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AN INFLUENCE OF KERNEL CONDITIONING METHOD ON ENERGY CONSUMPTION DURING FLAKING PROCESS

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Summary. The paper presents the range of energy consumption during flaking of grain mixtures after conditioning by two different methods. An influence of primary moisture content was determined as well as an influence of the selected hydrothermal treatment method for mixed groats products on energy consumption during their flaking process.

Key words: hydrothermal treatment of grain, flaking, energy consumption.

INTRODUCTION

A market of cereal flakes is an example of a diverse one, on which traditional along with new and attractive products can be found. Wider and wider offer of cereal flakes with different flavoring additives as well as muesli are the answer for consumers' increasing interests in easy and fast preparation of meals [Obuchowski 1998, Mościcki 2003a, Kowalewski 1998, Gorzelany et al. 1994, Kowalewski et al. 1992]. Regardless of the production technology, cereal flakes (mainly oats and corn, and less barley, rye, and rice) play very important roles in human feeding due to their composition and nutritional value. Depending on the raw material, they are valuable carbohydrate, crude fiber, vitamins B, minerals, and fats sources [Holtz et al. 2001, Furll et al. 1996, Horabik 2001, Opielak et al. 2001]. They are particularly recommended in children's diet as well as for people requiring an appropriate diet. Based on chemical analysis of specific raw materials, the attempts of producing multi-grain flakes with richer and varied nutrients contents have been recently undertaken. Although the concept of multi-grain mixtures gives positive effects in view of the nutritional value and attractiveness of a new product, it causes some technological difficulties in setting the parameters of their simultaneous (as multi-grain mixture) processing. Due to a specific and varied structure and chemical composition of cereal grains mixture, there is a need to search for new processing parameters (conditioning, flaking, crushing, etc.). A detailed description of a flaking process is quite complicated, because its course and energy consumption depend on many factors. In general, they can be divided into: mechanical-constructional, mechanical-exploitation of a crusher, and resulting from a spectrum of raw material's physical properties. Up-to-date publications on the process of cereal materials flaking were mainly focused on the effects of mechanical, constructional, and exploitation factors. On the other hand, there are few works related to the influ-

ence of factors resulting from kernel's physical properties on the process parameters, namely, the energy utilized for flaking. It can be assumed that during the kernel flaking process (compression) occurring between two cylinders, the crushing is gradual as kernels are introduced into the working gap, which is approximately wedge-shaped. Various chemical compositions, shape, and some deviations in geometrical parameters of three simultaneously flaked materials result in quite different flaking conditions and incomparable (with a single material flaking) energy inputs. It also refers to methods and processes associated with those materials' preparation as well as to the evaluation of energy consumption during flaking process. A principal task in setting the cereal kernels' mixture flaking process is to evaluate the unitary energy consumption [Romański et al. 2000, Panasiewicz 2000, Zhang et al. 1998, Mieszkalski et al. 2000, Lossman et al. 1993]. The above-mentioned issues became one of the main reasons for undertaking the studies upon the problem.

THE AIM OF STUDY

The study aimed at measuring the energy inputs for flaking process depending on initial moisture content of kernels and selected parameters of their preparation and processing (water and steam moisturizing). The scope of the initial moisture and selected hydrothermal methods influence for several mixtures on energy and labor inputs needed to realize the process of their simultaneous flaking was evaluated.

MATERIAL AND METHODS

Shelled oats and barley kernels as well as wheat grain were materials for study. Purified and fraction-sorted materials were mixed in equal proportions, wetted to the initial moisture contents w_1=10%, w_2=14%, w_3=18%, w_4=22%, and w_5=26%, and directed to flaking process. Another tested group consisted of kernels (previously moisturized to the above moisture levels) and subjected to hydrothermal process in a drying mixer device (moisturized using steam at pressure p=0.28MPa for t_{n1}=5min). The final grain moisture after hydrothermal treatment with water steam was w_{1k} =12,6%, w_{2k} =17,1%, w_{3k} =23,6%, w_{4k} =30,6% and w_{5k} =35,8%. Two groups of samples of 1kg weight each, prepared in the above-described way were flaked in a crusher (working gap s=0.1mm) and the consumed energy was measured.

Studies related to the flaking process were carried out in a crusher "Tytan" H-759 driven with the engine of 2.2 kW power, rated voltage 380V, rated current 5.2 A, and power factor 0.82. The working parts of the crusher consisted of two ribbed cylinders of 240 mm diameter and 50 mm width. The rib angle was 8^o in relation to cylinders' axes, the depth 0.3 mm. The circumferential velocity of cylinders was 0.252 m min^{-1}. Smooth and uniform supply of the working gap in the crusher with the material was realized using the belt transporter at efficiency of 40g s^{-1}. After launching and stabilizing the crusher, the transporter was turned on along with the computer equipped with a power converter that recorded net value of the energy consumed for crushing of 1kg of kernel mixture. The measurements were made in five replications for a given moisture content and moisturizing method. The final result was the arithmetic mean from all 5 replications. The scheme of stand for power and electric energy measurements during the flaking process is presented in Figure 1.

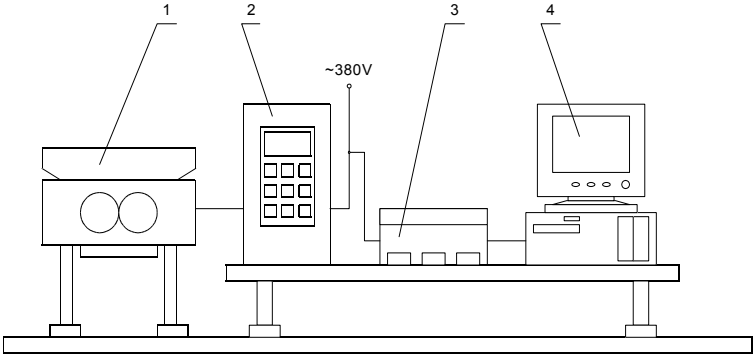

Fig.1. Scheme of laboratory stand for energy consumption measurement during grain flaking: 1-roller-crusher, 2-inverter, 3-energy converter, 4-computer

RESULTS AND DISCUSSION

The obtained results of investigations proved the complex character of mutual correlations between parameters concerning kernel hydrothermal treatment and energy consumption during the flaking process. It was found out that diverse levels of grain moisture a well as its processing with water steam have an influence on the course of flaking and energy consumption during the process, and also on the recorded technological value of the material (estimated only on the basis of visual observation). Figure 2 presents the examples of energy consumption during the crushing of kernels moisturized with water and steam.

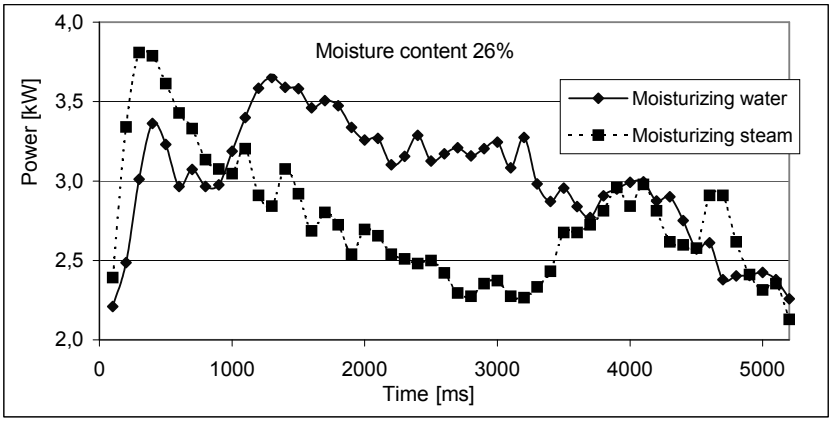

Fig.2. Exemplary function of power consumption changes during steamed and water moisturized grain flaking process

The achieved study results clearly indicated that different moisture contents and hydrothermal processing of kernel mixture influenced the raw material's technological value, its flaking process, and energy consumption during the process as well.

Moisturizing of mixed kernels to w_4=22% and w_5=26% moisture contents and then their hydrothermal processing with steam appeared to be the most advantageous method from the point of view of energy inputs. Significantly lower levels of energy were expended for that way of material preparation than at other moisture contents (Figure 3).

For kernel samples at initial moisture w_5=26% and moisturized with steam, only 7.94 Wh were used during their flaking, while for materials at w_2=14% and prepared by means of the same method – up to 13.28 Wh. The difference for both extreme moisture levels (w_1=14% vs. w_5=26%) amounted to 5.33 kWh, thus it decreased by about 40%. Such significant drop in energy consumption confirms a very strong effect of water steam on the inner structure of potatoes, especially their mechanical features. Favorable physical properties (color, taste, flavor) were also obtained for kernel moisturized with water steam.

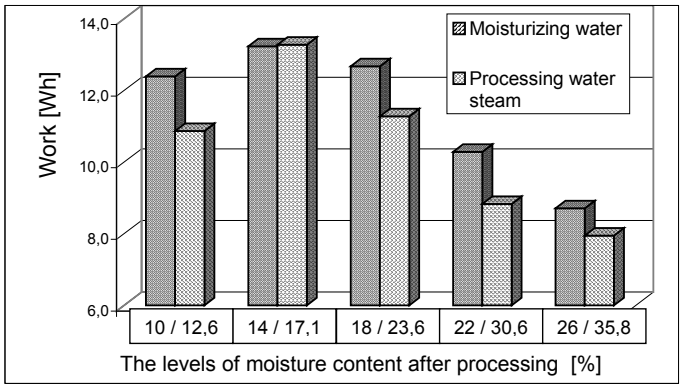

Fig. 3. Flaking labour at different moisture content levels and for different methods of hydrothermal treatment

With reference to the applied moisture contents, the highest energy inputs necessary for crushing (flaking) the kernel mixtures (regardless of the method) were recorded at moisture level of w_2=14% (Figure 4).

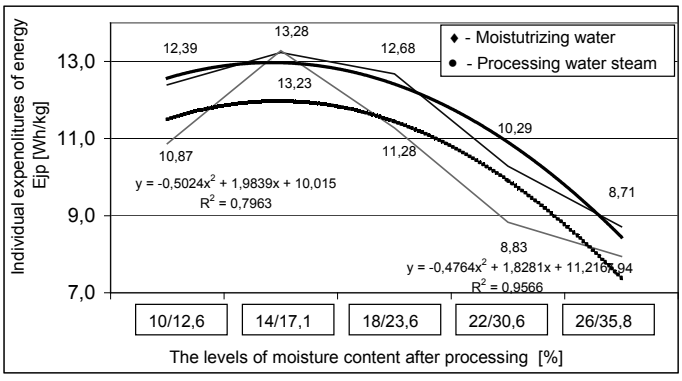

Fig.4. Relationship between grain flaking labour inputs and the applied moisture content levels

For that moisture level, regardless of whether kernels were moisturized with water or steam, very similar values of utilized energy were measured. Along with the moisture content increase (w_3=18%, w_4=22%, and w_5=26%), the difference in the consumed energy between moisturizing using water and steam increased.

The obtained study results revealed very similar energy and work values for flaking the kernels at w_1=10% and w_3=18% moisture contents, however, both for the former and the latter levels they were lower, amounting to 12.39 Wh and 12.67 Wh for water-moisturized and 10.87 Wh and 11.27 Wh for steam-moisturized samples. Such results suggest that stabilized and similar levels of work value needed to realize the kernel crushing process were observed for the range of moisture contents between w_1=10% and w_3=18%. At higher water contents (w_4=22% and w_5=26%), a considerable decrease of energy consumption during flaking was recorded. In the case of water moisturizing, it was a positive variant that led to some water savings, while for steam moisturizing, energy required to steam production should be compared with the amount minus energy for flaking.

The experiments allowed for an evaluation of the influence and scope of parameter changes during kernel hydrothermal processing on flaking energy consumption. Furthermore, the studies confirmed the possibility to produce multi-grain flakes (despite the different chemical compositions and different physical properties of the raw materials) applying a uniform technological line.

The regression equations and determination coefficients R^2 illustrating the changes of energy for kernel flaking are presented in Table 1. High values of determination coefficients (0.99) proved a good compatibility of the equations to the achieved results.

Table1. Equations of multiple regression and values of determination coefficient R^2 describing variability of energy consumption of flaking in function of raw grain moisture content of 0,05 relevance level

Way of moisturizing	Equation of regression	R^2
Moisturizing with water	$y = - 0{,}4764x^2 + 1{,}8281x + 11{,}216$	0,9566
Moisturizing with steam	$y = - 0{,}5024x^2 + 1{,}9839x + 10{,}015$	0,7963

Standard deviations for the achieved results of power measurements was within the range from 0.019 to 0.244 for w_1=14% moisture content, from 0.05 to 0.603 for w_2=18% moisture content, from 0.028 to 0.650 for w_3=22% moisture content, and from 0.015 to 0.521 for w_4=26% moisture content.

CONCLUSIONS

1. The experiments revealed an influence of the assumed kernel moisture levels (mixed at equal proportions) on energy consumption during their simultaneous flaking process.
2. Moisturizing the grain mixture using steam appeared to be the most effective method in view of energy consumption during the flaking process. Regardless of the initial moisture content of the studied raw material, the lowest energy inputs for flaking were expended in that variant.
3. An analysis of the results of investigations showed that the final moisture levels for which the expenditures of isolated energy of flaking were the lowest ranged within w_4=22% to w_5=26% for grain moisturized with water and w_4=30,6% to w_5=35,8% for that conditioned with water steam.
4. The performed experiments allowed for an evaluation of energy consumption for simultaneous flaking of kernels mixture and confirmed the possibility of producing multi-grain flakes

applying the same pre-treatment methods (moisturizing with water and steam conditioning) on a uniform technological line.

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WPŁYW METODY KONDYCJONOWANIA ZIARNIAKÓW NA ENERGOCHŁONOOŚĆ PROCESU PŁATKOWANIA

Streszczenie. W pracy przedstawiono zakres zmian jednostkowych nakładów energii na proces płatkowania mieszaniny ziarniaków poddanych wcześniej dwóm metodom kondycjonowania. Określono zakres wpływu wilgotności wyjściowej i wybranej metody obróbki hydrotermicznej, kilku zmieszanych ze sobą surowców kaszarskich na jednostkowe nakłady energii potrzebnej do realizacji procesu płatkowania.

Słowa kluczowe: obróbka hydrotermiczna ziarniaków, płatkowanie, energochłonność procesu.