for each type of nozzles:

– fine spray nozzles (VMD=approx.150 µm),
– coarse spray nozzles (VMD=approx. 400 µm).

Experimental fields consisted of three rows of tress 10 m long. In the central part of each, 2 trees were selected for collecting samples of deposition and coverage.

Spraying with a fluorescent dye was carried out in the atmospheric conditions suitable for treatments, namely, at the wind speed up to 3.0 $m \cdot s^{-1}$. In the experiment a cross-flow sprayer Munckhof was used at the driving speed of 5.0 km·h^{-1} (table 1) maintaining the same settings of a fan for all combinations in three phenological growth stages: flowering, development of fruit and maturity of fruit.

Tabele 1
Spray application parameters

Spray wolume (l·ha^{-1})	Working speed (km·h^{-1})	Number of nozzles	Nozlles type Lechler	Workin pressure (MPa)	Nozzle flow rate (l·min^{-1})	VMD (µm)
250	5.0	16	TR 80-01 ID 90-01	0.6	0.52	150 400
500	5.0	16	TR 80-015 ID 90-015	0.95	1.04	150 378
750	5.0	16	TR 80-02 ID 90-02	1.15	1.56	157 371

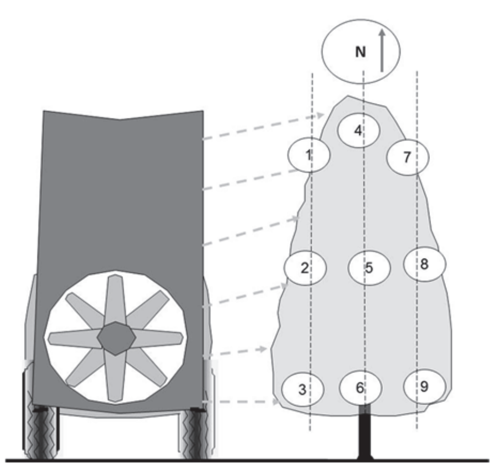

Figure 1. Sampling layout for deposition and coverage evaluation within tree canopy

Deposition of the fluorescent dye in tree canopies was measured on leaves, whereas the coverage was measured with the use of water-sensitive paper samples (WSP) mounted on leaves. From each of nine points, selected from two tree canopies, five leaves were collected for the deposition evaluation, which constituted the repeat of combinations of volumes and the nozzle type (fig.1)

The deposit of the dye was expressed as the mass of the substance per cm^2 of leaves. It was determined with the luminescent spectometer Perkin Elmer LS 55 and the digital planimeter with the image analysis system WinDias 3 (for area determination). The leave coverage degree was measured optically with the use of the multi-task microscope Nikon AZ100 with the image computer analysis system. All measurements and analyses were carried out in the according to the standard methodology used for this type of experiments in Department of Horticultural Engineering of the Research Institute of Horticulture.

Research results

The mean values of deposition and coverage in tree canopies obtained from two vegetation seasons are presented in figures 2-7. In order to determine the evenness of deposition and coverage, results were grouped in three vertical planes according to the plan of collecting samples presented in figure 1:

– external eastern plane,
– plane of tree row axis,
– external western plane.

In the flowering stage, the highest deposition in all tree planes was obtained for the spray volume of 250 $l \cdot ha^{-1}$ and the coarse spray treatment (figure 2). The average deposit for the coarse spray treatment in the tree axis was 25% higher than the deposit for fine spray treatment. In the early period of shaping leaves high spray volumes did not cause higher deposition in the canopies of the sprayed trees. In case of spray volumes of 500 and 750 $l \cdot ha^{-1}$ and both categories of droplet size and for the volume of 250 $l \cdot ha^{-1}$ and the fine spray treatment, mean values of deposition for particular vertical places did not differ significantly. It proves a high uniformity of deposition in tree canopies. According to the expectations, the highest coverage resulted from high spray volumes (figure 3).

For the spray volume of 750 $l \cdot ha^{-1}$ and both categories of droplet size, no significant differences were reported in coverage between extreme vertical planes and tree axis. The applied spray volume of 500 $l \cdot ha^{-1}$ in the form of fine droplets resulted in the coverage at the equally high level. The lowest coverage was obtained for 250 $l \cdot ha^{-1}$ and coarse droplets.

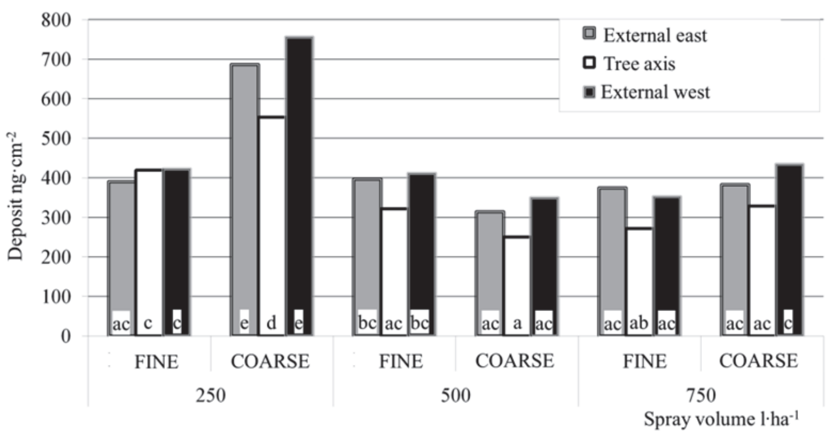

Figure 2. Mean values of deposition in vertical planes of tree canopies during flowering stage (means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

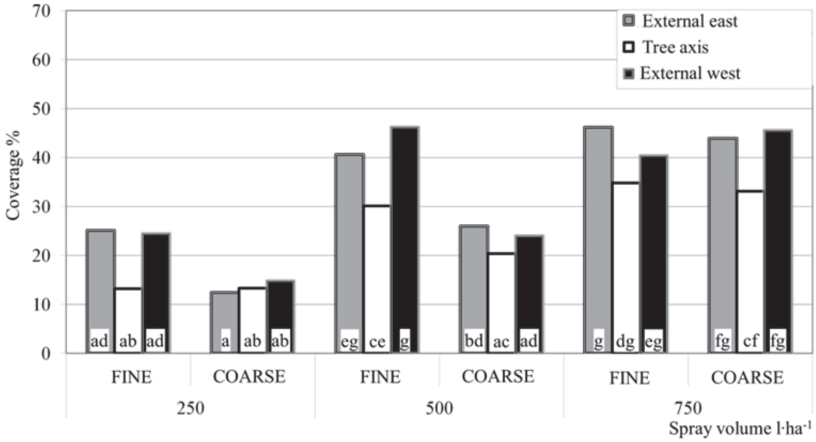

*Figure 3. Mean values of coverage in vertical planes of tree canopies during flowering stage (*means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

During development of fruit, a dynamic increase of leaf area took place. Tree canopies became dense, which resulted in increase of retention of spray. Despite expectations, higher spray volumes did not cause higher deposition. A considerable level of deposition was reported in comparison to the earlier phenological growth stage. Provided that in the flowering stage the level of deposition in particular vertical planes of tree canopies for all combinations of volumes and the sizes of the applied droplets was within 250-750 ng·cm^{-2}, during development of fruit stage it was only 150-350 ng·cm^{-2} (fig. 4).

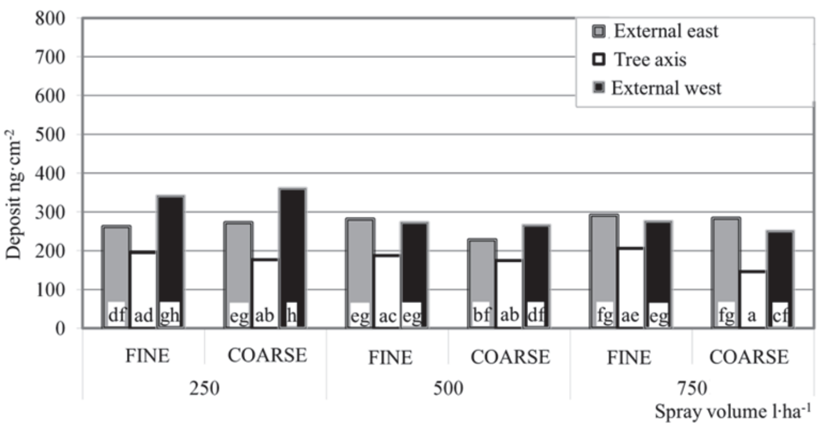

*Figure 4. Mean values of deposition in vertical planes of tree canopies during development of fruit (*means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

Moreover, significant differences in deposition between extreme vertical planes and the plane in the tree axis for all applied volumes and the droplet size, were reported. However, for fine spray treatments, an increase trend of deposition in the tree axis was reported. The highest mean values of coverage were obtained for fine spray treatments for volumes of 500 and 700 l·ha^{-1} (fig. 5).In both cases for coarse droplet treatments almost two times worse coverage in the tree axis plane was reported. In case of the volume of 250 l·ha^{-1} fine spray treatments resulted in identical coverage in all vertical planes as for the volume of 500 l·ha^{-1} and coarse droplets.

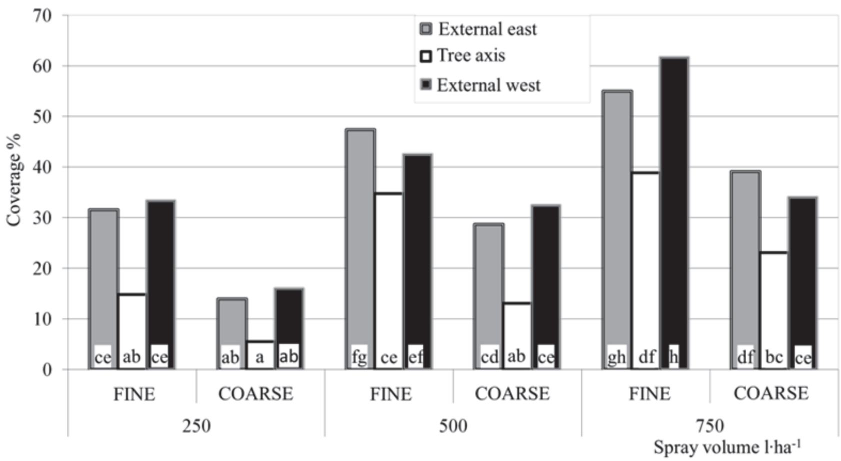

*Figure 5. Mean values of coverage in vertical planes of tree canopies during development of fruit stage (*means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

In the stage of the fruit maturity, the level of deposition in vertical planes of tree canopies for all combination of volumes and the sizes of the applied droplets was within 168-295 ng·cm^{-2}. The highest uniformity of deposition was reported for the volume of 750 l·ha^{-1} and the fine spray treatment (fig. 6). For the remaining combinations of volumes and droplet sizes differences of deposition between the extreme vertical planes and in the tree canopies axis were reported. Except for the volume of 750 l·ha^{-1} and the fine spray treatment, similarly as in the previous phenological stage, deposition in the vertical plane of tree canopies axis was at the same level not related to the applied spray volume and the droplet size. A trend for higher deposition in the tree axis for a fine spray treatment and the volumes of 500 and 750 l·ha^{-1} in comparison to the coarse spray treatment was also reported. Moreover, mean coverage reported for the volume of 500 l·ha^{-1} and the fine droplets was at a similar level as for the volume of 750 l·ha^{-1} and the coarse droplets.

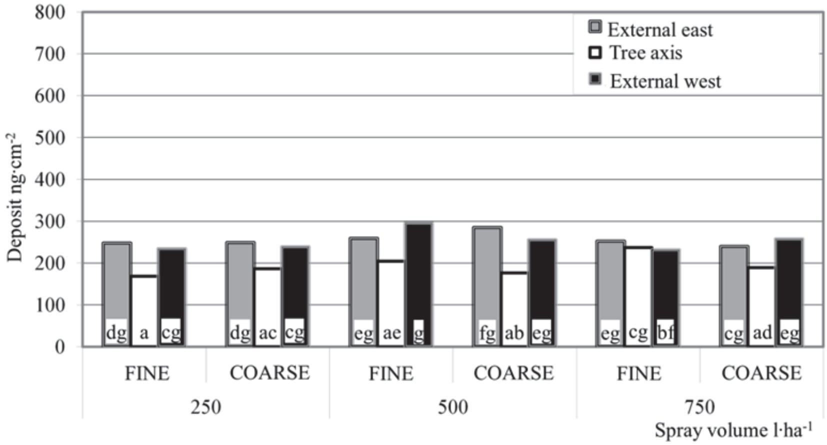

*Figure 6. Mean values of deposition in vertical planes of tree canopies during maturity fruit stage (*means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

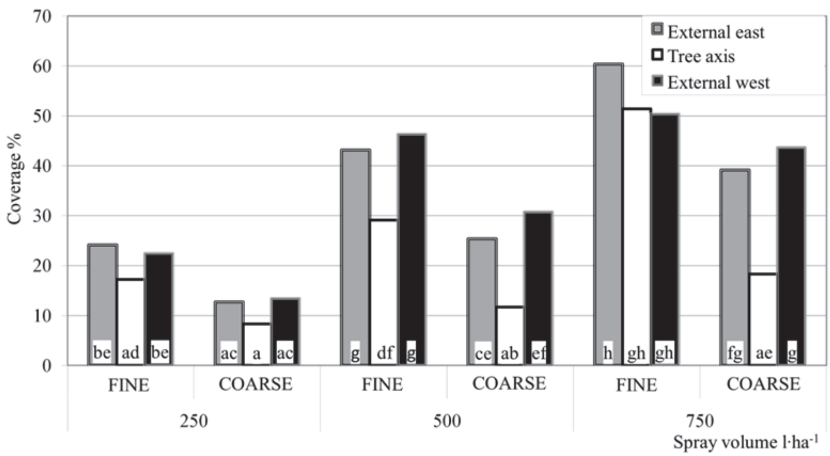

*Figure 7. Mean values of coverage in vertical planes of tree canopies during maturity fruit stage (*means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

Conclusions

1. In the flowering stage deposition in the zone, which was difficult to access namely in the tree axis for the coarse spray treatment and the spray volume 250 l·ha^{-1} was higher by 25% than the deposition caused by the fine spray treatment.
2. In all phenological stages, higher spray volumes did not cause the increase of deposition.
3. In the stages of fruit development and fruit maturity a clear decrease of the level of deposition of the fluorescent dye on leaves in comparison to the flowering stage was reported.
4. In both later phenological stages, the coverage in the tree axis as a result of fine spray and volumes of 500 and 750 l·ha^{-1} was two times higher than the coverage caused by the coarse droplets.

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WPŁYW DAWKI CIECZY, RODZAJU ROZPYLACZY ORAZ FAZY FENOLOGICZNEJ NA JAKOŚĆ ZABIEGU OCHRONY W SADZIE

Streszczenie. Celem badań było określenie wpływu dawki cieczy i rodzaju rozpylaczy na naniesienie i rozkład cieczy w koronie drzewa jabłoni oraz na pokrycie liści w różnych fazach fenologicznych. W badaniach stosowano zabiegi drobnokropliste (VMD=ok. 150 µm) i grubokropliste (VMD=ok. 400 µm) oraz dawki: 250, 500 i 750 $l \cdot ha^{-1}$. Opryskiwanie znacznikiem fluorescencyjnym wykonano opryskiwaczem z poprzecznym systemem emisji Munckhof przy prędkości roboczej 5,0 $km \cdot h^{-1}$. W okresie kwitnienia największe naniesienie uzyskano dla dawki 250 $l \cdot ha^{-1}$ i zabiegu grubokroplistego, natomiast dawka 750 $l \cdot ha^{-1}$ powodowała największe pokrycie w osi drzew. W okresie zawiązywania owoców naniesienie w osi drzewa utrzymywało się na tym samym poziomie niezależnie od dawki cieczy i wielkości kropel. W okresach zawiązywania i pełnego wykształcenia owoców największe pokrycie odnotowano dla zabiegów drobnokroplistych i dawek 500 i 750 $l \cdot ha^{-1}$. Zabiegi grubokropliste powodowały dwukrotnie mniejsze pokrycie w osi drzew.

Słowa kluczowe: naniesienie,pokrycie, jakość rozpylania,parametry zabiegu, opryskiwanie sadu

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SOME PHYSICAL PROPERTIES OF CEREAL GRAIN AND ENERGY CONSUMPTION OF GRINDING

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ABSTRACT

The objctive of the paper was to assess a relation between some physical properties of cereal grain and energy consumption. Grain of common wheat, spelt and triticale of 15% moisture was ground using a cylinder mill. A relation between energy consumption and vitreousness, thousand kernel weight, test weight and ash content have been determined. Unit energy consumption depended on vitreousness, test weight and ash content in grain. Unit energy consumption increases with the increase of vitreousness and test weight, and decreases with grain ash content. The grinding efficiency index increases with increasing vitreousness, test weight and thousand kernel weight and it decreases with increasing ash content in grain. Vitreousness influenced the consumption of energy more considerably than the test weight and grain ash content.

Introduction

Common wheat, spelt wheat and triticale are important crops which play a considerable role in human nutrition. Spelt wheat is one of the oldest subspecies of common wheat. In recent years it has attracted a lot of attention due to a more beneficial chemical composition and higher nutritional value compared to common wheat grain (Bonafaccia et al., 2000). On the other hand, triticale is a potential alternative to wheat in processed flour products. Grinding is the main form of processing cereal grain; its first purpose is to separate endosperm, pericarp and germ and then to reduce the size of endosperm particles to a fraction which passes through a sieve with an opening size not exceeding 200 μm (Posner, 2003). Grinding is one of the most energy-intensive processes (McCabe et al., 2004). About 60-75% of energy in industrial processing is spent on grinding (Danciu et al., 2009). The energy of grinding cereals has also attracted the attention of scientists. Pujol et al. (2000) as well as Danciu and Danciu (2011) described micro-mills designed to conduct precise measurements of consumption of mechanical energy when small amounts of wheat grain were ground. The amount of energy consumed during the grinding process depends on the type of mill applied, the mill settings and on the physical and chemical properties of grain and the degree of grinding (Dziki and Laskowski, 2002; Dziki, 2008; Fang et al., 1998; Greffeuille et al., 2007; Scanlon and Dexter, 1986; Wiercioch et al., 2008). A number of studies have dealt with the effect of moisture content in grain on the amount of energy needed to grind it (Kowalik et al., 2002; Marks et al., 2006; Opielak and Komsta, 2001; Romański and Niemiec, 2000). The energy consumption of the grinding process increases with grain moisture content. Energy consumption of grain grinding also depends on kernel hardness. Hard wheat requires more energy for grinding than soft wheat (Dziki and Przypadek-Ochab, 2009; Dziki et al., 2012; Greffeuille et al., 2007; Kilborn et al., 1982). The vitreosity of grain is related to its hardness. Kernels with more vitreous endosperm are usually harder (Glen and Johnson, 1994). An increase in grain hardness results in an increase in the amount of energy spent on grinding (Dziki et al., 2012; Laskowski and Różyło, 2003). According to the findings of the study conducted by Wiercioch et al. (2008), energy consumption of cereal grinding is also affected by the kernel weight. The amount of energy spent on grinding wheat grain is proportional to the weight of kernels.

An analysis of literature reports leads to the conclusion that the majority of studies have dealt with the effect of moisture content and hardness of kernel on the amount of energy needed to grind it. Far fewer studies have dealt with the correlation between grinding energy and other properties of grain, such as: thousand kernel weight, test weight, ash content in grain and vitreousness of grain. Therefore, the aim of this study was to asses the dependence between some physical properties of cereal grain and energy consumption.

Material and methodology of the research

The experiment was conducted with grain of four cultivars of common wheat (Bombona, Korweta, Parabola, Radunia), two cultivars of spelt wheat (Schwabenkorn, Franckenkorn) and two cultivars of triticale (Andrus and Milewo). Grain samples were purified and the spelt was hulled on an LD 180 ST 4 laboratory device manufactured by WINTERSTEIGER. The moisture content of the grain was determined (ICC Standard No. 110/1). Subsequently, moisture content was increased up to 15% by adding an appropriate amount of distilled water. This was done in leak-tight containers over 48 h. The following were determined: thousand kernel weight (PN EN ISO 520:2011), test weight (PN EN ISO 7971-3:2010), kernel vitreousness (PN 70/R-74008). The total ash content in grain was also determined according to PN-EN ISO 2171:2010 methodology. The grain was ground in a Quadrumat Junior mill manufactured by Brabender, with a cylindrical sifter tightly wrapped with a 70GG (PE 236 μm) sieve. It is a four-cylinder laboratory mill with an aspiration system and a drum sifter. The energy consumption of the grinding process was determined by measuring the amount of electricity consumed by the mill during its operation. The energy used to set in motion the mill parts was calculated by multiplying the active power of the idle run and the time of grinding. The work done to grind a sample of grain was calculated with the assumption that total energy consumed by the mill equals the total energy of grinding and the energy needed for putting the elements of the mill into motion. The unit energy of grinding Er ($kJ \cdot kg^{-1}$) was calculated from the formula:

$$E_r = \frac{E_c - E_s}{m} \tag{1}$$

where:
E_c – total energy needed for the mill work ($E_c = P_c \cdot t_r$), (kJ)
E_s – energy of the idle run ($E_s = P_s \cdot t_r$), (kJ)
P_s – active power consumed during the idle run, (kW)
P_s – active (total) power consumed by the mill, (kW)
t_r – sample grinding time, (s)
m – ground sample weight, (kg)

The grinding efficiency index K' ($kJ \cdot kg^{-1}$) (Greffeuillea et al., 2007) was also determined:

$$K' = \frac{E_c - E_s}{m_m} \tag{2}$$

where:
m_m – mass of flour, (kg)

Measurements were conducted in sextuplicate for each kind of grain. Calculations were made in the MS Excel® spreadsheet (Microsoft). The results were processed statistically. An analysis of variance was conducted for the mean values of each attribute in order to identify the statistically significant differences. Significance of differences between the attributes was determined by Tukey's test. Linear correlation coefficients between the measured attributes was calculated. Significance was assessed at two levels ($p<0.05$) and ($p<0.01$). Linear regression equations were also determined, which describe the effect of the attributes of grain on unit grinding energy. Statistical calculations were made with STATISTICA® for Windows v. 10 (StatSoft Inc.). Statistical hypotheses were tested at the level of significance of $p=0.05$.

Results and discussion

The unit grinding energy (Er) ranged from 35.9 $kJ \cdot kg^{-1}$ (spelt – Franckenkorn cultivar) do 70.1 $kJ \cdot kg^{-1}$ – (common wheat – Parabola cultivar) (fig. 1). Grinding the grain of common wheat required more energy than grinding grain of spelt or triticale.

This was confirmed by the study conducted by Cacak-Pietrzak and Gondek (2010), in which grinding of spelt grain was found to require less energy than grinding common wheat grain. The grain grinding efficiency K', which corresponds to the energy necessary to obtain a set amount of flour, ranged from 57.6 (Milewo triticale) to 101.4 $kJ \cdot kg^{-1}$ (Parabola wheat) (fig. 2). Like the energy used for grinding grain, the energy used to obtain 1 kg of flour (particle size under 236 μm) was larger for common wheat than spelt or triticale.

The grain under study was characterised by vitreousness ranging from 6-62%. The relationship between grain vitreousness and the unit grinding energy was linear (fig. 3).

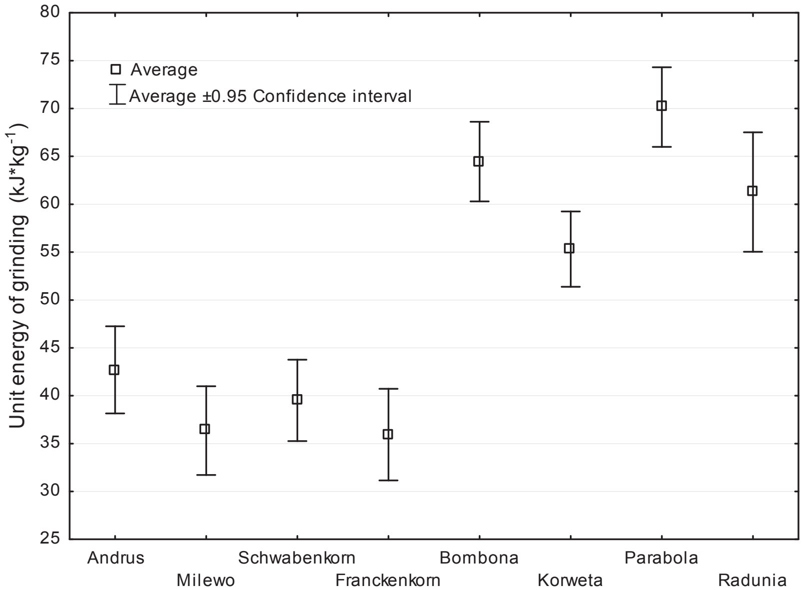

Figure 1. Average values of unit energy of grinding of the cereal grain (kJ·kg⁻¹)

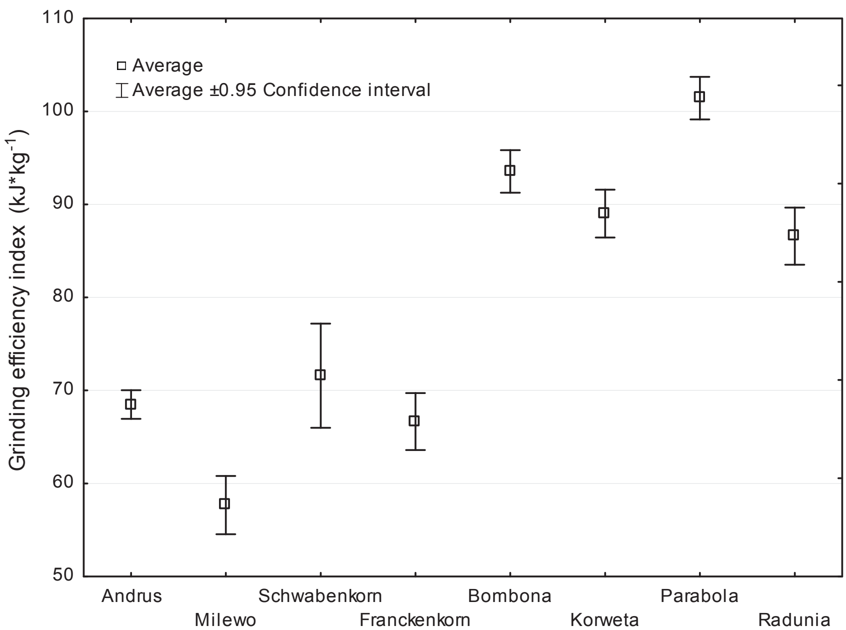

Figure 2. Average values of the index of grinding efficiency of the cereal grain

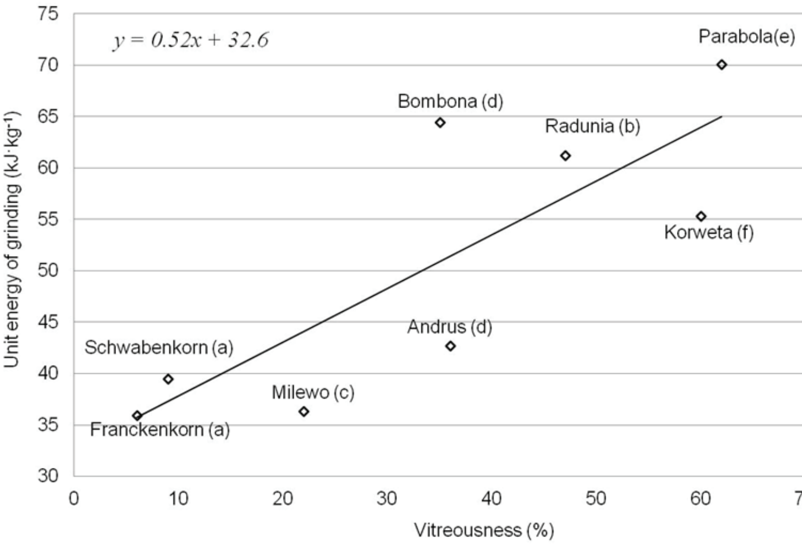

Figure 3. Dependence of the unit energy of grinding on vitreousness of grain (average values of vitreousness marked with these letters do not differ statistically significantly)

The linear correlation coefficient was 0.814 (Table 1) and was similar to that calculated by Dziki et al. (2012).

Table 1
Values of linear correlation coefficients between the researched properties

	Vitreousness	Test weight	Thousand kernel weight	Ash content
Unit energy of griding (E_r)	0.814**	0.750**	0.413	-0.692**
Grinding efficiency index (K')	0.772**	0.740**	0.541*	-0.681**

* – significant at $p< 0.05$; ** – significant at $p< 0.01$

The relationship between grain vitreousness and energy intensity of grinding was also studied by Laskowski and Różyło (2003). They showed grain vitreousness to affect unit grinding energy and a change of vitreousness from 15% to 85% resulted in an increase in the unit grinding energy by about 68%. This confirms the findings of studies of other authors (Dziki et al., 2012; Wiercioch et al., 2008).

This is caused by the internal structure of grain, because in them – unlike in floury grain, which is characterised by a loose structure of endosperm (grains of starch are separate from one another) – grains of starch are deeply embedded in the protein matrix (Edwards, 2010). The relationship between changes of the unit grinding energy and ash content is described by a linear equation: y=-64.569x+182.25, where r=-0.692 (fig. 4). The grinding energy decreased with increasing ash content in grain. The opposite relationship between the unit grinding energy and ash content in grain was shown in a study conducted by Dziki et al. (2012).

The test weight of grain as measured in this study ranged from 65.9 to 77.2 kg·hl^{-1}.

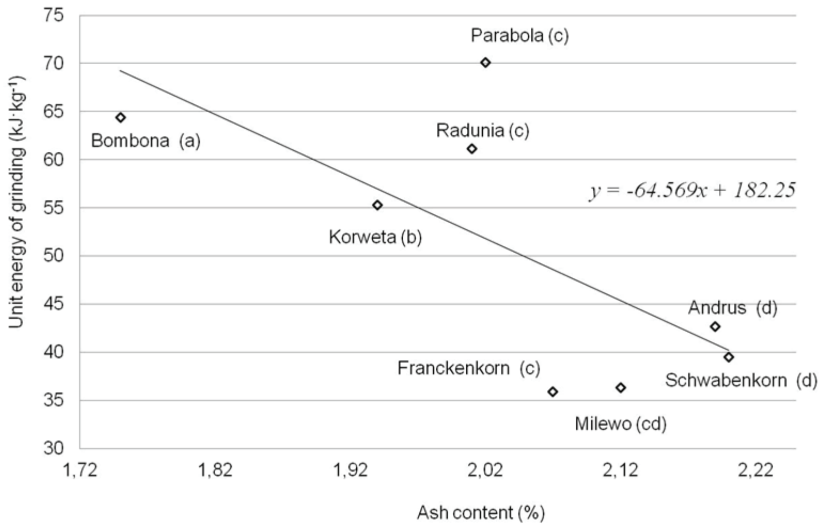

Figure 4. Dependence of the unit energy of grinding on the ash content in a grain (symbols as in figure 3)

As found in this study, a difference in vitreousness between 6% and 62% resulted in a difference in the unit grinding energy of about 95%. A number of studies (Cacak-Pietrzak et al., 2009; Laskowski and Różyło, 2003; Wiercioch and Niemiec, 2006) have indicated that grinding hard and vitreous grain requires more energy compared to floury grain. According to Cacak – Pietrzak (2009), vitreous grain is more durable and more energy is needed to grind it.

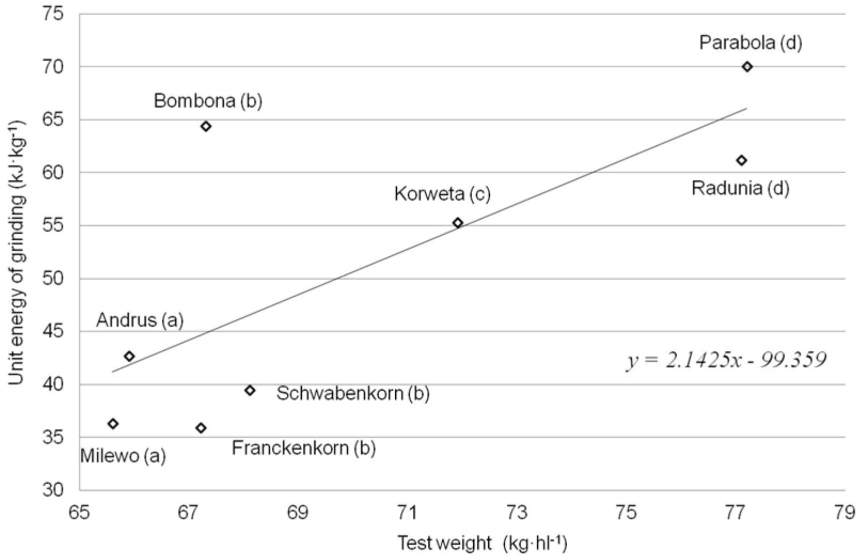

Figure 5. Dependence of unit energy of grinding on the test weight. (symbols as in figure 3)

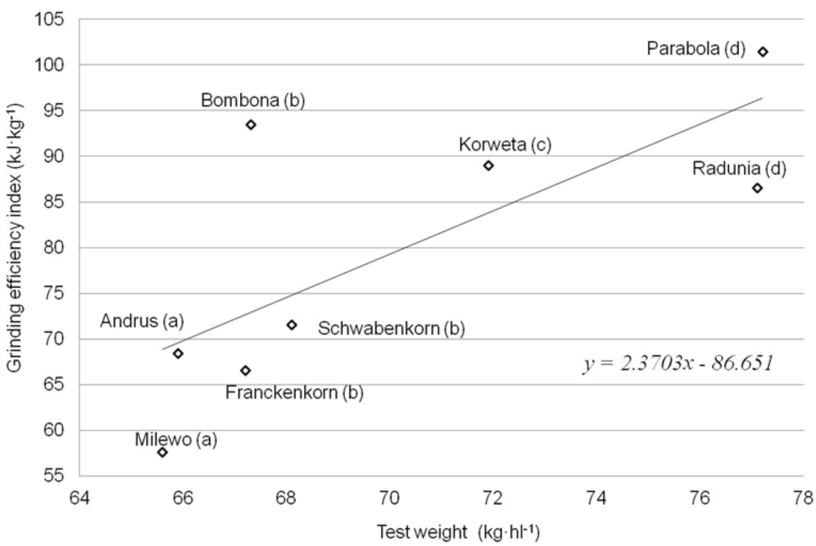

Figure 6. Dependence of grinding efficiency index on the test weight (symbols as in figure 3)

The relationship between the test weight of grain and the unit grinding energy was linear (Fig. 5). An increase in the test weight of grain was accompanied by an increase in the unit grinding energy (r=0.750). A significant correlation was found to exist between the test weight and the grain grinding efficiency index K' (fig. 6). The correlation coefficient was r=0.740. No significant correlation was found to exist between the thousand kernel weight (TKW) and the unit grinding energy. This study found a significant correlation between TKW and the grinding efficiency index K', i.e. the amount of energy needed to obtain 1 kg of flour (fig. 7).

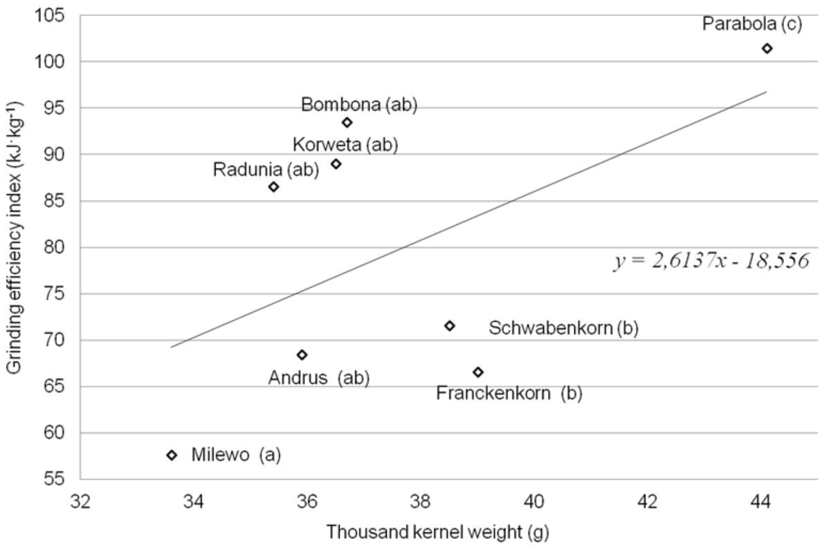

Figure 7. Dependence of grinding efficiency index on the thousand kernel weight (symbols as in figure 3)

This relationship is described by the equation: y=2.6137x–18.556; where r=0.541. It can be assumed that grinding large kernels requires more energy than grinding small ones to obtain the same amount of flour. Wiercioch et al. (2008) showed that the demand for energy needed for grinding increased with increasing kernel weight. It was found in this study that increasing the kernel weight two-fold contributed 46% to 80% to an increase in the unit grinding energy, depending on the material vitreousness.

Of the grain properties under study, vitreousness had a stronger effect on the energy consumption of grinding than the test weight or ash content (table 1).

Conclusion

1. Unit energy consumption depended on the vitreousness, test weight and ash content in grain. Unit energy consumption increases with the increase of the vitreousness and test weight, and decreases with the grain ash content.
2. The grinding efficiency index increases with increasing the vitreousness, test weight and thousand kernel weight and it decreases with the increasing ash content in grain.
3. Vitreousness influenced the consumption of energy more considerably than the test weight and grain ash content.

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WYBRANE WŁAŚCIWOŚCI FIZYCZNE ZIARNA ZBÓŻ A ENERGOCHŁONNOŚĆ ROZDRABNIANIA

Streszczenie. W pracy określono zależności między wybranymi właściwościami ziarna zbóż, a energochłonnością rozdrabniania. Ziarna pszenicy zwyczajnej, orkiszu i pszenżyta o wilgotności 15% poddano przemiałowi wykorzystując rozdrabniacz walcowy. Ustalono relacje między energochłonnością rozdrabniania, a szklistością ziarna, masą tysiąca ziaren, gęstością usypową i zawartością popiołu w ziarnie. Jednostkowa energia rozdrabniania zależała od szklistości, gęstości usypowej ziarna oraz od zawartości popiołu w ziarnie. Ze wzrostem szklistości i gęstości usypowej ziarna zwiększało się zapotrzebowanie na jednostkową energię rozdrabniania. Wskaźnik efektywności rozdrabniania zwiększał się wraz ze wzrostem szklistości, gęstości usypowej oraz masy tysiąca ziaren, a zmniejszał się ze wzrostem zawartości popiołu w ziarnie. Szklistość ziarna wywierała silniejszy wpływ na energochłonność rozdrabniania niż gęstość usypowa i zawartość popiołu.

Słowa kluczowe: Słowa kluczowe: ziarna zbóż, rozdrabnianie, właściwości fizyczne, energochłonność

CURRENT ISSUES

PASJE TWÓRCZE PROFESORA MIECZYSŁAWA SZPRYNGIELA – A CZAS CIĄGLE PŁYNIE…

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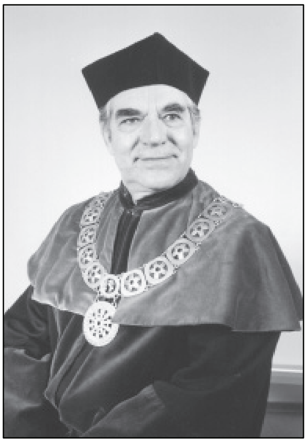

Rok 2013 wyznacza ważną datę w życiorysie Mieczysława Szpryngiela, oznaczającą oficjalne zakończenie kariery naukowej i osiągnięcia wieku emerytalnego. Wielu z nas, którzy taki stan już osiągnęli, woleli by uzyskać status spoczynku, ale ten przywilej w RP zachowano tylko dla nielicznych. Niezależnie od nazwy i formy przeniesienia, każda okrągła rocznica kojarzy nam się z jubileuszem. My w Polsce lubimy jubileusze i mno-żymy je nawet przesadnie. Każdy jubileusz wiąże się z czasem, a konkretnie z jego przemijaniem. Dlatego też moje rozważania na temat jubileuszu Profesora Szpryngiela proponuję rozpocząć od pojęcia czasu i jego kategorii.

Wg Pitagorejczyka Parena (Aforyzmy, cytaty, złote myśli na świadomość, 2011) czas jest czymś nieuporządkowanym, gdyż powoduje on utratę pamięci i zapomnienie.

Dla Arystotelesa (Arystoteles, 1990) czas jest bardziej przyczyną ginięcia niż powstawania. Św. Augustyn (Heidegger, 2008) rozważa również aspekty czasu. Wypowiada pogląd, że jest on bezcenny, nierozłączny ze zmianą, stanowi pewien wymiar świata materialnego i wiąże się z przemijalnością. Dlatego dzieli go na teraźniejszość, przeszłość i przyszłość. Z całą stanowczością stwierdza, że czas stworzył Bóg, który jednak znajduje się poza nim.

Zdaniem Kanta (Aforyzmy i cytaty łacińskie, 1999) czas i przestrzeń są apriorycznymi formami naszej zmysłowości. Mają one swoje źródło w podmiocie stosują się do wszystkich zjawisk. Czas i przestrzeń ukazują się nam w doświadczeniu jako średnie, bez doświadczenia stają się niczym.

Wg Newtona (Arystoteles, 1990) istnieje tylko jeden, uniwersalny i wszechobejmujący czas – płynie on w jednostajnym tempie i nic nie wywiera na niego wpływu. Jest więc absolutny i obiektywnie jednakowy w całym wszechświecie.

Wiele zmian w poglądach na czas wypowiedział A. Einstein wraz ze swoją teorią względności (Einstein, 2011). Oprócz samego pojęcia czasu, rozważenia wymaga także jego kategoria.

Powszechnie wyróżnia się czasy: absolutny, względny i biologiczny. Ten ostatni odzwierciedla biologiczne prawa natury i jest odporny na działania człowieka, towarzyszy mu od poczęcia, poprzez urodzenie aż do śmierci. Czas względny zależy od samego człowieka i zawsze kojarzy się z przeżyciami. Pewną jego odmianą jest wprowadzony przeze mnie czas psychologiczny. Jego czas trwania zależy od stanu napięcia psychologicznego i może być różny dla różnych osób a nawet grup osób. Klasycznym przykładem istnienia czasu psychologicznego jest końcówka meczu piłkarskiego, dla dwóch drużyn, z których jedna przegrywa a druga wygrywa. Dla tej pierwszej czas biegnie przerażająco szybko, dla drugiej zaś ślimaczo się wlecze. Podobnie jest z dwojgiem ludźmi w podróży przy korzystaniu z toalety. Osobie na zewnątrz czas dłuży się w nieskończoność, będącej w środku przemija szybko. Tak więc, ten sam absolutny czas może mieć charakter względny i zależy od stanu napięcia psychologicznego człowieka.

Niezależnie od kategorii, z czasem zawsze kojarzy się przemijanie. Stan przemijania odczuwa się w zależności od wieku i w miarę starzenia się następuje jego przyspieszenie. Dla potwierdzenia wyrażonej tezy podam kilka twierdzeń i myli, różnych autorów.

L. Jasińska wyraża pogląd, że „...większość młodych kobiet panicznie boi się czterdziestki, aby w wkrótce za nią zatęsknić”.

Paulo Coelho (Coelho, 2006) „… zawsze trzeba wiedzieć, kiedy kończy się jakiś etap w naszym życiu. Jeżeli uparcie chcemy w nim tkwić dłużej niż to konieczne, tracimy nadzieję i szansę poznania co przed nami”.

Rozwinięciem tej myśli jest stwierdzenie autora: „zbyt długo myśląc o marzeniach, tracisz czas na ich realizację”.

W chwilach bolesnych, wobec nieszczęśliwych wydarzeń, człowiek także odwołuje się do czasu, chcąc go zatrzymać a nawet cofnąć. Wiemy, że to jest niemożliwe. Wówczas uzyskujemy pocieszenie od przyjaciół, że czas goi rany. Odpowiedzią na to stwierdzenie jest przesłanie francuskie …”czas leczy nasze rany ale zmarszczki są bardziej uparte” (Aforyzmy, cytaty, złote myśli, 2011).

Na tle przytoczonych twierdzeń rodzi się pytanie: czy jubileusz jest powodem do radości czy smutku? Odpowiedź nie jest prosta ani jednoznaczna. Studiując wypowiedzi wielu filozofów wyrażam przekonanie, że nie należy bać się przemijania bo nie mamy na niego wpływu, natomiast nasz smutek rodzi się zawsze z czasu, który upływa a nie zostawia owocu. Dokonajmy więc bilansu osiągnięć naszego Jubilata aby odpowiedzieć na postawione wcześniej pytanie; smutek to czy radość?

Moja wiwisekcja w żadnym razie nie stanowi recenzji osiągnięć twórczych Profesora Szpryngiela. On jej już nie potrzebuje, jest z niej wyzwolony.

Dokładnie Jego osiągnięcia twórcze zna Jego własne środowisko lubelskie i będzie wyrażone w referacie Dziekana Marczuka. W moim wystąpieniu postać i osobowość „Mietka” chcę przedstawić z oddali, oczyma krakowskiego i krajowego środowiska. Dla odtworzenia człowieka, niezbędne są najważniejsze daty i liczby. Oto niektóre z nich. Urodził się 10.08.1943 roku w Łucku. Studia wyższe odbył w latach 1963-68 na Wydziale Rolniczym ówczesnej Wyższej Szkoły Rolniczej w Lublinie. Następnie kontynuował studia doktoranckie na Wydziale Techniki Rolniczej, uwieńczone stopniem doktora nauk technicznych, uzyskanym w roku 1975.

Stopień doktora habilitowanego w zakresie techniki rolniczej nadała mu ta sama Rada Wydziału w roku 1991. Tytuł profesora nauk rolniczych na wniosek tejże Rady uzyskał w roku 1999. Od roku 2004 został zatrudniony na stanowisku profesora zwyczajnego.

W latach 1996-2013 pełnił funkcję kierownika Katedry Eksploatacji Maszyn i Zarządzania w Inżynierii Rolniczej. W międzyczasie pełnił także funkcję prodziekana

(1993-1999) oraz dwukrotnie dziekana. Ze szczególnym sentymentem wspominam Jego dziekaństwo, gdyż w trakcie Jego kadencji (2000 r.) dostąpiłem zaszczytu wyróżnienia tytułem doktora h.c. lubelskiej Uczelni.

Fot. 1. Uroczyste wręczenie dyplomu doktora h.c. lubelskiej Uczelni prof. dr hab. Rudolfowi Michałkowi

Uzyskany w krajowym środowisku inżynierii rolniczej autorytet był podstawą wyboru do Komitetu Techniki Rolniczej PAN, a także do Klubu Seniora Mechanizacji Rolnictwa. Prof. Mieczysław Szpryngiel wyróżniał się także aktywną działalnością społeczną w organizacjach i towarzystwach naukowych m.in. w ZNP, SIMP, PTA, PTIR w szczególności zaś w LOK. Ta ostatnia uhonorowała Go licznymi medalami i wyróżnieniami.

Profesor Szpryngiel pozostawia po sobie poważny dorobek naukowy. Obejmuje on łącznie ponad 200 pozycji, w tym oryginalnych prac opublikowanych 90, patentów i wzorów użytkowych 20, skryptów i podręczników 5. Wypromował czterech doktorów, 57 magistrów i 18 inżynierów. Był recenzentem w 12-tu przewodach na tytuł i stopnie naukowe (Praca zbiorowa, 2010).

Jego zainteresowania naukowo-badawcze skupiły się na zagadnieniach:

- technologie kombajnowego zbioru roślin niezbożowych, głównie traw nasiennych i rzepaku,
- niekonwencjonalne źródła energii w rolnictwie, w tym elektrownie wietrzne i kolektory słoneczne, co najważniejsze w pełnym cyklu rozwojowym,
- testowanie i doskonalenie prototypów maszyn i urządzeń rolniczych

Fot. 2. Badania polowe prowadzone przez prof. M. Szpryngiela

Fot. 3. Największa pasja prof. M. Szpryngiela

Opisując postać naszego Jubilata koniecznym jest zwrócenie uwagi na Jego wielostronne zainteresowania pozazawodowe, czemu dałem wyraz w tytule artykułu. Jest człowiekiem utalentowanym wszechstronnie o ogromnych zdolnościach naukowych nie tylko w sensie wykonawczym ale także kreatywnym. Dawniej taką osobowość nazywano „złotą rączką”. Lista pasji twórczych jest długa, wymienię najważniejsze:

– wojskowość i militaria,
– myślistwo,
– modelarstwo,
– żeglarstwo,
– majsterkowanie,
– muzyka w sensie wykonawczym.

W całym środowisku inżynierii rolniczej był i jest projektantem i wykonawcą medali jubileuszowych i odznaczeń. Wszystko wykonuje z pasją i bezinteresownie. Jego dewizą życiową jest dawanie. Jako Dziekan Wydziału Techniki Rolniczej odegrał istotną rolę w rozwoju kadry naukowej dla całego krajowego środowiska.

Pomimo ogromnego obciążenia pracę zawodową i społeczną a także realizując swoje pasje życiowe, zawsze znajdował czas dla Rodziny. Jego związek małżeński z Celiną zawsze był wzorem dla nasz wszystkich. Jest ojcem dwóch córek i syna, a potomstwo Jego uczyniło Go dziadkiem 5 wnuczek i 3 wnuków.

Fot.4. Rodzina prof. dr hab. Mieczysława Szpryngiela

Razem tworzą zgraną i wzajemnie kochającą się rodzinę. Dzieci odziedziczyły po Ojcu talent artystyczny i wspólnie komponują piękne utwory i ozdoby świąteczne. W ostatnim konkursie telewizyjnym ich cerkiewka w opinii telewidzów została uznana za najpiękniejszą.

Czas jednak płynie a z nim odchodzą jedne obowiązki a na ich miejsce przychodzą nowe, inne ale ważne. Naszemu Jubilatowi, Rodzina ale też całe nasze środowisko inżynierii rolniczej nie pozwolimy wypoczywać. Corocznie któryś z ośrodków obchodzić będzie swój jubileusz i zapewne zechce upamiętnić go okolicznym medalem. Jestem przekonany, że „Mietek" nie odmówi pomocy. Całym życiem pokazał, że wszystko robi bezinteresownie z potrzeby rozwoju własnych pasji twórczych. Choć za swoją działalność społeczną został odznaczony i wyróżniony licznymi odznaczeniami, wyróżnieniami i nagrodami, to w moim przekonaniu nie są one proporcjonalne do zasług. Najwyższe przecież odznaczenie, jakie posiada, czyli Krzyż Kawalerski, przyznawano każdemu profesorowi, zgodnie z kartą nauczyciela, czyli za starość. Trzeba jednak przyznać, że „Mietek" szczególnie ceni sobie odznaczenie wojskowe i „LOK-owskie". Zauważyłem to, bowiem miałem kiedyś zaszczyt i przyjemność być razem z Nim odznaczonym.

Przytoczone fakty i liczby wydają się wystarczająco potwierdzać, że nasz Jubilat nie musi bać się przemijania. Upływający czas został przez Niego należycie i wszechstronnie wykorzystany, przynosząc obfite plony w wymiarze wielostronnym. Jego osiągnięcia, będą trwałym śladem i nie przeminą z czasem.

Nie bój się więc odchodzić z czynnej służby. Z własnego doświadczenia mogę Cię zapewnić, że odchodzisz, choć nie do końca, we właściwym momencie. Współczesne zarządzanie nauką pozbawia twórców najważniejszego atrybutu – komfortu psychologicznego. Dziś obowiązuje pościg za punktami, cytowaniami i listą filadelfijską, bo to daje awans.

Pamiętajmy jednak, że z najwyższej piramidy punktów nie zbudujemy nowoczesnej gospodarki i ludziom nie będzie się żyć dostatniej. Za to rosnąć będą antagonizmy i niezdrowa konkurencja a najzdolniejsi polscy twórcy będą budować obce mocarstwa.

Mietku, zapamiętaj, że nadzieja umiera jednak ostatnia.

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OD INŻYNIERII ROLNICZEJ DO INŻYNIERII BIOSYSTEMÓW – EWOLUCJA ZMIAN W BADANIACH I DYDAKTYCE. ZMIANY W NAUCZANIU JĘZYKÓW OBCYCH W ŚWIETLE POSTANOWIEŃ DEKLARACJI BOLOŃSKIEJ

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Metody kształcenia a co za tym idzie programy studiów, ulegają modyfikacjom lub czasami rewolucyjnym przebudowom w zależności od przemian ustrojowych i/lub potrzeb rynkowych. O opinię na ten zmian jakie nastąpiły w okresie ostatnich 50 lat chciałabym zapytać Pana Profesora Rudolfa Michałka, dwukrotnego Dziekana Wydziału Techniki i Energetyki Rolnictwa byłej Akademii Rolniczej, obecnie Uniwersytetu Rolniczego w Krakowie jak też i wybitnego naukowca z zakresu ekonomiki, organizacji, mechanizacji i energochłonności produkcji rolniczej.

Elżbieta Kloc: Panie Profesorze, czy jest Pan za rewolucją czy ewolucją na uczelniach wyższych?

Profesor Rudolf Michałek: Właściwie to teraz zaskoczyła mnie Pani tym pytaniem dlatego, że chciałbym sięgnąć w głąb czyli historię, która pokazuje, że nie była to rewolucja a ewolucja. Ja jestem przeciwnikiem rewolucji, która wiąże się z czymś krwawym, wojowniczym. Jestem za ewolucją i tak samo jestem za ewolucją, która dokonuje się w inżynierii rolniczej.

Elżbieta Kloc: Przejdźmy teraz do maszynoznawstwa rolniczego. Propagowanie wiedzy na temat zastosowania maszyn rolniczych w produkcji roślinnej ma swoją długą tradycję zapoczątkowaną przez księdza Krzysztofa Kluka w 1779 roku i Dezyderego Chłapowskiego, na terenie Wielkopolski (Michałek i Kowalski, 2002). Jak wyglądały początki tego kształcenia w Polsce?

Profesor Rudolf Michałek: Podała Pani w pytaniu dwóch prekursorów**.** Właściwie ksiądz Kluk nie był prekursorem samej inżynierii rolniczej, ale naukowcem z zakresu agronomii, który zwracał uwagę na najprostsze metody jakie stosowano przy uprawie roślin. Bardziej za prekursora od strony inżynierii rolniczej bym uznał Dezyderego Chłapowskiego, wykształconego w Anglii, który zaczął wdrażać nowe rozwiązania w Wielkopolsce i uruchomił pierwszą fabrykę maszyn rolniczych, która dała początek całemu przemysłowi maszyn i ciągników rolniczych. Początek zinstytucjonalizowanego kształcenia rolniczego to rok 1818 – Instytut Agronomiczny w Marymoncie, następnie Uniwersytet Wileński, a dalej Wyższa Szkoła Rolnicza w Dublanach w 1871 roku.

Elżbieta Kloc: Jak wyglądały początki kształcenia rolniczego w Krakowie?

Profesor Rudolf Michałek: W Krakowie zaczęły się od utworzenia Katedry w ramach Wydziału Filozoficznego Uniwersytetu Jagiellońskiego. W 1890 przy Wydziale Filozoficznym powołano do życia Studium Rolnicze. Prekursorem maszynoznawstwa w Krakowie był profesor Tadeusz Michał Gołogórski. W 1923 roku Studium Rolnicze przekształciło się w samodzielny Wydział Rolniczy Uniwersytetu Jagiellońskiego. W czasie wojny trwało tajne nauczanie. W roku 1953 wyłączono rolnictwo ze struktur uniwersyteckich. Powstała Wyższa Szkoła Rolnicza. W ramach Wydziału Rolniczego była Katedra Maszynoznawstwa z dwoma zakładami: Maszynoznawstwo Rolnicze kierowane przez profesora Michała Wójcickiego i Zakład Inżynierii rozumiany jako melioracja i geodezja pod kierownictwem profesora Franciszka Hendzla.

Elżbieta Kloc: Jakie zmiany zaszły w programach nauczania maszynoznawstwa od momentu usamodzielnienia się naszej uczelni?

Profesor Rudolf Michałek: Do 1962 roku nauczano przedmiotu maszynoznawstwo rolnicze, który obejmował budowę i eksploatację maszyn ze szczególnym uwzględnieniem maszyn i urządzeń do produkcji rolniczej. W 1962 przedmiot zmienił nazwę na mechanizację rolnictwa wnosząc do programów nauczania elementy organizacji i ekonomiki. W dalszym ciągu jednak kształcono rolników i zootechników a nie inżynierów rolnictwa.

Elżbieta Kloc: Kiedy więc zaczęło się kształcenie inżynierów rolnictwa?

Profesor Rudolf Michałek: W 1972 na skutek nacisków politycznych i wytycznych w kierunku powstawania dużych gospodarstw państwowych i koncentracji ziemi. Osobiście byłem wtedy przeciwny wyodrębnieniu tego kierunku studiów gdyż nasza uczelnia nie posiadała wystarczającej kadry naukowej – zaledwie trzech docentów bez habilitacji. W Krakowie kierunek ten powstał jako ostatni, po Warszawie i Lublinie. Ośrodek lubelski był najbardziej prężnym ośrodkiem mechanizacji rolnictwa pod kierownictwem profesora Janusza Hamana, absolwenta Akademii Górniczej i studiów rolniczych w Krakowie.

Elżbieta Kloc: W którym roku powstał samodzielny Wydział Techniki i Energetyki Rolnictwa?

Profesor Rudolf Michałek: W 1977. W tym czasie kadra naukowo-dydaktyczna składała się z trzech osób po habilitacji w tym jednego profesora, który został też pierwszym dziekanem. Był to profesor Ryszard Gąska. Do wydziału dołączono również Katedrę Melioracji i Mechanizacji Prac Wodno-Melioracyjnych kierowaną przez profesora Władysława Balę i Zakład Maszynoznawstwa Leśnego pod kierownictwem docenta Bolesława Wachackiego.

W momencie tworzenia studiów nie mówiło się już o mechanizacji rolnictwa a o technice rolniczej, która jest rozumiana jako zespół wszystkich środków trwałych będących na usługach rolnictwa w powiązaniu z organizacją i elementami ekonomiki. Następny krok w rozwoju to ewolucja techniki rolniczej w kierunku inżynierii rolniczej z silnymi akcentami zarządzania, ekonomiki i organizacji oraz dalszemu pogłębianiu i poszerzaniu zakresu i tematyki nauczania.

Elżbieta Kloc: Jakie trendy w nauczaniu inżynierii rolniczej obowiązują obecnie?

Profesor Rudolf Michałek: Rolnictwo daje tylko 1 procent dochodu narodowego i wszystko co rolnicze jest niemodne. W Polsce został tylko jeden Uniwersytet Rolniczy w Krakowie. Pozostałe zmieniły nazwę na uniwersytety przyrodnicze. Czy jest to poprawna nazwa? Nie, bo nauki przyrodnicze to przede wszystkim chemia, fizyka i biologia, które są domeną uniwersytetów, tzw. starych. Profil rolniczy jest inny od przyrodniczego, bo łączy elementy nauk przyrodniczych, technicznych i ekonomicznych. Sprawa nazewnictwa dotyczy też kierunków studiów. Nasz wydział również przekształcił się w Inżynierię produkcji.

Jakiej? Budowlanej, transportowej, przemysłowej? Nie. Ciągle rolniczej, ale znów chodziło o wyeliminowanie słowa „rolniczy". Teraz uczelnie idą jeszcze dalej i chcą kształcić w kierunku inżynierii biosystemów.

Elżbieta Kloc: Sądzę, że jest to związane ze spadkiem zainteresowania studentów tradycyjnym kierunkiem inżynieria rolnicza. Większość uniwersytetów na świecie ewoluuje w kierunku inżynierii biosystemów, która jest rozumiana jako „nauka lub nauczanie integrujące nauki techniczne i projektowanie z biologią stosowaną, naukami o środowisku i naukami rolniczymi" (Scarascia i in., 2010), „podkreśla również zastosowanie inżynierii do rozwiązywania problemów związanych z systemami biologicznymi takimi jak rolnictwo, produkcja żywności i biomasy" (Briassoulis i Papadiamandopoulou, 2001).

Profesor Rudolf Michałek: Dziekani przyjęli, że taki kierunek będzie atrakcyjny dla kandydatów i nowoczesny. Ja mam jednak wiele zastrzeżeń do terminu biosystem, gdyż „bio" oznacza wszystko co dotyczy przyrody ożywionej czyli rośliny, zwierzęcia i gleby bo w glebie części mineralne zajmują objętościowo mniej niż organiczne czyli cała mikroflora. Ale inżynieria rolnicza to nie tylko „bio", bo cała infrastruktura techniczna nie ma nic wspólnego z „bio". Proponuję zamiast „bio" dać w nazwie „agro", czyli to co jest „bio" plus infrastruktura techniczna, ekonomiczna i dlatego jestem za „agro", ale jak już wspomniałem jest to niemodne.

Elżbieta Kloc: Czyli Pan Profesor proponowałby nazwę inżynieria agrosystemów zamiast inżynierii biosystemów. Inżynieria biosystemów to bez wątpienia kierunek interdyscyplinarny. Czy według Pana Profesora taka interdyscyplinarność nauczania jest krokiem we właściwym kierunku?

Profesor Rudolf Michałek: Powiem szczerze, że jakbym potrzebował dobrego technika do rolnictwa to bym wziął po politechnice, bo nasi są za słabi z kierunków ścisłych. Czy oni są z rolnictwa dobrzy? Też nie, bo oni w ogóle tej tematyki nie mają. Czyli jest to trochę taki sztuczny twór.

Elżbieta Kloc: Interdyscyplinarność jest dzisiaj uważana za niezwykle nowoczesne podejście do kształcenia.

Profesor Rudolf Michałek: Tak, ale absolwenci nie mają głębokiej wiedzy z żadnej dziedziny. Nie mają ani dobrych podstaw biologicznych, ani technicznych. Nie jestem za takim profilem nauczania, bo nie kształci tak naprawdę specjalistów w żadnej dziedzinie. I oczywiście jak wielu z nich wybiera sobie swoją działkę badawczą, to muszą się uczyć sięgać do źródeł i oni są do tego przygotowani np. na naszym kierunku coraz mocniejszy jest kierunek dotyczący odnawialnych źródeł energii. Ja to widzę jako wielką przyszłość dla wydziału, bo póki co ani AGH, ani nauki techniczne nie zajmują się tą tematyką.

Elżbieta Kloc: Panie Profesorze, jest Pan również specjalistą od metodologii i organizacji badań naukowych, a Pana książka pt. „Uwarunkowania naukowego awansu w inżynierii rolniczej" jest unikatem w skali kraju. Kiedy zdecydowano się na wprowadzenie metodologii i organizacji badań naukowych do programów studiów?

Profesor Rudolf Michałek: Zacznijmy od genezy. Przedmiot metodologia badań naukowych został wprowadzony w 1972 w trzech ośrodkach akademickich: Lublinie, Warszawie i Krakowie. W Lublinie prowadził go profesor Haman, w Warszawie profesor Pabis a w Krakowie ja.

Elżbieta Kloc: O ile się orientuję Wydział Produkcji i Energetyki jest jedynym wydziałem na naszej uczelni, na którym przedmiot ten jest wykładany. To jest chyba jakieś przeoczenie w programach studiów, bo ten przedmiot powinni mieć wszyscy studenci naszej uczelni.

Profesor Rudolf Michałek: Tak. Przedmiot ten jest wprowadzany dopiero na studiach doktoranckich.

Elżbieta Kloc: Trochę za późno….

Profesor Rudolf Michałek: Tak, za późno.

Elżbieta Kloc: Jak zmieniła się metodyka pracy naukowej od momentu kiedy Pan Profesor zaczął swoją pracę na ówczesnej Wyższej Szkole Rolniczej?

Profesor Rudolf Michałek: Jeśli chodzi o sam sens badań, to on się nie zmienił. Zawsze nauka rozwiązywała problemy naukowe, a więc wypełniała lukę tam gdzie był określony stan niewiedzy. Wejściem do każdych badań naukowych jest postawienie i uzasadnienie problemu. Problem naukowy uzasadnia się na podstawie literatury. Zasadniczy przełom na tym etapie dokonał się poprzez dostęp do Internetu. Internet to jest rewolucja. A drugi etap pracy to jest przyjęcie metody i znów do tej metody mamy dostęp poprzez Internet. Jak chcę badania prowadzić to potrzebuję aparaturę. Za pomocą Internetu dowiem się kto, gdzie i jaką aparaturą dysponuje w Polsce czy za granicą. Opracowanie wyników następuje dziś przy użyciu programów komputerowych, więc i tu dokonał się olbrzymi przełom.

Elżbieta Kloc: Ja bym tu dodała jeszcze jeden istotny element badań naukowych – znajomość języka obcego. Kiedyś badania naukowe przeprowadzane były głównie w oparciu o literaturę rosyjską.

Profesor Rudolf Michałek: Tak, choć w inżynierii rolniczej był to głównie język niemiecki, którego sam zacząłem się intensywnie uczyć przed habilitacją.

Elżbieta Kloc: Obecnie mamy jednak do czynienia z hegemonią języka angielskiego. Właściwie jeżeli nie zna się biegle języka angielskiego to bardzo trudno być na bieżąco z literaturą naukową i czynnie uczestniczyć w międzynarodowym życiu naukowym.

Profesor Rudolf Michałek: Cały świat przeszedł obecnie na język angielski, nawet Chiny. Co spowodowało taką zmianę? Internet i komputeryzacja, informatyka.

Elżbieta Kloc: Deklaracja Bolońska z 1999 roku kładzie olbrzymi nacisk na współpracę międzynarodową uczelni wyższych zarówno na poziomie studentów jak też i naukowców. Jak obecnie wygląda ta współpraca na wydziale Inżynierii Produkcji i Energetyki?

Profesor Rudolf Michałek: Jeśli chodzi o kształcenie obcokrajowców to Polska jest na szarym końcu krajów europejskich – mamy zaledwie 1% studentów z innych krajów. U nas na wydziale mamy 5 Ukraińców, 3 Turków (którzy zazwyczaj studiują przez 1 semestr), paru Nigeryjczyków i pojedyncze przypadki studentów w ramach programu ERASMUS.

Elżbieta Kloc: Część wydziałów prowadzi również wykłady w języku angielskim. Czy pracownicy Wydziału Inżynierii Produkcji i Energetyki prowadzą takie wykłady?

Profesor Rudolf Michałek: U nas prowadzi takie wykłady około dziesięciu osób.

Elżbieta Kloc: Na ile istotna jest dzisiaj międzynarodowa współpraca naukowa?

Profesor Rudolf Michałek: Jest ona konieczna gdyż rozwój nauki nie może się odbywać w zamknięciu. Nauka jest światowa i rozlewa się na zasadzie naczyń połączonych i współpracy naukowej, która jest niemożliwa bez znajomości języka obcego, a głównie angielskiego.

Elżbieta Kloc: Jak Pan Profesor widzi miejsce nauczania języków obcych w naszej uczelni w świetle postanowień Deklaracji Bolońskiej dążącej do umiędzynarodowienia studiów?

Profesor Rudolf Michałek: Jak byłem dziekanem chciałem, aby lektorzy języków obcych byli przypisani do wydziałów i nauczali terminologii. Myślę, że to dobry pomysł.

Elżbieta Kloc: Bardzo się cieszę, że Pan Profesor tak to widzi, gdyż ja też uważam, że wśród lektorów również powinna być specjalizacja w zakresie terminologii i języka specjalistycznego. Obecne programy nauczania zakładają tylko120 godzin języka obcego na I stopniu studiów co stanowi minimum programowe. Jednocześnie tylko dwa wydziały tj. Wydział Ogrodniczy oraz Hodowli i Biologii Zwierząt zaplanowały 30 godzin lektoratu poświęconego nauczaniu języka i terminologii specjalistycznej. Co według Pana Profesora leży u podstaw takich decyzji na I i II poziomie kształcenia?

Profesor Rudolf Michałek: Ja uważam, że uczeń po maturze, który przychodzi do szkoły wyższej powinien mieć opanowany język obcy.

Elżbieta Kloc: Ale nie język specjalistyczny….

Profesor Rudolf Michałek: Studia Języków Obcych powinny być ukierunkowane na język fachowy. Jestem przeciwnikiem dużych grup. Grupa językowa to powinno być 5 osób.

Elżbieta Kloc: Bardzo dziękuję za rozmowę**.**

Zmiany w nauczaniu języków obcych w świetle postanowień Deklaracji Bolońskiej oraz nowych wyzwań przed jakimi stoją uczelnie wyższe – zdaniem lektora języka angielskiego.

Młodzież przychodząca obecnie na studia wyższe reprezentuje z roku na rok coraz lepszą ogólną znajomość języka obcego, jednakże biegłość w posługiwaniu się nim daleka jest od ideału, za co można winić obecny kształt matury z języka obcego, która dodatkowo, jest zdawana przez większość uczniów na poziomie podstawowym.

Aby umożliwić młodzieży uczestniczenie w Europejskim Obszarze Szkolnictwa Wyższego (Deklaracja Bolońska; Szkolnictwo Wyższe w Europie, 1999) w formie wymian i współpracy studentów, jak również rzetelne korzystanie z literatury naukowej w języku angielskim, będącym obecnie językiem nauki, koniecznym wydaje się przeprofilowanie nauczania języka obcego na uczelniach wyższych w kierunku nauczania języka i terminologii fachowej. Zajęcia takie powinny się odbywać na wszystkich trzech etapach kształcenia, jednakże ich zakres powinien się znacznie różnić.

Na pierwszym stopniu kształcenia akademickiego nauka języka powinna się koncentrować na wyrównywaniu ewentualnych braków ze szkoły średniej z zakresu języka ogólnego uzupełnionych o elementy nauczania podstaw języka specjalistycznego. Poświęcanie całego lektoratu na język fachowy mija się z celem, gdyż student na tym etapie kształcenia nie posiada wiedzy fachowej w języku ojczystym umożliwiającej mu efektywne korzystanie z zajęć w języku obcym. Reasumując, rzetelna nauka języka specjalistycznego jest możliwa dopiero na studiach magisterskich uzupełniających, gdyż wówczas student staje się pełnoprawnym i pełnowartościowym współuczestnikiem procesu dydaktycznego. Co więcej często służy on pomocą lektorom w wyjaśnianiu zawiłości przedmiotu zawodowego. Na takiej współpracy korzystają obie strony – lektorzy i studenci, którzy mogą się od siebie wzajemnie wiele nauczyć. Studenci są nieocenionym źródłem polskich ekwiwalentów obcojęzycznej terminologii fachowej, których często na próżno jest szukać w dostępnych słownikach. Należy również dodać, że znajomość obcojęzycznej terminologii przez studentów jest także dużym ułatwieniem dla pracowników naukowych prowadzących wykłady w języku obcym, gdyż student w nich uczestniczący nie boryka się już z nie znanym obcojęzycznym słownictwem, a może się skupić na merytorycznej stronie wykładu.

Niestety tylko nieliczne wydziały ujmują lektoraty z języków obcych w programach nauczania na studiach magisterskich i nawet te, które to robią, przeznaczają na nie zaledwie 30 godzin dydaktycznych, co w żadnym stopniu nie pozwala na szczegółowe zapoznanie się z terminologią fachową oraz jej utrwalenie. Z mojego doświadczenia zawodowego wynika, że aby taki kurs przyniósł wymierne korzyści w postaci lepiej wykształconego i konkurencyjnego na międzynarodowym rynku pracy absolwenta, konieczne jest poświęcenie 60 godzin dydaktycznych na zapoznanie się z językiem specjalistycznym. Co więcej, zajęcia takie powinny odbywać się w małych (maksimum do 15 osób) grupach i kończyć się egzaminem. Sądzę również, że uczelnia mogłaby wydawać odpowiednie certyfikaty o ukończeniu kursu o takiej tematyce a także umożliwić eksternistyczne zdawanie egzaminu dla osób zainteresowanych.

Na trzecim etapie kształcenia, czyli na studiach doktoranckich nauczanie języka ma zupełnie inny cel, gdyż koncentruje się ono się na jego aspekcie naukowym, umiejętności nie tylko biernego zrozumienia tekstu, ale przede wszystkim wykształceniu umiejętności logicznej i spójnej wypowiedzi według standardów anglosaskich ogólnie przyjętych jako obowiązujące w międzynarodowym świecie naukowym. Wypowiedź ta przyjmować może zarówno formę pisemną jak i ustną w postaci artykułu naukowego, streszczenia, referatu, prezentacji czy przygotowanie posteru. Nauczanie języka na studiach doktoranckich zwraca również uwagę na istotność w miarę poprawnej wymowy podając źródła i słowniki jak też i literaturę anglojęzyczną poświęconą pisaniu prac naukowych. Ostatnim ważnym komponentem kursu jest również dalsze pogłębianie słownictwa w wąskiej, interesującej studenta dziedzinie naukowej.

Reasumując, nauczanie języków obcych na uczelniach wyższych jest niezwykle istotne w nowej, zjednoczonej Europie, oferującej młodym ludziom możliwości o jakich nie mogły marzyć poprzednie pokolenia. Zadaniem uczelni wyższych jest umożliwienie korzystania z istniejących szans, poprzez rzetelne wykształcenie, które sprawi, że nasi absolwenci będą postrzegani jako jedni z najlepszych fachowców w swojej dziedzinie, dla których znalezienie interesującej pracy w międzynarodowych korporacjach nie będzie stanowić problemu. Szanse takie mogą być jednak łatwo zaprzepaszczone, jeżeli absolwent nie będzie w stanie biegle się posługiwać obcojęzycznym językiem specjalistycznym.

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