A C T A   A L I M E N T A R I A   P O L O N I C A
Vol. XIV (XXXVIII), No. 2 1988

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EFFECT OF KNIFE CUTTING EDGE SHAPE ON ELECTRIC ENERGY CONSUMPTION DURING MEAT COMMINUTION IN A MECHANICAL CUTTER

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Key words: mechanical cutter, energy consumption, comminution of meat

The effect of different shapes of cutting edges of knives on electric energy consumption during model comminution of sausage meat mixtures in a mechanical cutter was determined.

In recent times industrial cutters are increasingly often being equipped with knives having variously shaped cutting edges. However, there is no comprehensive information about the technological and energetic efficiency of the different kinds of knives. The manufacturers of cutters provide no data on this and the scientific publications on the subject are in most cases theoretical [1, 6, 7] or they report only fragmentary results of studies [2, 3, 5]. Moreover, the opinions of various researchers about the best knife cutting edge shape are widely divergent. Bakuno [1] concludes that the optimum knife in a cutter ought to have its cutting edge convergent with the rotation radius. Mironow and Titarchuk [6] believe that the smaller the angle of knife slide the better the cutting effect. Honikel and Egginger [5] claim that the application of knives with angle-line cutting edges leads to smaller temperature increments and lower heat discharge from the meat mixture. Diakun et al. [3] are of the opinion that the best quality and lower resistance of meat mixture is obtained when comminution is performed with knives of slide coefficient $\lambda = 1.5$-2.0. Given this situation, it was advisable to investigate this problem in order to answer questions posed by industrial experts.

Only some results of this investigation are presented here, namely those pertaining to the effect of selected shapes of knife cutting edges on electric energy consumption during comminution of sausage meat mixtures in mechanical cutters, i.e. on a factor of considerable importance in the age of energy conservation in industry.

MATERIAL AND METHODS

Experiments were performed in a model system. The cutter's capacity was 8 dm^3 and its shaft was equipped with three knives with one of the following cutting edge shapes: a logarithmic spiral section (slide coefficient $\lambda = 1.0$), a circle arc section (so called sickle knives), and angle-lined. The knife shaft was powered by a direct-current motor (2400 r.p.m.). The cutter bowl was filled to 70% capacity and its rotational speed was 20 r.p.m. The material used in the experiments was tough pork with a 40% addition of water, 2% addition of salt; curing agents were also added. Comminution time was 15 min. Power consumption was measured with a WAREG II recording apparatus from Czechoslovakia. Electric energy consumption during comminution was exspressed as J/100 kg meat mixture.

RESULTS AND DISCUSSION

Statistical analysis of results revealed the significant effect of knife kind on electric energy consumption during meat mixture comminution in a mechanical cutter (Table 1). Lowest consumption was in the case of knives with angle-line cutting edges, and the greatest consumption occured when the sickle knives were used. The difference between energy consumptions in these two case (5.1%) was statistically highly significant. The lowest active power consumption during the use of angle-line knives having the largest friction surface (Table 2) may suggest that in this case the knife-meat friction forces affected the torque moment of the knife shaft to a lesser extent than did the cutting forces. This may be accounted for

Table 1. Power consumption and electric energy consumption during 15 min of meat mixture comminution in a mechanical cutter for various shapes of knife cutting edges

Knife cutting edge shape	Power consumption (KW/100 kg of meat mixture)	Electric energy consumption ($J \times 10^6$/100 kg of meat mixture)
Angle-line	11.91	10.73
Logarythmic spiral	12.20	10.91
Sickle	12.52	11.23
$SD_{0.05}$ =	0.20	0.15
$SD_{0.001}$ =	0.30	0.25

Table 2. Active cutting edge length and friction surface of knives used in the experiments

Knife cutting edge shape	Active cutting edge length (m)	Friction surface (m^2)
Angle-line	0.19	44.5×10^{-4}
Logarithmic spiral	0.11	24.5×10^{-4}
Sickle	0.13	27.4×10^{-4}

by a drop of cutting resistance accompanying the increase of the cutting angle [1]: for selected distances between cutting edge points and the rotation axis, the cutting angle of angle-line knives was higher than the cutting angle of sickle knives. Aside from being affected by the knife cutting edge shape, energy consumption by the cutter engine was also found to be different in various stages of comminution. Maximum consumption occurred in the second and third minute of the process, and then gradually decreased as comminution progressed (Fig.). The dynamics of electric energy consumption during cutter operation

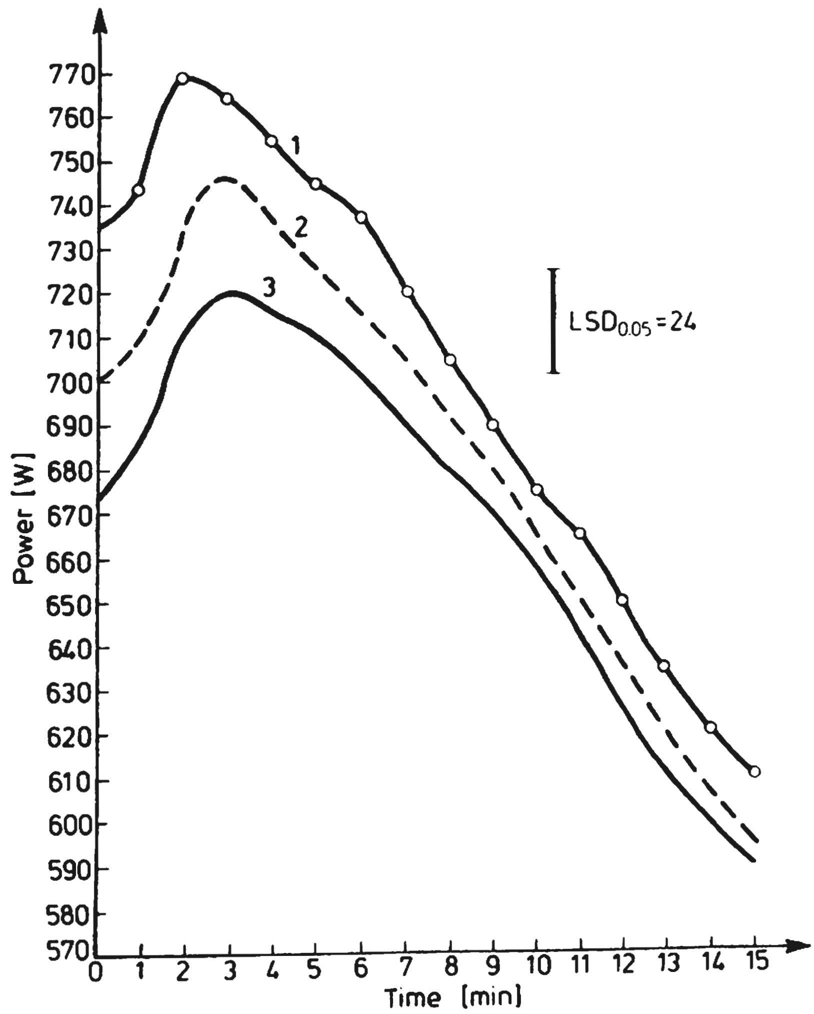

Fig. Relationship between power consumption by the motor and comminution time; 1 — sickle knife, 2 — logaritmic spiral knife, 3 — angle line knife

varied. The greatest differences in energy consumption for the various kinds of knives were observed in the third minute of comminution (Table 3); as time passed, these differences gradually diminished (Table 3).

Table 3. Differences (in per cent) in power consumption at various stages of comminution with respect to the shape of knives with angle-line cutting edges

Knife cutting edge shape	Comminutation time (min)			
	3	6	9	15
Logarithmic spiral	3.70	2.10	1.50	0.85
Sickle	6.25	5.00	3.00	2.60

The greatest electric energy consumption during the third minute of comminution may be explained by the fact that in the first 3-4 minutes of the process the meat mixture cutting and mixing is most intense, hence requiring large amounts of energy. These results are in agreement with the previous findings of Gorbatov [7].

It was also found during the experiments that a considerable proportion of energy consumed by the motor during meat mixture comminution went into maintaining the fixed speed of the cutting shaft. For the applied system of cutting unit drive and for the required shaft speed of 2400 r.p.m., power consumption during idling was 264 W which amounted to about 40% of the effective power required for a full comminution of the meat mixture. This is a considerable amount of energy, and efforts should be made to reduce it by redesigning the cutting unit drive system.

CONCLUSIONS

1. The shape of the knives' cutting edge has a statistically significant effect on electric energy consumption during meat mixture comminution in mechanical cutters. The lowest energy consumption was obtained using knives with angle-line cutting edges.
2. Energy consumption by the cutter motor decreases as time of comminution increases. Maximum energy consumption occurred in the second and third minute of comminution.
3. In the applied experimental conditions the energy required to comminute the meat mixture amounted to 60% of total energy consumed by the cutter motor.

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Manuskript received: September 1986
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WPŁYW KSZTAŁTU LINII CIĘCIA NOŻY KUTRA NA ZUŻYCIE ENERGII ELEKTRYCZNEJ W PROCESIE KUTROWANIA

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Streszczenie

W związku z montowaniem w ostatnim czasie w kutrach przemysłowych noży o różnym kształcie linii cięcia podjęto badania mające na celu ustalenie wpływu wybranych kształtów noży kutra na nakład energii elektrycznej w procesie kutrowania farszów wędlinowych. Badania prowadzono w układzie modelowym na kutrze o pojemności 8 dm^3. Na wale nożowym montowano każdorazowo po 3 noże w kształcie wycinka spirali logarytmicznej o współczynniku poślizgu $\lambda = 1{,}0$, wycinka łuku okręgu (noże sierpowe) oraz linii łamanej. Materiałem badawczym było mięso wieprzowe ścięgniste z 40% dodatkiem wody, 2% dodatkiem soli kuchennej oraz środkami peklującymi. Czas kutrowania wynosił 15 min. Pomiaru poboru prądu przez silnik napędzający wał nożowy dokonywano za pomocą przyrządu rejestrującego Wareg II. Analiza statystyczna wyników badań wykazała istotny wpływ rodzaju noży na zużycie energii elektrycznej w procesie kutrowania farszów. Najmniejsze zużycie energii elektrycznej stwierdzono przy zastosowaniu noży w kształcie linii łamanej, a największe dla noży sierpowych. Niezależnie od wpływu kształtu linii cięcia noży, stwierdzono również różnicę w poborze mocy przez silnik kutra w poszczególnych czasach kutrowania. Mianowicie maksimum poboru mocy stwierdzono w 2-3 min kutrowania. W miarę upływu czasu kutrowania pobór mocy zmniejszył się.