The analysis of the influence of initial processing of oat caryopses on the course and energy consumption of the flaking process

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S u m m a r y. The paper presents results of measurements of the energy consumption flaking process of dehulled oat grains depending on the method and parameters of moistening and moisture content. Measurement of energy consumption was determined according to the methodology at the different working gap size. The energy consumption of flaking process depends on the size of the working slot crusher. Its highest value was recorded at flaked grains at the working gap A_1= 0.1 mm. However, differences in power changes between the slits A_1 = 0.1 mm and A_2 = 0.2 mm ranged from 6% (for samples of moisture content M_5 = 18%), up to 32% (for dry grain M_1 = 10%). The most preferred method is moistening oats grain by the steam for less energy consumption in the flaking process. Regardless of the assumed initial moisture content, the lowest power values for their flaking were obtained for the samples moisted by steam for the time t_1 = 5 min.

K e y w o r d s: energy consumption, flaking, oat grain, hydrothermal treatment.

INTRODUCTION

In the processing of cereal resources, especially grits cereals, one of the most important issues is the knowledge of the application of hydrothermal procedures. They constitute the foundation for the initial grain processing before dehusking or flaking 4;7;14;15. A particularly important role, especially in the production of grits, breakfast flakes and the so-called breakfast cereal products, is played by different methods of conditioning grain and seeds [2, 3, 5, 12]. These procedures to a large extent influence both the course and the efficiency of processing, as well as trigger a range of changes in physical properties of the processed resources. As the final result, both factors determine the quantity and the consumption quality of ready-made cereal products or semi-products [12, 11, 10, 6].

Contrary to conditioning applied in the milling industry, which has been a scientific issue for a long time, the subject matter of research and practice of further use of hydrothermal processing procedures in the production of grits, breakfast cereals or preparation of cereal products have been the subjects of intense research only since the last decade. The research brings about higher interest in this subject matter and progress in scientific research and utilitarian experiments, which are aimed at finding wider possibilities of the application of cereal resources in the food industry [1, 8, 11, 17].

Although these processes are known and applied in processing cereal into flour, in the processing of grain and seeds into low-processed cereal products (except for highly-processed products which are produced with the use of methods of pressure agglomeration) they are only known in fragmentary studies mainly devoted to selected cereal and seeds of none-cereal plants. The application of these processes to a randomly selected resource in strictly defined conditions allows for achieving favourable changes in its physical properties, which is especially important in processing procedures. The group of more important properties includes structural-mechanical properties, whose properly directed alternation by hydrothermal processing is one of the basic tasks in preparatory processes of grain which undergo subsequent processing operations in cereal-milling and fodder industries. It particularly concerns preparing grain for grinding, dehusking and flaking processes or recently popular methods of the so-called preparation of grain and seeds [10, 11, 18, 14, 15]. It should be stressed that the application of a given method of hydrothermal processing and selection of its technological parameters (particularly the range and sequence of the procedure) are often the most important secrets of all eminent companies which process cereal resources. It results, among others, from the fact that these are complex processes, in which the influence and the scope of interactions of individual factors are interconnected and interrelated. Experiments within the scope of processing of cereal resources indicate that their adequate preparation, which consists in achieving technological features which would be close to the optimum for a given process is as important (or even the most important), as the correct determination of parameters for proper processing, including the process of flaking [13, 2, 4].

THE AIM AND SCOPE OF THE RESEARCH

The primary aim of the research was to measure energy expenditures of the process of flaking in relation to the final moistness of dehusked oat grain, changing parameters of its moistening with water and steam, and the working aperture of the grinding machine. The scope of the influence of the final moistness and selected methods of hydrothermal processing of oat caryopses were defined in relation to energy expenditures and work which was necessary for the execution of the process of flaking. The detailed scope of the research included preparation of the resource for the research, which consisted in separating the medium fraction and additional moistening of the resource with water and steam, as well as measuring energy consumption of the process of caryopses flaking with different working apertures of the grinding machine. The achieved research results were statistically processed.

RESEARCH METHODOLOGY

For the purposes of the research dehusked oat caryopses - variety Jantar were used, after the process of dehusking these were sorted in a sieve sifter, in which the holes had a longitudinal shape with the following sizes: 3.0x3.25 mm (upper sieve), and 1.8x2.25 mm (lower sieve). The initial moistness of caryopses was M=10%. Caryopses prepared in this manner were processed hydrothermally, which involved:

a) additional moistening with water leading to five levels of final moistness (M_1=10%, M_2=14%, M_3=18%, M_4=22% and M_5=26%) [PN-91/A-74010] [16];
a) moistening caryopses with steam with differentiated levels of initial moistness within the range M_{i1}=10%, M_{i2}=12%, M_{i3}=14%, M_{i4}=16% and M_{i5}=18%.

The time of caryopses processing with steam was t_1=5 min, t_2=10 min and t_3=15 min.

After conducting hydrothermal procedures, samples of caryopses which were additionally moistened to reach particular levels of final moistness, went through the process of grinding in the grinding machine with smooth rollers. The working apertures of the grinding machine were A_1=0.1 mm, A_2=0.2 mm and A_3=0.3 mm. During the process of flaking the measures of energy consumption in relation to the method of conditioning, final moistness of caryopses and the applied aperture in the grinding machine were conducted.

THE TEST STAND AND THE MEASUREMENT OF ENERGY CONSUMPTION OF THE FLAKING PROCESS

The measurement of energy consumption of the flaking process was conducted for two groups of the resource, i.e. caryopses additionally moistened with water and caryopses additionally moistened with steam. Processing with steam was carried out in a laboratory roaster-mixer, applying the pressure of steam p_s=0.28 MPa.

Following the process of moistening with steam, the grain was placed in a hermetic container and seasoned for 30 minutes. The samples prepared in this way, which weighed 1 kg, underwent the process of flaking at the laboratory test stand, which consisted of a grinding machine, an inverter, and a computer with software and equipment (Fig. 1).

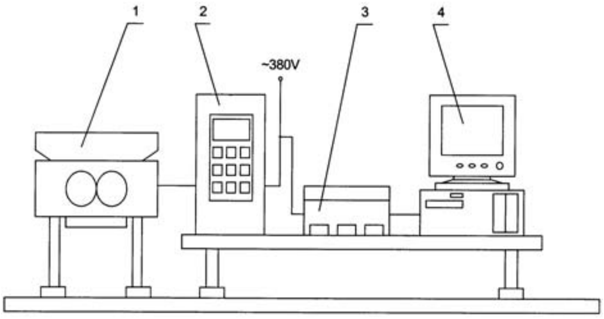


Fig. 1. A schematic of the stand for measuring energy consumption of the flaking process of grain resources: 1-grinding machine, 2-inverter, 3-power converter type Lumel PP83, 4-computer with a PCL-711B card

The process of flaking was carried out in a grinding machine "Tytan" H-759 adjusted to laboratory research, powered by a 2.2 kW engine with rated voltage of 380V, current rating of 5.2 A and power coefficient of 0.82. The working parts of the grinding machine were 2 smooth rollers with the diameter of 240 mm and the width of 50 mm. The circumference velocity of the rollers was 0.252 m×min^{-1}. Smooth and seamless feeding of the working aperture of the grinding machine with the resource was done thanks to a belt conveyor with the capacity of 40 g s^{-1}. After the start up of the grinding machine and stabilising its operation, the feeding conveyor (belt conveyor) and the computer with the power converter, which recorded the values of energy consumption necessary for grinding a sample of 1 kg grain, were turned on at the same time. The measurement was conducted during five repetitions for a given moistness and method of moistening resources. The arithmetic mean achieved after 5 repetitions was assumed as the result.

RESULTS OF THE RESEARCH AND THEIR ANALYSIS

The achieved research results indicated the complex character of correlations between parameters of hydrothermal processing of caryopses and energy consumption of the flaking process. It was ascertained that differentiated levels of grain moistness, hydrothermal processing and the working aperture of the grinding machine influenced both the technological value of the resource

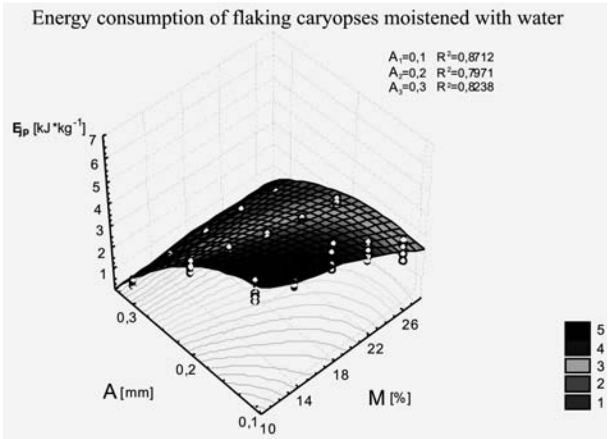


Fig. 2. The range of changes in energy consumption of the flaking process of caryopses which were moistened with water in relation to varied levels of moistness and the working aperture of the grinding machine A From the analysis of the achieved research results, which illustrate a complex pattern of connections and interrelations which occur between the conditions and parameters of oat grain moistening, flaking processes and energy consumption of these processes, it results that the variant closest to the optimum seems to be the moistening of the resource with steam for the period t_2=10 min and working aperture of the grinding machine A_2=0.2 mm

and the course of the flaking process, as well as energy consumption of flaking. The biggest influence on energy consumed for flaking was ascertained in relation to the size of the working aperture of the grinding machine. In the case of caryopses moistened with water the highest value was recorded during flaking caryopses with the working aperture A_1=0.1 mm and A_2=0.2 mm (Fig. 2). The differences in the scope of energy consumption between apertures A_1=0.1 mm and A_2=0.2 mm fluctuated from 6% (for samples with moistness M_5=18%), to 32% (for dry caryopses M=10%). For these two working apertures the value of energy consumption for grinding caryopses decreased together with an increase in their moistness. The only exception is grinding caryopses with the working aperture A_3=0.3 mm, where the lowest energy consumption, which was measured for the same level of moistness of the resource under research, was recorded.

A more favourable way, different from moistening caryopses with water before flaking, which leads to significant decrease in energy expenditures during flaking turned out to be the method of hydrothermal processing under differentiated conditions including different levels of initial moistness of the resource and time of moistening the resource with steam (Fig. 2).

The presented research results indicate that the time of moistening the grain with steam in a significant way influences the value of energy expenditures for the execution of the process of flaking, while similarly to grain moistened with water, the scope and character of changes of this parameter is reflected by complex parametric interrelations. The lowest energy demand for flaking was recorded for the variant in which the grain was moistened with steam for the period t_3=15 min and grinded in the working aperture A_2=0.2 mm and A_3=0.3 mm. In this case the demand for energy, depending on the initial moistness of the grain before steaming fluctuated within the range *8.13-8.70 kJ *kg*$^{-1}$ (for A_2=0.2 mm) and *7.85-8.13* kJ*kg^{-1} (for the aperture A_3=0.3 mm) (Fig. 3b and c). As compared to the shortest moistening time t_1= 5 min, the demand for energy for the same sizes of the working aperture A_2=0.2 mm and A_3=0.3 mm, taken at different levels of initial moistness was *12.68-18.11 kJ*kg*$^{-1}$ *and 9.21-13.22 kJ*kg*$^{-1}$, respectively.

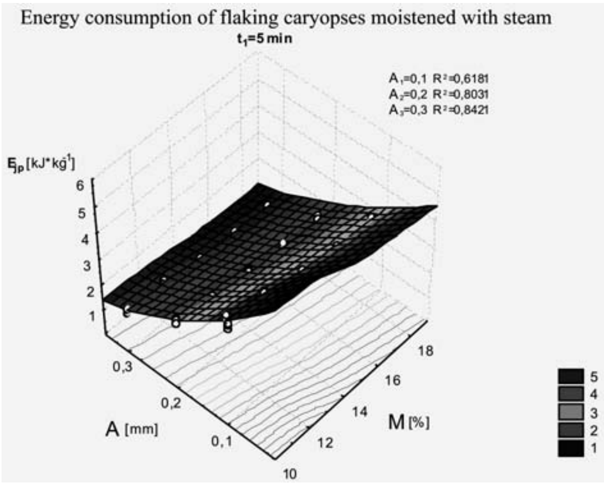
The achieved, quite big differences of energy consumption of the process of flaking, related to the compared extreme values of grain moistening time (t_1=5 min and t_3=15 min), prove that longer moistening times (steaming), lead to very intensive influence of steam on the change of the internal structure of grain, and especially on its structural-chemical properties. The detailed analysis of the obtained research results with the use of Tukey's multiple comparison confidence intervals indicates that the values of means regarding energy consumption of the process of grain flaking which was moistened for a short period of time (t_1=5 min), are considerably different from mean values of this parameter for the remaining times of moistening (t_1=5 min and t_3=15 min).

Table 1. Multiple comparison confidence intervals (Tukey's test), for the two-way analysis of variance – time of caryopses moistening with steam* working aperture of the grinding machine

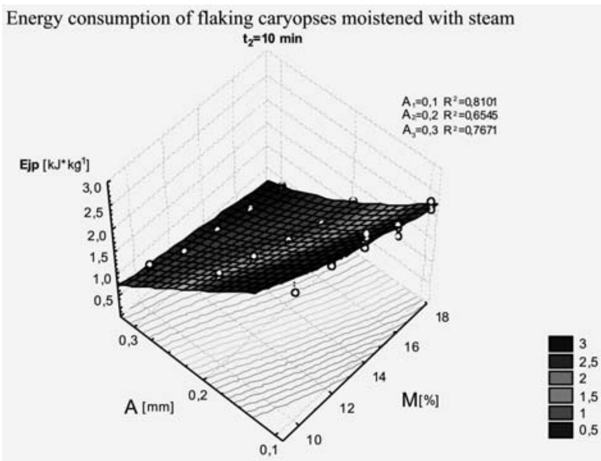
t_1, t_2, t_3 [min]	A [mm]	a	b	C	D	e	f
10	0.3	****					
15	0.2	****	****				
15	0.1	****	****	****			
10	0.2		****	****			
5	0.3			****	****		
10	0.1				****	****	
5	0.1					****	****
15	0.3					****	****
5	0.2						****

a,b,c,d,e,f homogeneous groups; the same literal indicator determines the lack of crucial difference between means within a given group at the level of significance α=0.05.

a)



b)



c)

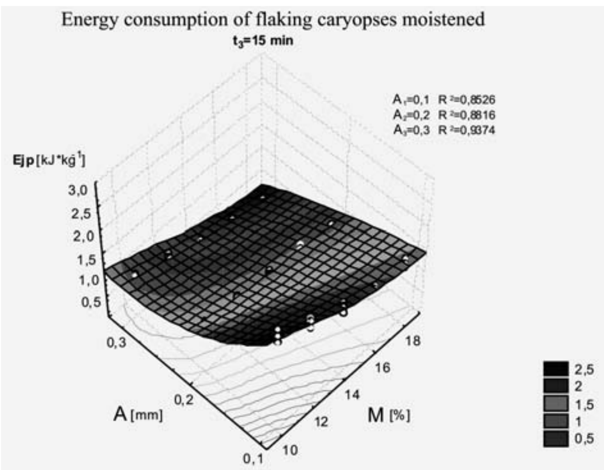


Fig. 2. Energy consumption of flaking caryopses moistened with steam in relation to the working aperture of the grinding machine A; time of moistening:

a) t_1=5 min, b) t_2=10 min c) t_3=15 min

CONCLUSIONS

After conducting the research the following conclusions were drawn up:

1. Flaking oat caryopses is a complex process whose course and energy consumption are influenced by many factors.
2. The analysis of research results regarding energy consumption of the caryopses flaking revealed a vast range of changes of this parameter, which mainly results from the diversity of the working aperture and the time of moistening and not so much from the level of the initial moistness of the resource.
3. As regards the method of moistening and parameters of hydrothermal processing, the lowest energy consumption (for research ranges) was recorded for grain moistened with steam for the period t_3=15 min (irrespective of the size of the working aperture). Shortening of moistening time caused an increase in expenditures of energy on flaking while a simultaneous, noticeable influence of initial moistness of grain was recorded.
4. The biggest influence on energy consumption of the process of flaking was ascertained in relation to the size of the working aperture, while the highest values were recorded for the aperture A_1=0.1 mm (irrespective of the time of moistening and the initial moistness). The differences in the range of changes of energy consumption between apertures A_1=0.1mm and A_2=0.2mm fluctuated from 6% (for samples of moistness M_5=18%) to 32% (for dry caryopses M_1=10%).
5. In the assessment of energy consumption of flaking (the lowest demand for energy) and the course of the process, the best effects (close to the optimum in this scope of research) were ascertained for the variant in which the time of moistening was t_2=10 min and the working aperture was A_2=0.2 mm.
6. In the case of long-term moistening of a resource with steam (t_3=15min) only slightly lower values of energy consumption, similarly to samples moistened through the period t_1=5min and t_2=10min, were achieved. Consequently, long-term and energy-consuming moistening with steam is unprofitable.
7. The conducted statistical analysis of research results, which included changes of energy during the flaking of caryopses in relation to different factors determining the process, allowed for the specifying of the full image of interrelations between these factors.

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ANALIZA ZABIEGÓW OBRÓBKI WSTĘPNEJ ZIARNIAKÓW OWSA NA PRZEBIEG I ENERGOCHŁONNOŚĆ PROCESU PŁATKOWANIA

S t r e s z c z e n i e. W pracy przedstawiono wyniki badań pomiarów nakładów energetycznych procesu płatkowania obłuszczonych ziaren owsa w zależności od metody i parametrów nawilżania oraz wilgotności wyjściowej. Pomiar energochłonności określano dla poszczególnych, założonych w metodyce wielkości szczeliny roboczej gniotownika. Największy wpływ na energochłonność płatkowania stwierdzono w odniesieniu do wielkości szczeliny roboczej gniotownika. Jej najwyższą wartość odnotowano przy płatkowaniu ziarniaków przy szczelinie roboczej A_1=0,1mm. Natomiast różnice w zakresie zmian poboru mocy pomiędzy szczelinami A_1=0,1mm i A_2=0,2mm wahały się od 6% (dla prób o wilgotności M_5=18%), do 32% (dla ziarniaków suchych M_1=10%). Najbardziej korzystną metodą w odniesieniu do zużycia energii w procesie płatkowania okazało się nawilżanie ziarniaków owsa parą wodną. Niezależnie od założonego metodycznie poziomu wilgotności początkowej surowca najniższe wartości mocy idącej na ich płatkowanie uzyskiwano dla próbek nawilżanych parą przez czas t_1=5 min.

S ł o w a k l u c z o w e : nakłady energetyczne, płatkowanie, owies, obróbka hydrotermiczna.