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THE ESTIMATION OF TECHNOLOGICAL EFFECTIVENESS OF THE WORK OF CHOPPER KNIVES WITH THE SHEAR EDGE IN THE SHAPE OF CIRCLE SEGMENT

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ABSTRACT

The aim of the research was to compare the work of knives of different construction with shear edge in shape of circle segment. Experiments were conducted under semi-technical conditions by the use of chopper with the capacity of bowl equal to 10 dm^3. On knife shaft of the chopper were assembled each time three knives coded with symbols S I, SII, S III and S IV. The technological effect of the work of knives was evaluated based on assessment of the quality of meat batters and sausages. The best quality of meat batter and sausages was achieved during comminution with knife S II, while the worst one effect was observed by the use of knife S IV. The experiments have shown that about quality of shear and shear and friction resistance during meat comminution with knives of different construction of shear edge decide mostly: shear angle, friction surface of knife and length of shear edge.

Key words: comminuting, chopping, chopper knives shape

INTRODUCTION

Comminution is the basic technological operation used during production of finely comminuted sausages. This operation should assure the optimal grinding degree of muscular, connective and adipose tissues and uniform fat dispersing in the dispersing phase.

Technological effect of comminution is affected by many factors. Generally, they can be divided in three groups:

- factors connected with raw material,
- factors connected with technology of meat batter production
- factors connected with technical parameters of devices used for production of meat batters.

Among three groups of factors mentioned above, the role of raw material and the role of technological factors in meat comminuting are recognized in the best way. Least distinguished is instead the third group of factors, which include: speed of rotating knives and bowl, shape of geometrical edge of shearing knives, angle of knife blade, quantity of knives and manner of their installing on knife shaft, wear life of knives, shape of bowl, filling degree of bowl and deaerating degree of meat batter.

Estimation of the influence of factors mentioned above on quality of meat batters and sausages is till now little valued, however the problem exists and will grow up follow the development of new constructional solutions of meat choppers. This conclusion was explicitly confirmed in experiments done by Dolata [3] and Dolata and Rywotycki [4].

Essential influence on quality of meat batters and sausages demonstarates the shape of geometrical edge of cutting knife in choppers. In industrial choppers are applied knives with different shapes of cutting edge. Results of experiments done up to now, indicate the large divergence of opinions relating shape of chopper knives recommended to the practice.

Taking into considration the shear angle and its dependence of the radius qualifying the distance of point on shear edge of knife and the turn axis, Bakunc [1] divided knives on:

- straight knives – where the angle of shear in every point of blade is equal to zero ($a=0$),
- knives with straight line cut coming together with the radius of turn, where the shear angle diminishes due to the incresase of turn radius ($a1>a2$),
- knives in the shape of circle segment, so-called sickle-shaped knives, where the shear increases due to the increase of turn radius ($a1<a2$),
- knives with shear edge in shape of broken line, so-called broken line shaped knives, where the shear angle on each straight section diminishes due to the increase of turn radius,
- knives in shape of logarithmic spiral segment, so-called logarithmic shaped knives, being characterized by the constant shear angle in all points of shear edge of knife ($a1=a2$).

From the study on individual electric energy consumption during shearing meat with different knives, Pielejew [9] reported that individual consumption of energy was minimal for shear angle of knife $a = 50°\text{-}60°$ and this value was eaual to 0.7 – 0.8 of value obtained for the angle

a=0°. By further increase of shear angle, the individual energy consumption value increases and for shear angle a=70° was equal to 1.20-1.25 of value obtained for a=0°, while afor shear angle a=90° this value brings nearer to the infinity.

In opinion of Milanowski and Diakun [8], the knife of chopper should demonstrate constant shear angle (slip coefficient) on all length of shear edge. It influences on the unification of shear circumstances of raw material, and on the resistance and shear quality of meat batter during comminution.

Honikel and Egginger [6] reported good technological effect by the use of knives with shear edge in shape of broken line. In comparison with sickle shaped knives lower increase of temperature during comminution and lower weight losses during thermal treatment of sausages were observed. These results are confirm also by data collected from the companies SEYDELMANN (Germany) and LASKA (Austria).

In the study presented below knives with shear edge in shape of circle segment were tested. The effect of the work of such knives was evaluated based on quality of obtained meat batters and sausages and the amount of energy consumed during comminution.

MATERIALS AND METHODS

Technical characteristic of chopper

The chopper of F. M. and U. P. S. "SPOMASZ" Company located in Ostrów Wlkp (Poland) was used during the study. Basic technical data of this chopper were as follows: total capacity of bowl-10 dm^3, speed of rotating knives – 2400 rpm, speed of rotating bowl-19 rpm, nominal power of variable current engine propeling knife shaft-1. 1 Kilowatt

Characterization of experimental knives

All knives have been done by the use of stainless steel (type 2 H13). Hardness of knives after tempering was equal to 48 ± 3 HRC. Angle knives sharpening carried out 20°. Each time three knives were assembled on knife shaft. Maximal radius R of knives carried out 0,118 m. Shape and construction of knife coded S II was elaborated based on results of own experiments. Knives coded S I, S III and S IV are typical knifes, most often assembled in choppers working in meat processing industry under commercial conditions. More detailed technical characteristis of tested knives are given in Table 1.

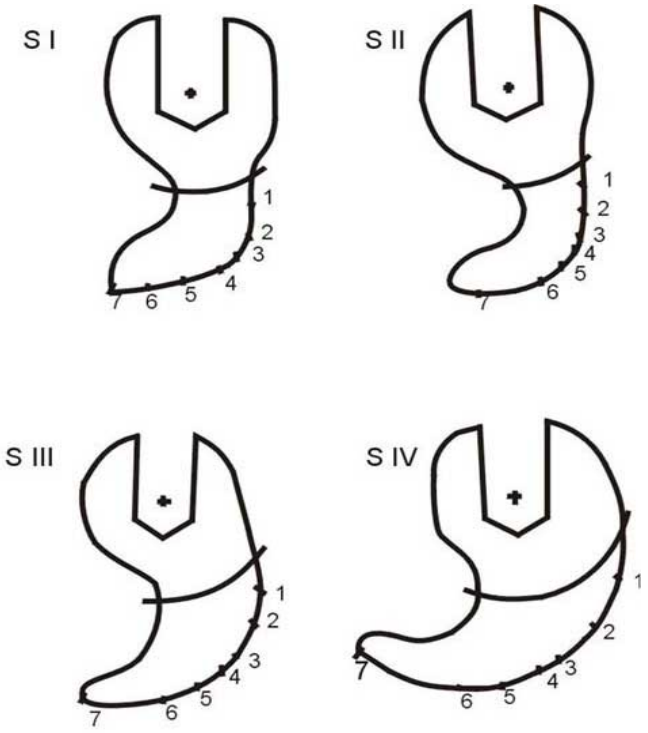
Table 1. Technical parameters of knives

Knives Shape	Length of active shear edge [m]	Friction surface [$m^2 \cdot 10^{-4}$]	Shear angle (degrees) for:						
			0.6 R (1)	0.7 R (2)	0.8 R (3)	0.85 R (4)	0.9 R (5)	0.95 R (6)	R (7)
S I	0.116	26	26	33	52	69	70	71	72
S II	0.131	24	32	34	46	51	62	70	88
S III	0.151	33	48	54	59	65	70	79	89
S IV	0.196	46	60	62	67	72	74	78	88

Organization of experiment

The study was conducted under semitechnical conditions. The work of knives with shear edge in shape of circle segment (sickle shaped knives) with different constructions and shapes (Figure 1) were compared. Experiment has ben done in three charges. The meat batter was collected directly after production, while sausages were collected after 24 h storage in the refrigerator (6-8 °C).

Figure 1. Drawings of the experimental knives- sickle shape knives



Experimental material and technological process

Muscles from shank part of ham and pork trimmed fat of ham were collected in local meat processing plants from chilling hogs 24 h after slaughter. The recipe of experimental sausage was as follows: pork meat without bones (III class) -3 kg, pork trimmed fat-1 kg, water-40 % of batch mass, NaCl-2 %, $NaNO_2$-0, 015 %.

Raw material was first chopped with meat grinder (with mesh of φ = 2 mm) and cured for 24 h in temperatures equal to 4-6°C. Subsequently the raw material was comminuted with addition of ice. Obtained meat batter were stuffed in artificial casing with diameter φ = 35 mm by the use of manual stuffing device. Sausages were smoked with hot smoke (70°C) and scalded in water (72 – 75^{o} C, 20 minutes). After chilling with water, sausages were stored in refrigerator for 24 h in temperature equal to 4-6°C.

Analytical methods

Basic chemical composition, free water content, apparent viscosity and thermal drip of meat batter were determined.

Basic chemical composition, weight losses during production and storage, texture and sensoric evaluation of sausages were also evaluated.

Basic composition was determined using generally accepted analytical methods. Content of free water in meat batter was determined by means of blotting-paper method elaborated by Wołowińska and Kelman [11].

Apparent viscosity was examined by means of rotary viscometer Rheotest 2 type RV, using speed of cutting off equal to D = 1/s.

Thermal drip was determined based on amount of water and fat solution released during thermal treatment of meat batter sample [7].

Weight losses during production and storage of sausages were calculated from differences between mass of sausages before smoking and scalding and after 24 h of storage in refrigerator.

The INSTRON 1140 machine was used for evaluation of texture of experimental sausages including test of compression and test of shear with knife of Warner – Bratzler [10]. For test of compression sausage samples with diameter $\varphi = 2.5 \times 10^{-2}$ m and height 2×10^{-2} m were used. Speed of cap carried out 5×10^{-2} m/min, while speed of register paper tape was 2×10^{-2} m/min. Samples were subjected to twice compression to the half of initial height of sample.

From obtained graph of general texture profile detailed parameters of texture were determined according to method of BOURNE [2]. There are following characteristics: maximal compression force (F_{smaks}) and cohesion (compactness). During shear of samples with Warner – Bratzler knife the maximum shear force (F_{cmax}) and the shear work (A_c) were determined. Speed of knife carried out 0.5 m/min and the speed of registering paper tape was 1m/min. Samples with diameter equal to $\varphi = 2.5 \times 10^{-2}$ m were subjected to measurements.

Sensoric evaluation of sausages was executed by means of 5- points scoring method. The following quality characteristics were evaluated: degree of comminution, cohesion, juiceness and consistence. Five qualified persons took part in evaluation of sausages each time.

RESULTS AND DISCUSSION

Analysis of results showed statistically significant influence of shape of cutting edge of sickle knives on qualitative parameters of meat batters and sausages and electric energy consumption during process of comminution (Tables 2, 3 and 4). The best quality of batters and sausages were obtained if knives coded S II were used. In the meat batter produced by the use of these knives least content of free water, highest apparent viscosity, lowest thermal drip and lowest increase of temperature during comminution were observed (Figure 2, Table 2). Also the texture of sausages produced from this meat batter was the best (Table 3). Weight losses during production and storage of these sausages were lowest, too (Table 4).

Table 2. Mean values of temperature increase, apparent viscosity, free water and electric energy consumption for meat batters comminuted with knives of sickle shape

Characteristics	Unit of measure	Knives				LSD
		S I	S II	S III	S IV	α =0,05
Apparent viscosity	Pa*s	399	409	392	381	6
Free water	%	7.9	7.1	8.4	9.0	0.5
Temperature increase	°C	9.7	9.1	10.4	11.5	0.5
Electric energy consumption per 1 kg of meat batter	kWh	$1.90 \cdot 10^{-2}$	$1.96 \cdot 10^{-2}$	$2.00 \cdot 10^{-2}$	$2.06 \cdot 10^{-2}$	$0.04 \cdot 10^{-2}$

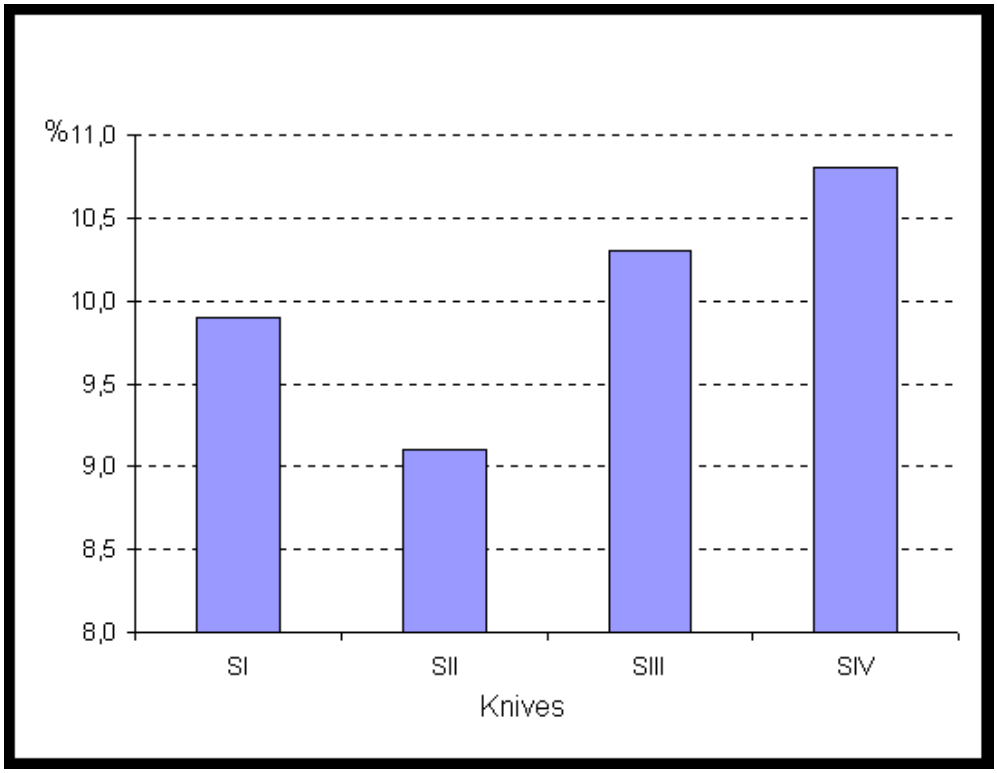
Table 3. Mean values of texture characteristics of sausages: maximum compression force, cohesion, maximum shear force and shear work for knives of sickle shape

Characteristics	Unit of measure	Knives				LSD
		S I	S II	S III	S IV	α =0,05
Max. compression force	N	31.5	32.5	30.9	30.0	0.5
Cohesion	-	0.624	0.635	0.615	0.605	0.008
Max. shear force	N	4.1	4.3	4.0	3.9	0.1
Shear work	J	$8.5 \cdot 10^{-2}$	$9.2 \cdot 10^{-2}$	$8.0 \cdot 10^{-2}$	$7.2 \cdot 10^{-2}$	$0.5 \cdot 10^{-2}$

Table 4. Mean values of total weight loss and sensory hodonic scale test of susages manufactured with knives of sickle shape

Characteristics	Unit of measure	Knives				LSD
		S I	S II	S III	S IV	α =0,05
Weight loss	%	12.1	11.3	12.2	12.9	0.5
Comminution degree	points	3.9	4.1	3.8	3.7	0.1
Cohesion	points	4.1	4.3	3.9	3.8	0.1
Juiceness	points	3.9	4.0	3.8	3.7	0.1
Consistence	points	4.1	4.3	3.9	3.8	0.1

Figure 2. Thermal drip



Results obtained during instrumental analysis corresponded well with results of sensoric evaluation of experimental sausages. Sausages produced from meat batters obtained by the

use of knives coded S II collected highest scores (Table 4). They were comminuted in the best way), demonstrated good cohesion and firm consistence. Similarly, the energy effect for these knives was the best among tested possibilities (Table 2). Only little lower in respect to quality were evaluated meat batters and sausages produced by means of knives coded S I, while the worst results were obtained by sausages produced with the use of knives coded S IV.

Results of experiences with the use of sickle shaped knives confirmed observations made during experiences with other shapes of knives [5]. Obtained results indicated that shear angle, friction surface of knife and length of shear edge are main factors determining shear quality, resistance of friction and shear during meat comminution. These features determined also better useabilty of knife coded S II. Shear angles in zone of greatest speeds of shear with knife S II were shaped on the level: 51°, 62° and 70°, while for knives S I, S III and S IV these values carried out: 69°, 70° and 71°, 65°, 70° and 79° and 72°, 74° and 78°, respectively (Table 1). The friction surface of meat batter with knife S II carried out 24 x 10^{-4} m^2, and f.e. of knife S IV – 46 x 10^{-4} m^2, so it was almost twice lower in comparison to the friction surface of knife S IV. The shear edge of knife S II was also considerably shorter (0, 131 m) as the shear edge of knife S IV (0, 196 m) (Table 1).

CONCLUSIONS

1. The best quality of meat batters and experimental sausages produced with the use of knives in shape of circle segment obtained for the knife coded S II, and the worst results were obtained for the knife S IV.
2. The least electric energy consumption per 1 kg of meat batter was found by the use of knife S II, and highest value of this parameter was observed when the knife S IV was used.
3. About quality of shear and shear and friction resistances during meat comminution with knives of different shapes decide mostly the following factors: the shear angle, the friction surface of meat batter and the length of shear edge.

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