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OPTIMIZATION OF FORCES IN CUTTING POULTRY CARCASSES WITH DISC KNIVES

The object of research was the process of cutting poultry carcasses of chickens, ducks, and geese using disc knives. In the food industry, when processing poultry, and especially when disassembling it, which divides the carcasses into certain parts and sizes, carcass cutting operations are widely used. This process significantly affects the level of energy consumption of the entire production and the quality of the finished product. The main working parts of cutting machines are knives, the purpose of which depends on the entire technological process of chopping.

The dependence of the cutting forces of meat with bones of chickens, ducks and geese on the rotation speed of the disk knife and its sharpening angle at different product temperatures was experimentally established. It was established that with an increase in the cutting speed, the cutting force decreases. Approximate relationships were obtained for quantitative description of the influence of cutting speed on cutting force for different types of poultry, which allow to predict the energy consumption of the process. For producers, the range of cutting speed of poultry carcasses by the disk cutting body of the machine can be recommended from 6.5 to 9 m/s. The influence of the blade sharpening angle on the energy intensity of grinding poultry carcasses was studied; a rational range of sharpening angle was determined, at which cutting forces are minimized while maintaining the stability of the tool. Taking into account the structural and mechanical characteristics of poultry carcasses, operational indicators and technological requirements for the quality and cleanliness of the cut surface, the range of sharpening angle of the knife cutting edge is 20–26°. An applied aspect of using the obtained result is the possibility of improving the design parameters of disk knives and will ensure increased equipment productivity and cutting quality. However, the cutting force depends not only on the species and fatness, but also on the age, sex of the bird and the location of the muscles.

Keywords: *cutting force, poultry carcasses, blade sharpening angle, disc knife, disc rotation speed.*

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1. Introduction

The most important problems of human development (energy, ecology, nutrition) are typical for the food sector, and their solution is associated with the search for fundamentally new approaches to raw material processing [1]. Enterprises that produce food products, especially meat-based ones, must comply with the norms of the international standard ISO 14001:2015 [2]. The development of new technologies to preserve the quality of meat products is of great importance in view of the growing global demand for safe, durable and functional food products that meet modern standards of healthy nutrition [3]. In the conditions of modern production, the relevance of research aimed at increasing the efficiency and acceleration of processes related to the separation of food raw materials is increasing. Innovative technologies in the food industry should focus on the creation of high-performance cutting equipment that ensures the most efficient execution of cutting operations. The implementation of such solutions allows to reduce energy consumption, improve the quality of the final product, increase the productivity of lines, reduce the material consumption of equipment, optimize cutting modes and use wear-resistant tools with coatings that reduce friction. Increasing cutting efficiency is possible due to the reduction of material resistance during division into parts, which is achieved by optimizing the geometry and kinematics of the cutting element – in particular, by changing the cutting speed and the angle of sharpening of the blade.

According to forecasts, by 2050 the world population may grow to approximately 10 billion people. This will lead to an increase in the total global demand for food by 35–56% between 2010 and 2050 [4]. Poultry meat consumption in Europe averages 28 kg per capita and is regularly increasing (+17% over the last decade) [5]. Therefore, one of the main goals of food manufacturers should be not only to improve the quality of food products, but also to reduce the costs of their processing.

Poultry meat mainly comes from a standard production system using fast-growing strains grown in intensive indoor conditions. However, various alternative systems using outdoor large-scale rearing conditions and slow-growing lines can also be found. These different production systems can affect the quality of the poultry carcass and its processing [6]. In the food industry, poultry processing, and especially in the manufacture of canned food, carcass cutting operations are widely used. This process significantly affects the level of energy consumption of the entire production and the quality of the finished product. The main working parts of cutting machines are knives, the purpose of which determines the entire technological process of grinding.

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In poultry processing, almost 20–25% of the live weight is secondary products [7]. These include necks, carcasses, wing tips, backs, legs, breasts, as well as meat and bone residues. These products have a significant weight among the by-products of poultry processing [8].

The process of grinding food products, as well as other parameters of processing technology, significantly affects the quality, biological and nutritional value and shelf life [9]. However, the influence of cutting speed and knife sharpness on the efficiency and productivity of machines associated with poultry carcass cutting operations has not been well documented.

The authors of the work [10] investigated and optimized various designs to increase the efficiency of high-speed cutting tools used for food products. The authors focused mainly on the general patterns of behavior of food materials during cutting; in particular, they determined the initial cutting forces and characterized the effect of speed. The study did not sufficiently analyze the influence of cutting tool parameters on the cutting process. Such parameters include the sharpening angle, blade shape, thickness and type of tool. It has not been sufficiently studied how these parameters affect the cutting force. This is especially true for structurally heterogeneous objects, such as poultry carcasses with skin, muscle tissue and bones.

The main and most important part of a meat grinder is the cutting mechanism. The productivity of all known types of machines is determined by the speed of meat passing through the disk, that is, the speed of exit from the "knife-body" zone [11]. However, studies of cutting forces are devoted to meat grinders for obtaining minced meat, and not to chopping poultry carcasses into pieces.

The study [12] presents the influence of the main internal technical characteristics of the knife on its cutting efficiency. This study prompted the development of a special system for measuring the initial cutting ability and cutting-edge retention. This design process was preceded by the study of test conditions (cutting speed, nature and thickness of the sample, knife inclination angle, etc.), which ensured the optimal operation of the test bench. This equipment was then used to study the influence of the blade inclination angle, steel grade and sharpening angle on cutting efficiency. It was shown that the cutting force varies depending on the inclination of the blade. Therefore, the use of knives with curved blades and/or a blade inclined relative to the knife handle is preferable in terms of reducing the cutting force. However, the studies conducted by the authors did not apply to poultry carcasses. In the food industry, there are many varieties of technical blades with different contours, as well as different cutting-edge geometries. The assessment of the ability of technical blades to separate (cut) animal tissues is not a simple task and is usually based on the assessment of cutting effects in the technological process. A unique feature of the conducted studies was the use of a relatively high value of the cutting speed $V_f = 0.214$ m/s, which corresponded to the real conditions of this process carried out in industry. The obtained test results allow to unambiguously choose the most advantageous variant of the knife geometry from four different variants used for testing and assessing the cutting force of flat technical blades used in flounder processing [13]. However, in this work, the authors studied the configuration of a flat knife, not a disk knife. In [14], it was analyzed how the actual cutting angle changes depending on the angle of inclination and sliding speed of the cutting edge under the conditions of using different sharpening angles. For the oblique cutting method, the relationship between the useful resistance force and the cutting speed at different edge inclination parameters and specified sharpening angles was established. In the case of the sliding mode, it was found how the useful resistance force changes depending on the feed rate, taking into account the variable sliding speed and calculated sharpening angles. The dependence of the transformed dimensionless sharpness of the knife on the angle of inclination of the cutting edge and its sliding speed at different values of the constructive sharpness was also determined. The results obtained demonstrate that under conditions of oblique and sliding cutting, a significant decrease in the useful resistance force is observed compared to standard cutting and the mechanism of fiber destruction also changes, which contributes to increasing the efficiency of the cutting tool. One of the key design parameters of the tool in this case remains the sharpening angle. However, the research is devoted to cutting meat, not meat with bone.

The authors of [15] investigated the effect of imposed vibrations on friction reduction in food samples. However, poultry carcasses were not considered as the object of the study.

According to the authors [16], if when cutting meat products, the unit of energy consumption is taken when cutting with a knife with a rectangular blade shape ($\beta = 90°$), then when cutting with a knife with an angle of 30° the energy consumption is 0.5–0.6 of the above. However, sharpening reduces the stability and durability of the blade and makes it difficult for the knife to exit the material. The study shows that when cutting meat products, the most rational sharpening angle, taking into account the magnitude of the cutting force and energy consumption, is $\beta = 12$–$16°$. At $\beta < 12°$, the cutting resistance increases, the cutting edge becomes crumpled, which leads to rapid blunting of the cutting part of the tool. At $\beta > 20°$, the stability of the cutting part of the tool increases, but the energy consumption for product deformation increases and at $\beta = 45°$ the cutting resistance is 1.5–3 times greater compared to the case of cutting with a blade with $\beta = 10°$.

The authors of [17] found that the sharpness of the blade affects the gripping forces, cutting moments and cutting time. Sharp blades require significantly lower peak and average cutting moments. They also require lower gripping forces than blunt knives.

When studying the influence of the geometry of the cutting tool on the cutting force of fish, it was found that the minimum cutting force is obtained at sharpening angles of the cutting edge from 17° to 25° for knives with different angles of inclination of the cutting edge to the cutting object [13]. It is also noted in the work that when the sharpening angle is reduced to less than 17° and increased to more than 25°, the specific cutting force increases. The type of sharpening at the same sharpening angles of the cutting edge has practically no effect on the cutting force.

The authors of the works [16, 17] note that when the radius of the cutting edge rounding and its height increase, micro-unevenness increases the cutting force. Meat fibers when cut with a blunt blade tear without cutting, the energy consumption for elastic deformation of the meat increases.

The aim of research is to determine the cutting forces of poultry meat depending on the rotation speed and sharpening angle of the blade of the disk knife. This will allow reducing energy costs for the process of grinding poultry carcasses.

2. Materials and Methods

2.1. Poultry carcass samples

The object of research was the process of cutting poultry carcasses of chickens, ducks and geese using disk knives. Poultry carcasses (chickens, ducks and geese) were purchased from meat pavilions in the city of Kyiv (Ukraine): 5 pieces of each species. After transportation to the laboratory, the carcasses were cooled and frozen to a temperature of –5°C before the start of the experiments.

2.2. Description of the experimental unit

To conduct studies of the influence of technological and design parameters on the cutting forces of poultry carcasses in dynamic modes, a unit was developed, the scheme of which is shown in Fig. 1.

The unit consists of a frame 1, on which a lever 2 is fixed, along which the platform 3 moves due to the load 4, which is connected to the platform through the block 5. The knife shaft 6 is driven by an electric motor 7 through a belt drive 8.

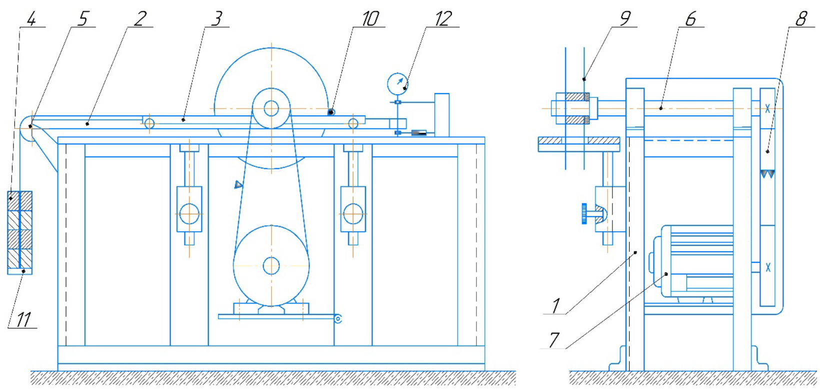

Fig. 1. Scheme of the experimental unit: 1 – frame; 2 – lever; 3 – platform; 4 – load; 5 – block; 6 – shaft; 7 – electric motor; 8 – belt drive; 9 – knives; 10 – material under study; 11 – washer; 12 – dynamometer

A replaceable knife head 9 with cutting knives is fixed on the knife shaft. The cutting speed is regulated by changing the number of revolutions by selecting the diameters of the pulleys D1 and D2.

The process of measuring cutting forces is carried out in the following order.

The object being examined 10 (usually a bird's leg, as the strongest part of the carcass) is fixed on a prism, which is fixedly connected to the platform 3. Previously, the platform is in the extreme right position.

Then, using the drive and tachometer, the necessary experimental rotation frequency of the knife head 9 is set.

After stabilizing the rotation frequency, a corresponding load 4 is installed on the washer 11, due to which the platform 3 with the object under investigation will move, which is pressed against the knives with the corresponding force *Q*.

In the cutting process, forces arise that will deflect the lever 2 along which the platform with the experimental sample moves.

The lever rests on the force plate. The movement of the lever is fixed by means of a tool placed on the stationary table of the installation. The indicator leg rests on the lever.

2.3. Experimental scheme

To determine the rational modes of poultry carcass grinding, comprehensive studies were conducted in laboratory conditions on an experimental unit.

The purpose of the experiments was to determine the dependence of the cutting effort of poultry carcasses on the rotation speed of the disk knife and the angle of its sharpening.

2.4. Statistics

Each measurement was performed three times, and the results are presented as the average value together with the corresponding standard error. Data analysis was performed using Microsoft Excel 2016 and MatCad 14. To determine the presence of significant differences between the samples, a one-way analysis of variance (ANOVA) was applied. Statistical significance was established at *p*-value of less than 0.05.

3. Results and Discussion

The efficiency of the machine for cutting poultry carcasses into pieces is largely determined by the speed of movement of their organs. When the cutting organ interacts with meat products that are ground at positive temperatures, long molecular and non-molecular chains are oriented in the direction of movement of the knife cutting edge.

With an increase in the cutting speed, the force acting on the fiber is less distributed along the fibers and they are cut at smaller elongation values. With an increase in the speed of interaction of the knife blade with the meat product, changes occur in its structure. At positive temperatures, the reorientation of structural elements is less pronounced. This is explained by the different speeds of relaxation processes in different components of the meat structure. The time for the process is reduced, as is the possibility of redistribution of forces in the volumes of meat near the cutting zone.

From this it can be assumed that when cutting by sliding, the speed of movement of the cutting organs is important. With its increase, the volume of meat that is deformed and the number of fibers that are cut simultaneously decreases. As a result, the total cutting force of meat products decreases.

To study the influence of the speed of movement of the cutting organs on the magnitude of the cutting forces, experimental studies were conducted on the proposed installation (Fig. 1). In the process of cutting meat with a blade, local temperature increases occur in the zone of destruction of the meat structure from 10°C at cutting speed of 10 m/s to 135°C at speed of 70 m/s. A large number of temperature rise centers that arise lead to partial denaturation of proteins in places adjacent to the cut surface. Therefore, an immeasurable increase in the cutting speed, in addition to increasing the energy consumption for the process, causes a decrease in the quality of the pieces (the bone "burns"). The selection of cutting speeds, which is recommended, should be carried out taking into account all process indicators. Based on previous studies, taking into account the operation of industrial equipment, the range of changes in the cutting speed within the limits during sliding cutting from 3 to 9 m/s was selected.

The arithmetic average values of the obtained cutting forces are presented in Table 1. Graphical representation of the dependence of tangential Q_τ, normal Q_n, components of the total force Q of sliding cutting of meat with chicken bones is shown in Fig. 2. The average values of the forces of cutting meat with duck and goose bones on the speed of movement of the cutting organ at the sample temperature of minus 5°C, 0°C, +10°C are given in Tables 2, 3.

Table 1

Dependence of tangential Q_τ, normal Q_n, components and total force Q of sliding cutting of meat with chicken bones on the cutting speed V, and temperature at the angle of contact of the knife with the product $\tau = 60°$

Force type Q_n, Q_τ, Q (N/m)	Temperature, °C	Value at cutting speed, V, m/s			
		3	5	7	9
Normal component	–5	127.5	124.4	120	114.4
Tangential component		39.8	34.9	29.1	22.6
Total cutting force		133.7	129.3	123.6	116.8
Normal component	0	123.8	118.8	112.8	111
Tangential component		34	25.2	20.4	19
Total cutting force		128.4	122.1	114.6	112.7
Normal component	+10	112	109.5	106.2	104
Tangential component		19.9	17.4	14.3	12.3
Total cutting force		113.8	110.9	107.3	104.9

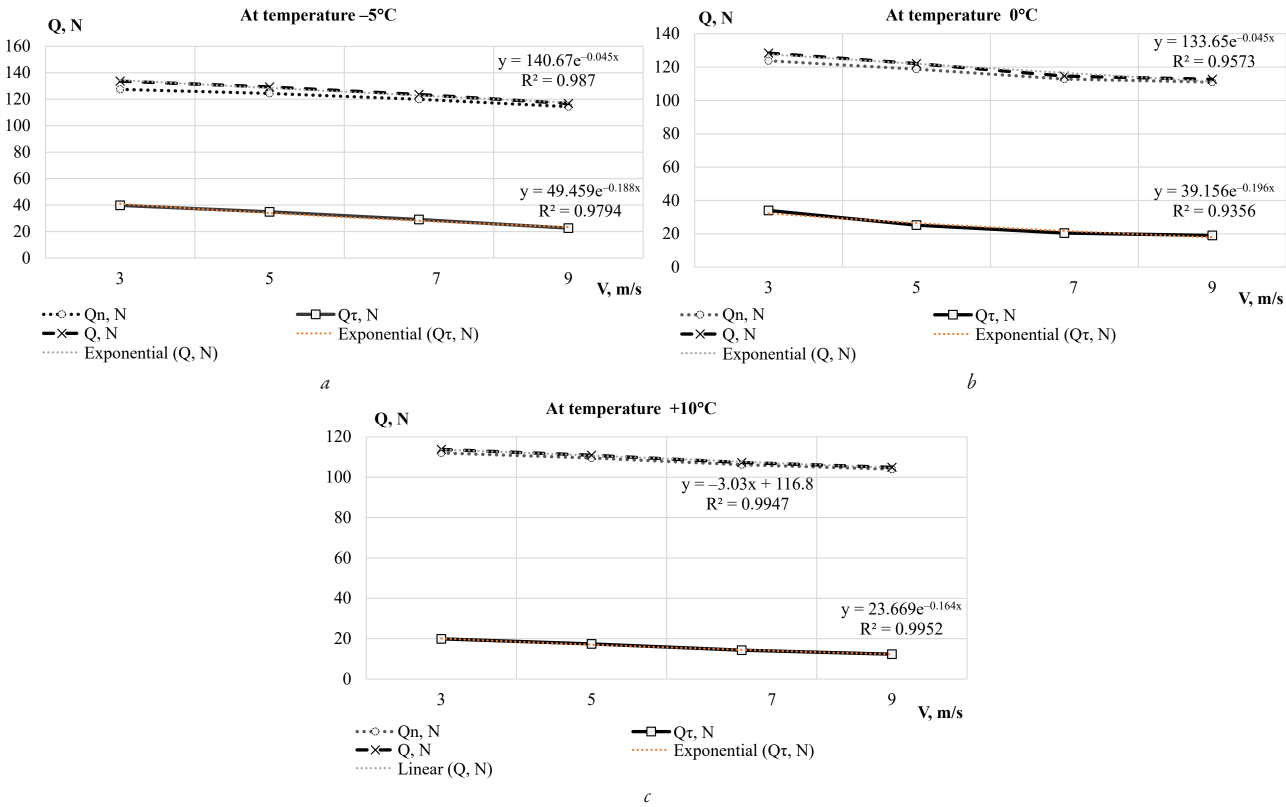

Fig. 2. Dependence of cutting forces (tangential Q_τ, normal Q_n, components and total effort Q) by sliding meat with bones of chickens on cutting speed V, and temperature at the angle of meeting of the knife with the product $\tau = 60°$: *a* – temperature of the poultry carcass –5°C; *b* – temperature of the poultry carcass 0°C; *c* – temperature of the poultry carcass +10°C

Table 2

Dependence of tangential Q_τ, normal Q_n, components and total effort Q of sliding meat with bones of geese on cutting speed V, and temperature at the angle of meeting of the knife with the product $\tau = 60°$

Force type Q_n, Q_τ, Q (N/m)	Temperature, °C	Value at cutting speed, V, m/s			
		3	5	7	9
Normal component	–5	151.5	147.6	142.1	134.8
Tangential component		58.1	51.5	42.9	33.0
Total cutting force		162.3	156.4	148.4	138.7
Normal component	0	146.5	140.4	134.8	130.5
Tangential component		49.6	40.4	33.0	27.7
Total cutting force		154.7	146.1	138.8	133.4
Normal component	+10	131.2	128.0	123.8	120.8
Tangential component		28.6	24.9	20.5	17.6
Total cutting force		134.3	130.4	125.5	122.1

Table 3

Dependence of tangential Q_τ, normal Q_n, components and total force Q of sliding cutting of duck bone-in meat on cutting speed V, and temperature at the angle of contact of the knife with the product $\tau = 60°$

Force type Q_n, Q_τ, Q (N/m)	Temperature, °C	Value at cutting speed, V, m/s			
		3	5	7	9
Normal component	–5	137.1	133.7	128.7	122.5
Tangential component		47.7	42.2	35.1	27.5
Total cutting force		145.2	140.2	133.4	125.6
Normal component	0	132.8	127.3	122.7	118.5
Tangential component		40.9	33.2	27.5	22.8
Total cutting force		139.0	131.6	125.8	120.8
Normal component	+10	119.5	116.7	112.9	110.5
Tangential component		23.7	20.7	16.9	14.7
Total cutting force		121.8	118.5	114.1	111.5

For mathematical description of experimental data of cutting force on speed V of sliding cutting, the MatCad 14 program was used. According to experimental data, the functional dependence was selected

$$Q = a \cdot b^{v}\ (\text{H}), \quad (1)$$

where a, b – constant coefficients given in Table 4; v – cutting speed, m/s.

The magnitude of the coefficients in the functional dependence (1) of sliding cutting force at a temperature of 0°C are given in Table 4.

Table 4

Coefficients of the approximating function $Q = a \cdot b^{v}$ of the dependence of the components of sliding cutting force on the cutting speed at a temperature of 0°C

Bird species	Force	Coefficients of the approximating function $Q = a \cdot b^{v}$					
		meat		bone		meat with bone	
		a	b	a	b	a	b
Chicken	Tangential component	55.6	0.987	103.7	0.99	130.6	0.981
	Normal component	12	0.91	15.8	0.914	45.3	0.899
	Total cutting force	56.6	0.985	104.8	0.989	136.9	0.977
Goose	Tangential component	66.9	0.984	151.8	0.989	155.1	0.981
	Normal component	18.6	0.909	26.3	0.914	66.5	0.906
	Total cutting force	69.0	0.982	153.7	0.988	166.0	0.975
Duck	Tangential component	61.5	0.985	109.6	0.989	104.2	0.981
	Normal component	15.1	0.91	17.8	0.916	54.6	0.907
	Total cutting force	64.3	0.981	110.8	0.988	148.6	0.977

Analysis of the obtained experimental data showed that during sliding cutting, the values of the total cutting force decrease with increasing cutting speed. This can be explained by the fact that with increasing cutting speed, the force acting on the fibers being cut has less time to spread into the product matrix. Fibers in the cutting zone receive a tensile force faster, which is sufficient for their rupture. Therefore, the number of fibers that are simultaneously cut by the edge decreases with increasing cutting speed, i. e. they accumulate less and less in front of the cutting edge and deform smaller and smaller volumes of the product. As a result, better cutting forces are provided for poultry meat, which require less effort to destroy the structural bonds of the product in the cutting zone.

Due to the fact that a decrease in the actual cutting angle and constructive sharpness entails a decrease in the forces of resistance to cutting, undesirable resistance forces decrease with increasing sliding speed. This allows to reduce energy consumption when cutting poultry carcasses.

The sharpening angle of the cutting part of the working organs for cutting poultry carcasses into pieces significantly affects the cutting process. It is known that when cutting fibrous and plate materials, the strength of which is many times lower than the strength of the cutting tool materials, they tend to reduce the sharpening angle of the knife β. This leads to a decrease in the normal component of the total cutting effort, and hence the energy consumption for the cutting process decreases. As the sharpening angle of the cutting tool decreases, the forces of resistance to the penetration of the cutting organ into the product after the destruction of the muscle structure also decrease. Since the speed of displacement of the cut surfaces by the thickness of the wedge decreases and, accordingly, the rate of deformation of the product volumes being chopped decreases. At the same time, with a decrease in the sharpening angle of the cutting tool blade, the rigidity of the wedge section decreases. This leads to bending of the cutting edges of the blade, rapid blunting of the knives and, accordingly, an increase in cutting resistance and the frequency of resharpening of the knives. The experiments were carried out on an experimental unit (Fig. 1).

The experimental dependences of the sliding cutting force Q (H) of poultry carcasses (chickens, ducks, geese) on the angle of sharpening of the knife blade β at a product temperature of $T = 0$°C, a knife-product contact angle of $\tau = 60°$ and different speeds V (m/s) are shown in Fig. 3, and the values are given in Table 5.

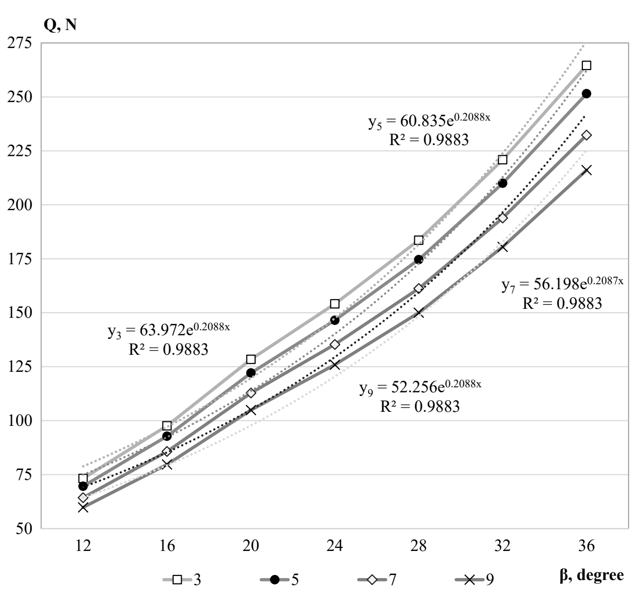

Fig. 3. Dependence of cutting force on the angle of sharpening of the knife blade Q (H) of meat with chicken bones on the angle of sharpening of the knife blade β at product temperature $T = 0$°C, angle of meeting of the knife with the product $\tau = 60°$ and different speeds V, m/s

Table 5

Dependence of sliding cutting force Q (H) of meat with chicken bones on the angle of sharpening of the knife blade β at product temperature $T = 0$°C, angle of meeting of the knife with the product $\tau = 60°$ and different speeds V, m/s

Speed, m/s	The magnitude of the cutting force at the sharpening angle, β, degrees						
	12	16	20	24	28	32	36
3	73.2	97.6	128.4	154.1	183.6	220.9	264.6
5	69.6	92.8	122.1	146.5	174.6	210.0	251.5
7	64.3	85.7	112.8	135.3	161.2	193.9	232.3
9	59.8	79.7	104.9	125.9	150.0	180.5	216.1

For mathematical description of the dependence of the cutting force on the angle of sharpening of the knife blade, the MathCad 14 program was used. According to the experimental data, let's obtain the dependence

$$Q = a + b\beta + c\beta^2 \text{ (H)}, \quad (2)$$

where a, b, c – constant coefficients, the values of which are given in Table 6; β – the angle of sharpening of the blade, degrees.

Table 6 shows the values of the coefficients of the functional dependence (2) of the sliding cutting force of poultry carcasses (chickens, ducks, geese) at a temperature of 0°C.

Table 6

Data on the coefficients of the approximating function $Q = a + b\beta + c\beta^2$ of the dependence of the sliding cutting force on the angle of sharpening of the knife blade at a product temperature of $T = 0$°C and a cutting speed of $V = 5$ m/s

Type of poultry carcass	Approximating function coefficients $Q = a + b\beta + c\beta^2$								
	meat			bones			meat with bones		
	a	b	c	a	b	c	a	b	c
Chickens	0.905	1.213	0.041	18.838	2.277	0.078	23.324	2.813	0.096
Ducks	0.925	1.377	0.045	19.974	2.394	0.082	24.981	3.046	0.103
Geese	1.955	1.449	0.049	27.462	3.323	0.114	42.786	2.636	0.163

The analysis of the obtained data showed that with an increase in the angle of sharpening of the knife, the cutting force increases. As a result of the experiments, it was found that if the angles of sharpening of the knives are less than 16°, then after some time an increase in the cutting force is observed. Under these conditions, the cutting edge of the knife blade bends, its accelerated wear and the need for frequent resharpening occur. As a result, energy consumption increases for the process of cutting poultry carcasses. If the sharpening angle β is more than 20°, the blade's resistance to bending and chipping increases, and the radius of rounding of the cutting edge of the knife increases. The rate of deformation of the product by the side faces of the wedge of the working body also increases, which leads to an increase in the magnitude of the cutting forces.

At the same time, the volume of the product that is deformed by the cutting body also increases, which leads to an increase in the normal component of the cutting force.

Based on the results obtained, poultry processing equipment manufacturers can improve the design parameters of disc knives, which directly affects the efficiency of the cutting process. Thanks to the study of the dependence of the cutting force on the rotation speed and the sharpening angle of the blade, the optimal ranges of these parameters were determined, namely:

– the recommended range of rotation speed of the disc knife is from 6.5 to 9 m/s. In this range, a decrease in the total cutting force is observed, which, in turn, reduces the energy consumption of the entire production process. The ability to predict energy costs using the obtained approximate dependencies allows enterprises to accurately calculate and optimize their production capacities;

– the rational range of the sharpening angle of the cutting edge of 20–26° was determined. In this range, the minimum cutting force is achieved while maintaining the stability of the tool. The use of knives with a sharpening angle of less than 16° leads to rapid wear and the need for frequent resharpening, while angles greater than 26°, although increasing blade stability, significantly increase cutting forces and energy consumption.

The data obtained allow manufacturers to create machines that operate with optimal parameters, ensuring reduced operating costs and increased productivity of poultry processing lines.

The results of the research are valuable for optimizing the process of cutting poultry carcasses, but their application in practice has certain limitations that must be taken into account.

The study was conducted at temperatures of −5°C, 0°C and +10°C. These results may not be fully representative of carcasses processed at other temperature regimes, for example, during deep freezing. Also, the study covered only chicken, duck and goose carcasses. The cutting force also depends on the age, sex and fatness of the bird, which was not fully taken into account. Therefore, to implement the results in practice, it is necessary to conduct additional studies for other types of poultry and their specific characteristics.

The experiments were conducted using one type of knife (disc) and one angle of contact of the knife with the product (60°). In real production conditions, knives of a different configuration and other cutting angles can be used, which may affect the final result.

Further studies can be aimed at optimizing the geometric parameters of disc and other types of knives, as well as cutting modes to reduce cutting forces and energy consumption. It is important to study the influence of the structure of carcasses on the quality of processing and wear of cutting organs, as well as research with carcasses of other types of poultry.

4. Conclusions

1. It has been established that with increasing cutting speed, the cutting force decreases. The minimum energy consumption for the cutting process is achieved in a certain range of speeds. Product quality and the cleanliness of the cut surface also depend on the cutting speed. It is recommended for manufacturers to use the cutting speed of poultry carcasses by the disk cutting body of the machine in the range from 6.5 to 9 m/s.

2. Taking into account the structural and mechanical characteristics of poultry carcasses, operational indicators and technological requirements for the quality and cleanliness of the cut surface, the range of the sharpening angle of the knife edge is 20–26°.

3. The cutting force of chicken meat and bone raw materials is lower compared to waterfowl meat and bone raw materials (ducks, geese). However, the cutting force depends not only on the type and fatness, but also on the age, sex of the bird and the location of the muscles.

4. The established cutting modes ensure the cleanliness of the cut surface and the preservation of the meat structure, which reduces the loss of meat juice and increases the nutritional value of the product. Optimization of grinding parameters contributes to the improvement of organoleptic properties and creates the prerequisites for improving technological processes in the meat processing industry.

Conflict of interest

The authors declare that they have no conflict of interest regarding this research, including financial, personal, authorship or other, which could affect the research and its results presented in this article.

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The research was conducted without financial support.

Data availability

The manuscript has no related data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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