TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2013, Vol. 13, No. 2, 35–40

Force and work of cutting of sponge-fatty cake with oat flakes content

Elżbieta Kusińska, Agnieszka Starek

Department of Food Engineering and Machinery, University of Life Sciences in Lublin, Poland,
Doświadczalna 44, 20-280 Lublin, tel. 48 81 461 00 61, e-mail: elzbieta.kusinska@up.lublin.pl

Received May 9.2013; accepted June 14.2013

Summary. The processes of food processing are an important research instrument. The paper presents the results of study of force and work of cutting of sponge-fatty cake with the addition of oatmeal. The variable parameters in the experiment were the amount of oat flakes added (0, 5, 10, 15%), and knife wedge angle (2.5°, 7.5°, 12.5° and 17.5°). Additionally, sensory assessment was performed for the purpose of selection of the desired amount of oat flakes addition. Statistical analysis of the results showed a significant correlation of force and work of cutting on the amount of the additive and knife wedge angle. The cutting quality is affected by: the amount of the flakes additive and knife geometry. The most preferred energy and quality is achieved at the knife angle 2.5° and 7.5°, and the most unsuitable angle is 12.5° and 17.5°. The greatest force and the work occurred during the cutting of sponge-fatty cake with the addition of oatmeal in the amount of 15%, while the smallest – without the additive. The best cutting quality was obtained using the additive flakes in an amount not exceeding 10% of the knife with an angle of 2.5° and exacerbation of 7.5°.

Key words: cutting, sponge-fatty cake, oat flakes.

INTRODUCTION

Agrifood industry, which includes the production of bakery and confectionery as well biscuit making is a very important branch of the Polish industry, as food items and beverages account for about 17% of the Polish industrial production. One of the fastest growing sectors of the food industry's current production of confectionery [17].

When reaching for a cake we pay attention mainly to such characteristics as flavor, calories, freshness, appearance and quality [2]. The state of confectionery is influenced by the ingredients that are included in the recipe. Currently, there is a tendency for consumers to search for products containing (in addition to basic, traditional use) additives generally recognized for taste and health benefits, enabling the creation of products with new properties [7, 14]. Such criteria are met by oatmeal. Oats has as well-balanced amount of protein and soluble fiber, carbohydrates and fats, vitamins and minerals. Inclusion of oats in the diet is beneficial for both healthy people and diabetics [5, 12].

Knowledge of the effects of additives on the quality of the final product is useful not only to producers for the production of ready-mix cakes, but also cake manufacturers, who in addition to the quality of the product (the desired hardness or brittleness) can reduce the unhealthy factors, reducing the amount of sugar or fatty products [1, 16].

In order to determine the quality of the baked matter, sensory evaluation is usually performed. It consists in determining the batch uniformity, appearance, taste and smell, as well as the structure of the cake [9].

Currently, instrumental texture evaluation methods of the tested products are popular, including mechanical methods. They allow determination of mechanical parameters of pastries. Knowledge of these properties is essential for the development of new products and evaluation of the quality of finished products [4].

Fast development of production techniques in the confectionery industry allowed for the mechanization of virtually all the stages of production, including the cutting of cakes. The research on work of cutting boils down largely to the optimization of blade design features and parameters of the grinding process [3]. Cutting is the direct impact of the active material of the cutting tool on the cut material. The movement of the knife may be perpendicular or parallel to the cutting edge. Knives of different shapes are used for shredding the products. The most common are three types of knives: knives with a flat blade, with a straight continuous one, flat knives with a comb blade and knives with a scoop-shaped blade. The highest prevalence was found of flat knives with a blade angle [6, 13, 10, 11].

The cutting tests on confectionery products aimed at reducing the workload and a high efficiency of the cutting process while maintaining a good quality of cakes. However,

the efficiency of the grinding process is affected not only by the geometric features of cutting elements, but also the structure of the material to be shredded, which results in the quality of the portion dough [8].

OBJECTIVE AND SCOPE OF RESEARCH

The scope of the study comprised the development of the recipes and the baking of pastries, determination of the effect of the knife wedge angle on the force and work of the process of cutting cakes, and sensory assessment of the products, which allowed the selection of cakes of the highest quality and best cutting performance.

METHODS

The experimental material was four kinds of sponge-fatty cake obtained from wheat flour "Luksusowa" type 550 with 0, 5, 10 and 15% by the addition of instant oatmeal Melvit S.A. In each case, the weight of flour and oat flakes was 500 g, flakes were added in the natural entire form. Other dough ingredients were: 250 g of eggs, 350 g of sugar, 250 g of margarine Kasia, 200 g of 2% milk and 18 g of baking powder. The samples included cake with zero oatmeal. Baking pans were lined with the prepared cakes. The thickness of the dough was 50 ± 2 mm. Cakes were baked for 60 minutes at 160°C. Five cakes were made of each sample with oat addition. When the pastries cooled down, they were sealed in polyethylene bags and kept in a refrigerator at temperature of 6°C.

The cutting process was performed, which was conducted on texture analyzer type TA.XT. plus cooperating with the computer. In the study knives were used with the shapes of 2.5°, 7.5°, 12.5° and 17.5° angle. Approach angle, defined as the angle between a plane perpendicular to the direction of movement and the cutting edge of the knife was 0°. Speed during cutting was constant at 50 mm·min^{-1}. Laboratory tests were carried out in thirty repetitions on slices of cakes length 50 mm, width 40 mm and thickness of 20 mm (for each knife and for all types of cakes). The results of the measurement were in the form of graphs representing the relation between the cutting force and knife displacement, from which the values of the cutting force and work were determined (Fig. 1).

In the area A-B force increases from zero to a value that causes the compression of the material by the knife. In this area, the material is compacted at the threshold of the cutting process. At point C, there is a maximum cutting force, which gradually decreases to 0 (point D), which completes the process.

The cakes sensory assessment was conducted by the trained team of 10 people in accordance with the Polish Standard PN-A-74252 [15].

RESULTS

In order to investigate the effect of oatmeal addition on the process of cutting the sponge-fatty cake and its suitability for consumption, the force and cutting work for knives of various shapes were tested.

The results of measurements are presented in Fig. 2 and 3.

It was found out that the dough prepared with the addition of oatmeal was characterized by higher values of maximum force and work cutting than the dough without oats. The values of maximum force and work in case of the addition of flakes reached 15% and amounted to 5.05 N and 0.063 J (for knife wedge angle of 17.5°). And the lowest cutting force and work were recorded for the control, for the knife wedge angle of 2.5° – 2.58 N and 0.033 J.

The resulting standard deviations from the mean values of mechanical parameters (Fig. 2 and 3) indicate substantial

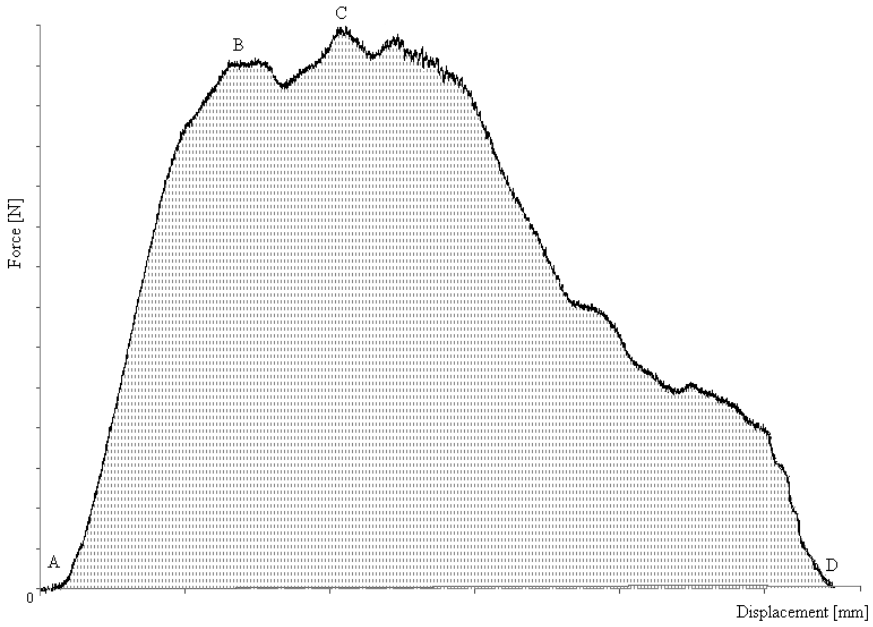

Fig. 1. Example of force-displacement relationship obtained during the cake cutting

heterogeneity of the tested products. They probably arise from their heterogeneous internal structure and surface after adding unminced oatmeal.

The relations presented in Figures 2 and 3 are described by equations (1) and (2):

$$F = 2{,}3057 + 0{,}0919k_z + 0{,}0766d, \quad (1)$$

$$R^2 = 0{,}883;\ \alpha \le 0{,}05,$$

$$W = 0{,}0291 + 1{,}09 \cdot d^2 \quad (2)$$

$$R^2 = 0{,}91;\ \alpha \le 0{,}05,$$

where:
F – cutting force [N],
W – cutting work [J],
k_z – knife wedge angle [deg],
d – addition of the oat flakes[%].

The results were subjected to two-way analysis of variance, which indicates that the cutting force has a significant impact (at the significance level $\alpha \le 0{,}05$) on the exacerbation of knife angle and the addition of oatmeal. Between research results there is a correlation between the independent variables at a high level. And the work of cutting is considerably affected by tightening the knife angle. The values of correlation coefficients calculated using a multiple regression analysis are shown in Table 1

Table 1. Correlation coefficients

Parameter	Knife wedge angle [deg]	Addition of the oat flakes [%]
Force [N]	0,916	0,885
Work [J]	0,772	-

During the testing of the impact of knife wedge angle and percentage content of oatmeal on the mechanical properties, attention should be paid to the behavior of crumb cake during the cutting process. For each type of knife and for different content of oatmeal the graph of force-displacement proceeds quite differently. The changes in graph's outline are shown in Figs. 4 and 5.

Observations carried out during the analysis of graphs can be summarized as follows: for all the studied pastry, the most appropriate wedge angle is that of 2.5° and 7.5°. For other knives with larger wedge angles the forces increase negatively.

During the cutting of crumb cake without the addition of oatmeal, we note a significant stress on the surface when the knife wedge going into the product, which causes a large deflection device and deformed end product. As a result, we get rough dough pieces with low quality.

For the added amount of 15%, the knife encounters the resistance of the material, which is due to an excessive amount of oatmeal. Cakes are damaged and mostly disrupted. The resulting pieces are baked at the intersection of the irregular structure and uneven thickness of the cut, causing losses in the material and reduced taste.

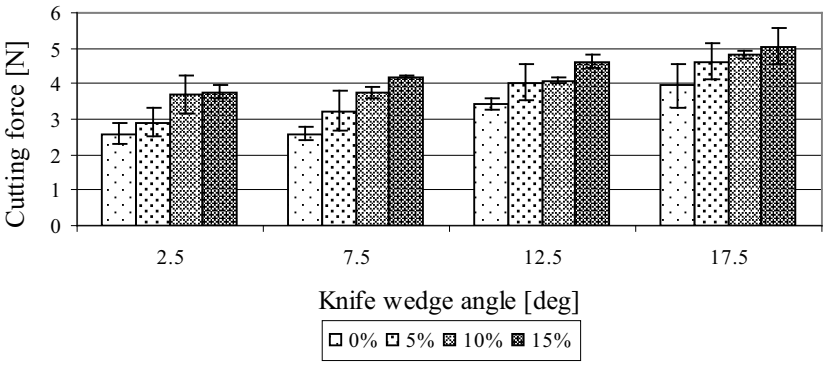

Fig. 2. Relation of cutting force of sponge-fatty cake with different addition of oatmeal to knife wedge angle

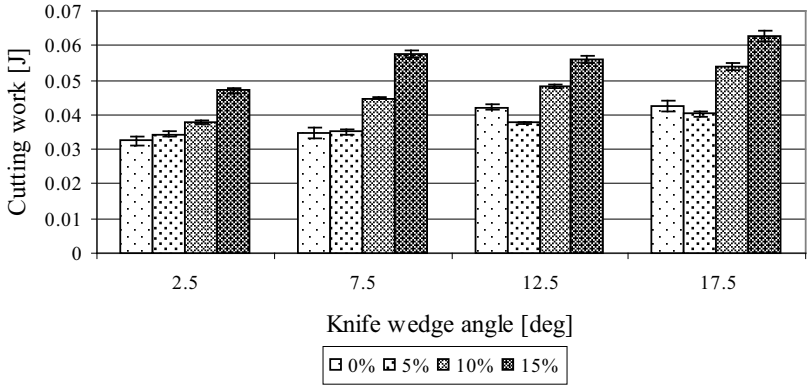

Fig. 3. Relation of cutting work of sponge-fatty cake with different addition of oatmeal to knife wedge angle

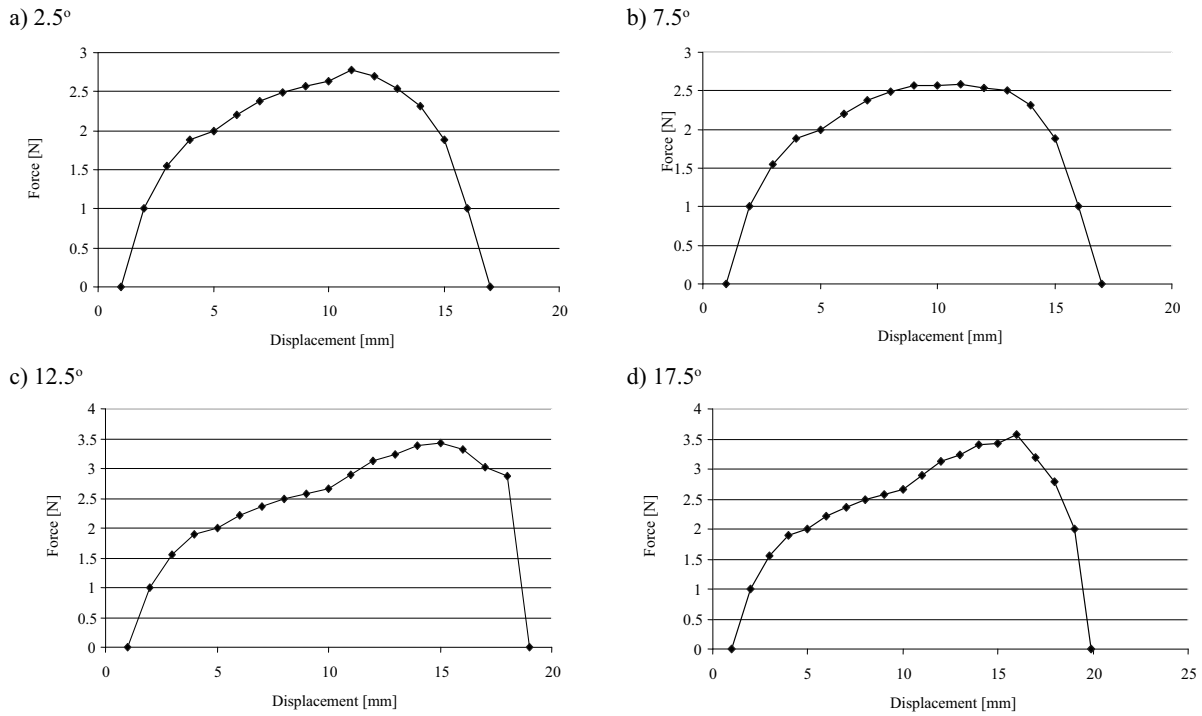

Fig. 4. Graphs proceedings of the force-displacement during the cutting of sponge-fatty cake with 0% addition of oatmeal for knives with wedge angle: a) 2.5°, b) 7.5°, c) 12.5°, d) 17.5°

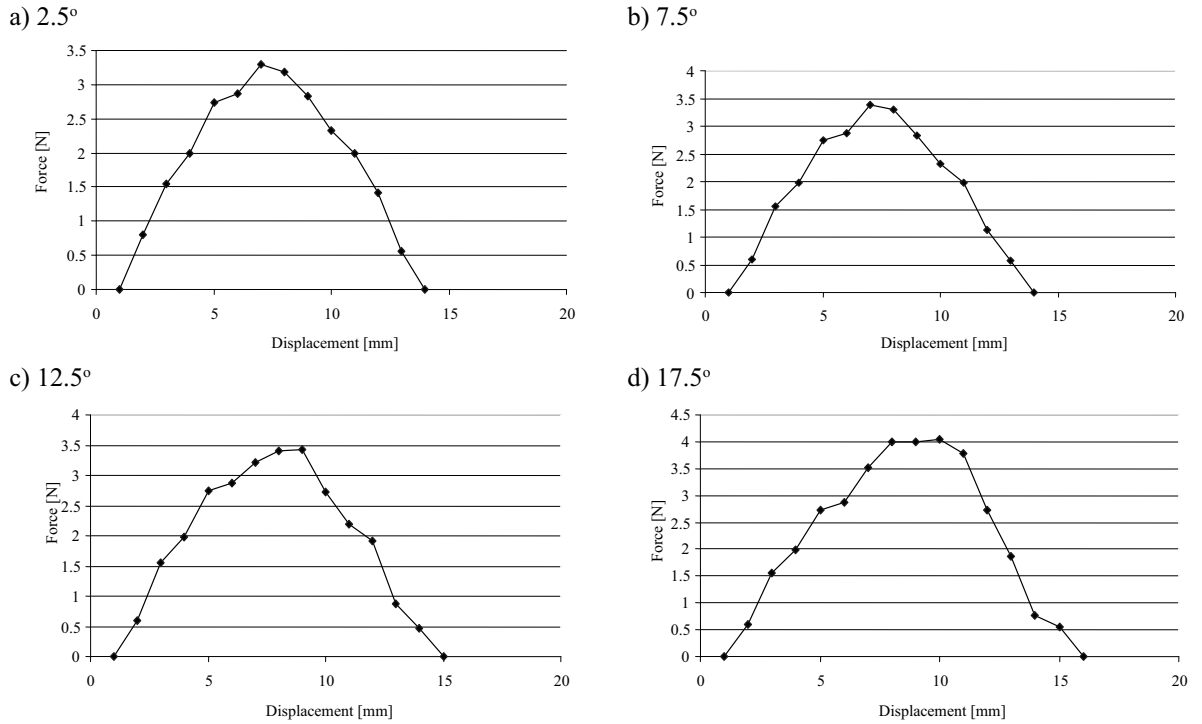

Fig. 5. Graphs proceedings of the force-displacement during cutting of sponge-fatty cake with 15% addition of oatmeal for knives with wedge angle: a) 2.5°, b) 7.5°, c) 12.5°, d) 17.5°

Depending on the course of the force for the addition of oatmeal at 5 and 10%, the displacement is steady and stable throughout the entire process of material distribution. Cakes are cut once and the area of intersection is fairly uniform. In this case, the dough pieces are precisely structured, have regular shape and the desired form stays without damage, as evidenced by organoleptic tests.

The results of sensory assessment of sponge-fatty cake carried out in accordance with PN-A-74252: 1998 indicate that the up to 10% addition of oatmeal to flour had a positive effect on the results of organoleptic assessment of cakes (very good flexibility and a mild taste and smell). Cakes made only from wheat flour also took the first level of quality (but they had slightly worse color of cover even with the

best taste and smell). However, the 15% share of oatmeal caused the baking quality deterioration (variations in shape, differences among the individual items).

CONCLUSIONS

1. With the increase in the knife wedge angle and addition of flakes, the force and work of cutting reach higher values.
2. The best quality of baked pieces is obtained using the additive flakes up to 10% for the knives with wedge angle of 2.5° and 7.5°.
3. The scoring shows that the best overall quality of the dough was achieved with the addition of flakes in the amount of 5 and 10%. It obtained 20 points out of the 20 possible and passed to the first class quality. Confectionery with the 15% share of flakes qualified to class II in accordance with the requirements.

REFERENCES

1. **Boobier W. J., Baker J. S. 2007**. Functional biscuits and coronary heart disease risk factors. British Food Journal, 3(109), 260-267.
2. **Borowy T., Kubiak M. 2010**. Tekstura wyróżnikiem jakości produktów piekarskich i cukierniczych. Cukiernictwo i Piekarstwo, 7-8(129), 33-36.
3. **Flizikowski J. 2006**. Globalny algorytm innowacji maszyn, Bydgoszcz, BTN-BKWoZ, ISBN 978-83-932977-0-2.
4. **Gibiński M., Gambuś H., Nowakowski K., Mickowska B., Pastuszka D., Augustyn G., Sabat R. 2010**. Wykorzystanie mąki owsianej – produktu ubocznego przy produkcji koncentratu z owsa – w piekarstwie. Żywność. Nauka. Technologia. Jakość, 3 (70), 56-75.
5. **Kobus Z., Guz T., Kusińska E., Nadulski R. 2011**. Influence of moisture and vertical pressure on airflow resistance through oat grain. Agricultural Engineering, 7(132), 29-35.
6. **Kowalik K., Sykut B., Marczak H., Opielak M. 2013**. A method of evaluating energy consumption of the cutting process based on the example of hard cheese. Eksploatacja i Niezawodność – Maintenance and Reliability, 15 (3), 241-244.
7. **Kowalski S., Lukasiewicz M., Juszczak L., Sikora M. 2011**. Charakterystyka teksturalna i sensoryczna mas cukierniczych otrzymanych na bazie miodu naturalnego i wybranych hydrokoloidów polisacharydowych. Żywność. Nauka. Technologia. Jakość, 3(76), 40-52.
8. **Kusińska E., Starek A., 2011**. Właściwości mechaniczne tekstury ciasta biszkoptowo-tłuszczowego. Inżynieria Rolnicza, 5(130), 157-164.
9. **Marzec A. Kowalska H., Gąsowski W. 2010**. Właściwości mechaniczne ciastek biszkoptowych o zróżnicowanej porowatości. Acta Agrophysica, 16(2), 359-368.
10. **Matuszewski M., Styp-Rekowski M. 2009**. Mikrocechy geometryczne elementów rozdrabniających. Inżynieria i Aparatura Chemiczna, 48(2), 94-95.
11. **Nadulski R., Strzałkowska K., Skwarcz J. 2010**. Wpływ kąta zaostrzenia noża na przebieg cięcia wybranych warzyw korzeniowych. Inżynieria Rolnicza, 7(125), 161-166.
12. **Otles S., Cagindi O. 2006**. Cereal based functional foods and nutraceuticals, Acta Scientiarum Polonorum. Technologia Alimentaria, 5(1), 107-112.
13. **Panasiewicz M., Mazur J., Sobczak P., Zawiślak K. 2012**. The analysis of the influence of initial processing of oat caryopses on the course and energy consumption of the flaking process. TEKA Komisji Motoryzacji i Energetyki Rolnictwa, 12 (1), 195-199.
14. **Piispa E., Alho-Lehto P. 2004**. Oat products digestibility studies and their nutritional information. Proceedings 7th International Oat Conference, Agrifood Research Reports 51. Peltonen-Sainio P., Topi-Hulmi M. (eds.). Finland, MTT Agrifood Research, ISBN 951-729-879-X.
15. PN-A-74252. 1998. Wyroby i półprodukty ciastkarskie. Metody badań.
16. **Rydzak L., Andrejko D. 2011**. Effect of different variants of pretreatment of wheat grain on the particle size distribution of flour and bran. TEKA Komisji Motoryzacji i Energetyki Rolnictwa, 11c, 283-290.
17. **Tajner-Czopek A., Kita A. 2005**. Analiza żywności – jakość produktów spożywczych. Wrocław, Wyd. Akademii Rolniczej we Wrocławiu, ISBN 83-89189-63-1.

SIŁA I PRACA CIĘCIA CIASTA BISZKOPTOWO-TŁUSZCZOWEGO Z DODATKIEM PŁATKÓW OWSIANYCH

Streszczenie. W procesach technologicznych przetwarzania żywności istotne znaczenie mają badania instrumentalne. W pracy przedstawiono wyniki pomiaru siły i pracy cięcia ciasta biszkoptowo-tłuszczowego z dodatkiem płatków owsianych. Parametrami zmiennymi w doświadczeniu były: ilość dodanych płatków owsianych (0, 5, 10, 15%) oraz kąt zaostrzenia noża (2,5°; 7,5°; 12,5° i 17,5°). Dodatkowo wykonano ocenę sensoryczną, która pozwoliła na dobór pożądanej ilości płatków. Analiza statystyczna wyników wykazała istotną zależność wartości siły i pracy cięcia od ilości użytego dodatku i kąta zaostrzenia noża. Na jakość cięcia wpływają: ilość zastosowanego dodatku płatków oraz geometria ostrza. Najkorzystniejszym energetycznie jak i jakościowo kątem zaostrzenia noża jest kąt 2,5° i 7,5°, a najbardziej nieodpowiednim 12,5° i 17,5°. Największa siła i praca wymagane są podczas cięcia ciasta biszkoptowo-tłuszczowego z dodatkiem płatków owsianych w ilości 15%, a najmniejsza – bez dodatku. Najlepszą jakość cięcia otrzymano przy zastosowaniu dodatku płatków w ilości nie przekraczającej 10% dla noży o kącie zaostrzenia 2,5° i 7,5°.

Słowa kluczowe: cięcie, ciasto biszkoptowo-tłuszczowe, płatki owsiane.