

## Influence of freezing regimes on the quality, physico-chemical and functional-technological characteristics of quail meat and semi-finished products from it

DAVIT TSAGAREISHVILI – DODO TAVDIDISHVILI – OTARI SESIKASHVILI – ELENE GAMKRELIDZE

### Summary

Freezing dynamics of quail meat and minced semi-finished products were studied during the freezing process in various modes. The cooling-freezing curves were constructed and the duration of the cooling, crystal formation and freezing processes was determined. The physico-chemical and functional-technological characteristics of samples frozen by different methods was investigated. It was established that the best results were achieved by the shock freezing method at a temperature of  $-30\text{ }^{\circ}\text{C}$  using speed  $9.4\text{ m}\cdot\text{s}^{-1}$  and humidity 85 %, when mass losses amounted to 0.5 % and 0.7 %, respectively, in the case of quail meat and minced semi-finished products, water holding capacity 72 % and 68 % and water binding capacity 67 % and 80 %, respectively. The characteristic of fat retention of unfrozen quail meat was established at 25 %. It was determined that after five weeks of storage in shock freezing storage cells, the pH value of quail meat and crushed semi-finished product was pH 5.79 and pH 5.80, acid number values  $5.25\text{ mmol}\cdot\text{kg}^{-1}$  and  $5.27\text{ mmol}\cdot\text{kg}^{-1}$ , and peroxide values  $9.1\text{ mmol}\cdot\text{kg}^{-1}$  and  $9.7\text{ mmol}\cdot\text{kg}^{-1}$ , respectively. Thus, the shock freezing method allows to improve the quality of products and functional-technological indicators in less time and less costs. It can be used in various ready meals after their long-term storage.

### Keywords

quail breast meat; shock freezing; minced semi-finished product; quality characteristic; physico-chemical characteristic; functional-technological characteristic

Reduction of food protein deficiency and the search for the new sources of proteins are very important contemporary problems. It is especially relevant to expand the use of raw materials containing a wholesome protein of animal origin. In this regard, quail meat is in focus, the increase in supply of which is facilitated by the rapidly growing rates of development of quail farming in recent years. A study of the quality of quail meat of various breeds bred in Georgia showed that quail meat has a high protein content, a moderate amount of fat and a relatively low energy value. An amount of 100 g of quail meat satisfies daily needs of a person for protein at a level of 41.4 % and for fat at a level of 8.4 % [1]. Quail meat pro-

tein contains all the essential amino acids in an optimal ratio, has no limited amino acids and 100 g of meat satisfies the daily needs of a person at a level of 28–48 % [2]. Quail meat is balanced in terms of fatty acid composition; with the content of polyunsaturated fatty acids it exceeds the “ideal protein” benchmark by three times and, at the same time, it contains less unsaturated fatty acids than other types of poultry meat [3, 4]. The content of fatty acids, amino acids, cholesterol, vitamin E, total cholesterol, and some basic macro- and micro-elements testifies to the high nutritional value of quail meat [4]. Quail meat has a higher protein content [4] and a moderate, balanced indicator (composition) of fat compared to chicken meat;

**Davit Tsagareishvili, Otari Sesikashvili**, Department of Mechanical Engineering, Faculty of Engineering – Technical, Akaki Tsereteli State University, 59 Tamar Mepe Str., 4600 Kutaisi, Georgia.

**Dodo Tavidishvili**, Department of Food Technology, Faculty of Engineering-Technological, Akaki Tsereteli State University, 59 Tamar - Mepe Str., 4600 Kutaisi, Georgia.

**Elene Gamkrelidze**, Department of Chemical Technology and Ecology, Faculty of Engineering – Technological, Akaki Tsereteli State University, Tamar Mepe Str. 59, 4600 Kutaisi, Georgia.

*Correspondence author:*

Otari Sesikashvili, e-mail: otar.sesikashvili@atsu.edu.ge

it contains less muscle tissue fat, which is why it is characterized by a lower energy value [5]. It is noteworthy that the meat of wild birds is characterized by a low fat-holding capacity; in particular, fat-holding capacity for quail meat is 25 % and for chicken meat is 31 % [3, 5].

According to data of IONIȚĂ et al. [6], the quail carcass yield varies within 67.8–78.0 %, its protein content is higher than that of broiler chicken and duck, its fat content is relatively low and its vitamins and minerals content is higher [2, 7]. The foregoing indicates the completeness of quail meat and its good dietary properties, which is why the demand for it is rapidly increasing in many countries. Considering that breeding quail is a fast-growing and quick-maturing branch of poultry farming [8], this demand can actually be met by producing frozen semi-finished products from it.

The functional and technological indicators of frozen semi-finished products are affected by, on the one hand, the increase in the size of ice crystals formed during freezing of free water in the meat. This leads to destruction of the tissue structure and, on the other hand, release of the moisture contained therein during the extraction from the damaged tissue. All this leads to mass losses and the latter is directly linked to functional and technological disadvantages [9, 10]. Based on these facts, practical relevance is given to the selection of the freezing mode, which will allow us to maintain or improve the functional, technological and qualitative parameters of quail meat. Special importance is given to the study of the dynamics of changes in the freezing temperature of semi-finished products, the influence of freezing methods on the nature of temperature changes, as well as the duration of storage, physico-chemical and functional-technological aspects.

Knowledge obtained by studying the freezing dynamics will allow construction of experimental curves based on experimental data, identifying areas of cooling, crystallization and freezing on these curves, as well as observing the nature of changes in these areas over time when using various methods of freezing. Depending on which method provides minimal damage to the tissue structure of quail meat, optimal freezing conditions can be chosen and storage duration with preserved quality can be estimated.

Based on the above, the purpose of this study was to characterize the freezing process of quail meat and its minced semi-finished products. Also, their physico-chemical, functional and technological indicators were studied. In particular, it was necessary:

- to study the freezing temperature change

of quail meat and its minced semi-finished products over time under the conditions of freezing with various methods,

- to determine the optimal freezing conditions and choose the freezing method,
- to study the physical and chemical indicators of frozen quail meat and its minced semi-finished products,
- to study the functional and technological characteristics of quail meat and its minced semi-finished products,
- to define the possibility of using quail meat and its ground semi-finished products in functional nutrition.

## MATERIALS AND METHODS

### Samples

The objects of research were the following types of samples:

- Manchurian quail breast meat – hereinafter referred to as quail breast meat,
- minced semi-finished product of quail breast meat,
- broiler chicken breast meat – hereinafter referred to as chicken breast meat (control sample).

We bought slaughtered quail at the quail farm in Odilauri Village of Terjola municipality in Georgia and slaughtered chickens at a poultry factory in the Etsera Village in Georgia of the same municipality. This was because according to the current legislation, slaughtering is permitted only at the slaughterhouses.

For a separate experimental study, we used three samples for a separate research object. The studies were conducted in the Laboratory of Refrigeration Equipment and Food Production Technology (Akaki Tsereteli State University, Kutaisi, Georgia).

### Equipment

We studied the freezing process using the natural convection method in a traditional, conventional type of freezing cell D400DF (Klimasan, Manisa, Turkey), at a temperature of  $-18^{\circ}\text{C}$ , an air circulation speed of  $0.1\text{ m}\cdot\text{s}^{-1}$  and a relative humidity of 85 %. The quick freezing process at a temperature of  $-30^{\circ}\text{C}$ , with an air circulation speed of  $9.4\text{ m}\cdot\text{s}^{-1}$  and a relative humidity of 87 %, was investigated using a shock freezing device 15×GN 1/1 model (Thermotechnika Crown Cool, Brno, Czechia). We completed the freezing process (that is, we considered the meat

frozen) when its temperature in the depth of the meat tissue was  $-10^{\circ}\text{C}$ . We used a meat grinder FMG-1113 (Franko, Berlin, Germany) to obtain the minced semi-finished product. We measured the temperatures inside the product using a digital multimeter Aneng DT9208A (Zotech, Taipei, Taiwan) with a contact thermocouple. The measurement range varied between  $-40^{\circ}\text{C}$  and  $1370^{\circ}\text{C}$ , the measurement error was 1.5 %.

## Methods

Regarding physico-chemical characteristics, we determined pH [7] using the pH meter COM-360 (HM Digital, Redondo Beach, California, USA), the acid number by method ISO 660:2020 [11] and the peroxide number by method ISO 3960:2017 [12]. The moisture content was determined by method ISO 24557:2009 [13], the proteins content by method ISO 937:1978 [14], the fat content by method ISO 8262-3:2009 [15] and the ash content by method ISO 2171:2007 [16].

We took 60 g of quail breast meat, the average thickness of which was 25 mm and prepared the minced semi-finished product of quail breast meat by passing it through a meat grinder. Then we took 60 g of the product from the obtained mass and placed it in a polymer pan also with a thickness of 25 mm. For comparison, we took a control sample of chicken breast meat with the same dimensions of 25 mm thickness and also placed it in a polymer pan. Chicken breast meat has a different composition than quail meat. We determined the difference between these two in the kinetics of the freezing process and the duration of storage. The comparison of samples of crushed semi-finished products allowed us to determine the influence of the quality of crushing on the shelf life and functional-technological indicators.

In the first case, five samples of quail breast were placed in a traditional freezing refrigerator and frozen at  $-18^{\circ}\text{C}$  at an air velocity of  $0.1\text{ m}\cdot\text{s}^{-1}$  (without air circulation). At the end of each week, we determined the functional-technological parameters for one research object. We also used the shock freezing method during the freezing of research objects. The freezing temperature was  $-30^{\circ}\text{C}$ , and the air velocity was either  $0.1\text{ m}\cdot\text{s}^{-1}$  (without air circulation) or  $9.4\text{ m}\cdot\text{s}^{-1}$  (with air circulation). We repeated these experiments three times for all five samples of the individual research object. We used a similar method for the quail breast semi-finished product and for the control chicken breast meat.

We determined the functional-technological characteristics at the end of each week during five weeks comprising determination of water-bind-

ing capacity by pressing using the Grau-Hamm method [17, 18], determination of water-holding capacity based on the difference between the amounts of moisture released after freezing and storage [19, 20] and determination of mass losses during storage based on the mass difference between the newly frozen and stored products [21]. To determine the mass of products, we used an electronic digital analytical balance SF-400C model (Toms, Qilin, China) with a weighing accuracy of 0.01 g.

## Scientific hypothesis

Freezing at a slow rate leads to deterioration of the quality of frozen products, destruction of the cellular structure and, accordingly, to mass losses. Therefore, the use of a low-temperature environment with a high, maximum effect of heat transfer (cold air inflation method) to ensure a fast freezing process may give us guarantees of maintaining high quality and functional-technological indicators of the products.

## Statistical analysis

To analyse the test parameters of the product, a statistical analysis of the obtained data was conducted and the reliability of the obtained data was evaluated by the method of the mathematical statistics T-test using Windows IBM SPSS Statistics version 20.0 program (IBM, Armonk, New York, USA). To describe the ordered sample, we used statistical functions of the average arithmetic value and the average standard error. We chose a reliability value of  $p < 0.05$ .

## RESULTS AND DISCUSSION

At the initial stage of the study, we determined the chemical composition of quail and chicken breast meats (Tab. 1). The data showed that quail breast meat has a high protein and moderate fat content. An amount of 100 g of quail breast meat meets the daily needs of an adult for animal proteins and fats by 40.4–42.2 % and 7.9–8.3 %, re-

**Tab. 1.** Chemical composition of quail and chicken breast meat.

Indicators	Quail breast meat	Chicken breast meat
Moisture [%]	72.9	69.8
Proteins [%]	20.2	19.0
Fat [%]	5.9	9.1
Ash [%]	1.2	0.9
Energy value [kJ]	558.6	660.7

spectively, and in terms of calories by 4.5–4.7 % [22].

During freezing, the tissue structure of the meat can be damaged but, at this time, there is no loss of moisture because it is in the solid phase in the mesh of the damaged tissue. During thawing, this ice crystals melt, pass into the liquid phase and then leave the product on the surface of the damaged tissue. Therefore, the shorter the defrosting time, the smaller the mass losses. The defrosting time depends on the way of proceeding with the freezing process [10].

Then we studied the temperature change of the quail breast meat and minced semi-finished product over time using various methods and modes of freezing. Fig. 1 and Fig. 2 illustrate that the duration of freezing using the traditional method was 20 min for the quail breast meat and 18 min for the minced semi-finished product and, in the case of freezing with the ultra-fast shock method, 7 min for the quail breast meat and 6 min for the minced semi-finished product. The picture of the temperature change of quail breast meat corresponds to the shape of the curves of the cooling-freezing process and therefore allows us to judge the temperature intervals of cooling, crystal formation and freezing, as well as the duration of these processes, that is, the total time of freezing.

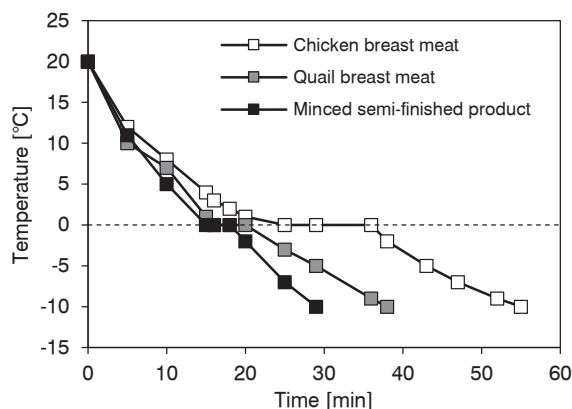
When freezing using the traditional way (Fig. 1), from the total time of freezing to the cooling process (to 0 °C temperature), was 15 min for the minced semi-finished product, 17 min for the quail breast meat and 25 min for the chicken breast meat. The period of crystal formation (horizontal area of the curve) 3 min for the minced semi-finished product, 3 min for the quail breast meat and 11 min for the chicken breast meat and the direct freezing process (temperature interval from 0 °C to –10 °C) 11 min for the minced semi-

finished product, 18 min for quail breast meat and 20 min for chicken breast meat.

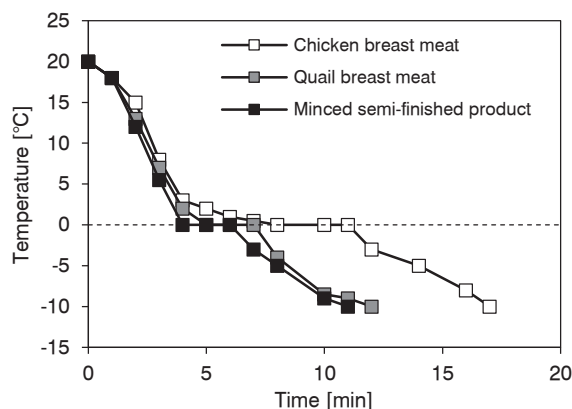
When using the shock-freezing method (Fig. 2), from the total time of freezing to the cooling process (to 0 °C temperature), was 4 min for the minced semi-finished product, 5 min for the quail breast meat and 8 min for the chicken breast meat. The period of crystal formation (horizontal area of the curve) 2 min for the minced semi-finished product, 2 min for the quail breast meat, and 3 min for the chicken breast meat and the direct freezing process (temperature interval from 0 °C to –10 °C) 7 min for the minced semi-finished product; 7 min for quail breast meat and 9 min for chicken breast meat. The magnitudes of the indicators that we obtained were similar to those published previously by FAROUK et al. [23]. The experiment revealed that when using the quick-freezing method, the crystal formation period for quail breast meat was shorter (2 min) than for the control sample (chicken breast meat, 3 min), suggesting that the crystal growth process took less time, the structure was damaged to a lesser degree, there was less mass loss and, accordingly, functional and technological indicators remained better.

The storage time of meat products has a great influence on the processes of acidity changes in them [6, 22]. Therefore, in our research, we studied the magnitudes (indicators) of changes in pH, acid number and oxygen peroxide number of frozen, crushed semi-finished products at various stages of storage.

Tab. 2 shows the values of the pH change, the change in the amount of acidity with respect to active oxygen and the change in the amount of peroxide of quail breast meat, shredded semi-finished products and chicken breast meat frozen in the refrigerator by the shock method. These



**Fig. 1.** Temperature progress during traditional freezing.



**Fig. 2.** Temperature progress during shock freezing.

**Tab. 2.** Physical and chemical indicators of frozen minced semi-finished products.

Samples	Storage time (week)					
	0	1	2	3	4	5
<b>pH</b>						
Quail breast meat	5.87	6.01	5.97	5.95	5.96	5.79
Minced semi-finished product	5.89	6.03	6.05	5.97	5.93	5.80
Chicken breast meat	5.83	5.93	5.91	5.88	5.87	5.74
<b>Acid number [mmol·kg<sup>-1</sup>]</b>						
Quail breast meat	0.52	1.20	1.92	2.10	3.39	5.25
Minced semi-finished product	0.54	1.22	1.94	2.12	3.42	5.27
Chicken breast meat	0.36	0.53	1.44	1.67	2.87	4.05
<b>Peroxide number [mmol·kg<sup>-1</sup>]</b>						
Quail breast meat	0	2.00	4.10	5.90	8.10	9.10
Minced semi-finished product	0	2.20	4.30	6.50	8.50	9.70
Chicken breast meat	0	1.30	2.70	3.50	5.20	6.70

The acid and peroxide numbers are defined in relation to active oxygen.

**Tab. 3.** Mass losses of frozen samples.

Sample	Freezing regimes		
	$T = -18\text{ }^{\circ}\text{C}, v = 0.1\text{ m}\cdot\text{s}^{-1}$	$T = -30\text{ }^{\circ}\text{C}, v = 0.1\text{ m}\cdot\text{s}^{-1}$	$T = -30\text{ }^{\circ}\text{C}, v = 9.4\text{ m}\cdot\text{s}^{-1}$
<b>Mass losses [%]</b>			
Quail breast meat	3.1	1.2	0.5
Minced semi-finished product	3.7	1.5	0.7
Chicken breast meat	4.1	1.8	0.8

$T$  – freezing and temporary storage temperature,  $v$  – air speed in the chamber.

**Tab. 4.** Water holding and water binding capacities of frozen samples.

Sample	Freezing regimes		
	$T = -18\text{ }^{\circ}\text{C}, v = 0.1\text{ m}\cdot\text{s}^{-1}$	$T = -30\text{ }^{\circ}\text{C}, v = 0.1\text{ m}\cdot\text{s}^{-1}$	$T = -30\text{ }^{\circ}\text{C}, v = 9.4\text{ m}\cdot\text{s}^{-1}$
<b>Water holding capacity [%]</b>			
Quail breast meat	65	70	72
Minced semi-finished product	60	64	68
Chicken breast meat	63	67	70
<b>Water binding capacity [%]</b>			
Quail breast meat	57	62	67
Minced semi-finished product	61	68	70
Chicken breast meat	54	63	65

$T$  – freezing and temporary storage temperature,  $v$  – air speed in the chamber.

values indicated that in the control sample these indicators were lower than in the case of quail breast meat and ground semi-finished products, hence the lower the fat content in raw and frozen ground semi-finished products, the higher their acid and peroxide indicators.

Through further studies, we determined the functional-technological indicators of frozen quail breast meat and frozen minced semi-finished products after their heat treatment (cooking). Tab. 3 shows the experimental data of mass loss

of quail breast meat and its minced semi-finished product frozen by traditional and shock methods, as well as the control sample (chicken breast meat) after thawing. The results showed that the mass losses in the first two cases were much less than in the control sample. These data indicated the possibility of wide use of quail meat, minced semi-finished product in various dishes and long shelf life with low mass loss. These results are similar to those previously published by GAMBUTEANU et al. [24].



Tab. 4 presents the experimental data of water-holding and water-binding capacity of frozen quail breast meat, minced semi-finished product and chicken breast meat (control sample) comparing the shock freezing method with the traditional freezing method. We found that in the case of all three samples, better results were obtained using the shock-freezing method, which indicated that the functional-technological characteristics are affected not only by the temperature of the coolant but also by its circulation speed and cooling speed. This is consistent with the data published previously by Jo et al. [25].

Compared with the traditional freezing method, the use of the shock-freezing method improved indicators of water-holding capacity of samples in the case of quail breast meat by 10.7 %. The obtained results were approximately consistent with values described in the works of CHWASTOWSKA-SIWIECKA et al. [26] and LEYGONIE et al. [9].

## CONCLUSION

The combination of the data obtained indicates that different methods of freezing give us a different picture of freezing time, which is due to the different physical properties of ice and water as well as their impact on the tissue structure. Freezing at a slow rate leads to deterioration of the quality of frozen products, destruction of the cellular structure and, accordingly, mass losses. Therefore, to ensure a fast freezing process, it is necessary to use a low-temperature environment ( $-30^{\circ}\text{C}$ ) with a high, maximum effect of heat transfer (with a cooling air circulation speed of speed  $9.4\text{ m}\cdot\text{s}^{-1}$ ), since air flow blowing on the object to be cooled is characterized by a higher heat transfer (cold) coefficient than a non-circulating, stationary air environment. Accordingly, the shock freezing method gives us the desired effect in less time (10–12 min) and with less costs, in order to achieve better quality and functional-technological indicators of the products.

## Acknowledgements

This work was supported by Akaki Tsereteli State University, Kutaisi, Georgia.

## REFERENCES

1. Tavdidishvili, D. – Pkhakadze, M. – Jgamadze, T.: Investigation of the chemical composition and technological properties of the meat of quail bred in Georgia. Bulletin of Akaki Tsereteli State University, 2023, 2023, No. 2(22), pp. 212–221. ISSN: 2233-3711. <<https://moambe.atsu.edu.ge/en/article/474>>
2. Lukanov, H. – Pavlova, I. – Genchev, A. – Penkov, D. – Peltekov, A. – Mihaylova, G.: Quality and composition of meat in different productive types of domestic quail. Journal of Central European Agriculture, 24, 2023, pp. 322–339. DOI: 10.5513/JCEA01/24.2.3871.
3. Boni, I. – Nurul, H. – Noryati, I.: Comparison of meat quality characteristics between young and spent quails. International Food Research Journal, 17, 2010, pp. 661–667. ISSN: 2231-7546. <[http://www.ifrj.upm.edu.my/17%20\(03\)%202010/IFRJ-2010-661-666%20Nurul%20Malaysia.pdf](http://www.ifrj.upm.edu.my/17%20(03)%202010/IFRJ-2010-661-666%20Nurul%20Malaysia.pdf)>
4. Quaresma, A. G. – Antunes, I. C. – Gil Ferreira, B. – Parada, A. – Elias, A. – Barros, M. – Santos, C. – Partidário, A. – Mourato, M. – Roseiro, L. C.: The composition of the lipid, protein and mineral fractions of quail breast meat obtained from wild and farmed specimens of Common quail (*Coturnix coturnix*) and farmed Japanese quail (*Coturnix japonica domestica*). Poultry Science, 101, 2022, article 101505. DOI: 10.1016/j.psj.2021.101505.
5. Gecgel, U. – Yilmaz, I. – Gurcan, E. K. – Karasu, S. – Dulger, G. C.: Comparison of fatty acid composition between female and male Japanese quail meats. Journal of Chemistry, 2015, 2015, article 569746. DOI: 10.1155/2015/569746.
6. Ioniță, L. – Popescu-Micloșanu, E. – Roibu, C. – Custură, I.: Bibliographical study regarding the quails' meat quality in comparison to the chicken and duck meat. Universitatea de Științe Agricole și Medicină Veterinară "Ion Ionescu de la Brad" Iași, seria Zootehnie, 56, 2011, pp. 224–229. ISSN: 1454-7368. <[https://www.uaia.ro/firaa/Pdf/Pdf\\_Vol\\_56/L\\_Ionita.pdf](https://www.uaia.ro/firaa/Pdf/Pdf_Vol_56/L_Ionita.pdf)>
7. Genchev, A. – Myhaylova, G. – Ribarski, S. – Pavlov, A. – Kabakchiev, M.: Meat quality and composition in Japanese quails. Trakia Journal of Sciences, 6, 2008, pp. 72–82. ISSN: 1312-1723. <[http://tru.uni-sz.bg/tsj/TJS-Vol.6%20N4%202008/Genchev\\_kachestvoEn.pdf](http://tru.uni-sz.bg/tsj/TJS-Vol.6%20N4%202008/Genchev_kachestvoEn.pdf)>
8. Faitarone, A. B. G. – Pavan, A. C. – Mori, C. – Batista, L. S. – Oliveira, R. P. – Garcia, E. A. – Pizzolante, C. C. – Mendes, A. A. – Shere, M. R.: Economic traits and performance of Italian quails reared of different cage stocking densities. Brazilian Journal of Poultry Science, 7, 2005, pp. 19–22. DOI: 10.1590/S1516-635X2005000100003.
9. Leygonie, C. – Britz, T. J. – Hoffman, L. C.: Impact of freezing and thawing on the quality of meat: Review. Meat Science, 91, 2012, pp. 93–98. DOI: 10.1016/j.meatsci.2012.01.013.
10. Tsagareishvili, D. – Tavdidishvili, D. – Tsagareishvili, Sh.: Study and comparative analysis of the dynamics of changes in freezing and thawing temperatures of chicken meat. Bulletin of Akaki Tsereteli State University, 2023, 2023, No. 1(21), pp. 161–171. ISSN: 2233-3711. <<https://moambe.atsu.edu.ge/en/article/447>>
11. ISO 660:2020. Animal and vegetable fats and oils. Determination of acid value and acidity. Geneva :

- International Organization for Standardization, 2020.
12. ISO 3960:2017. Animal and vegetable fats and oils. Determination of peroxide value – Iodometric (visual) endpoint determination. Geneva : International Organization for Standardization, 2017.
  13. ISO 24557:2009. Pulses. Determination of moisture content. Air-oven method. Geneva : International Organization for Standardization, 2009.
  14. ISO 937:2023. Meat and meat products. Determination of nitrogen content – Reference method. Geneva : International Organization for Standardization, 2023.
  15. ISO 8262-3:2005/IDF 124-3:2005. Milk products and milk-based foods. Determination of fat content by the Weibull-Berntrop gravimetric method (Reference method). Geneva : International Organization for Standardization, 2005.
  16. ISO 2171:2023. Cereals, pulses and by-products. Determination of ash yield by incineration. Geneva : International Organization for Standardization, 2023.
  17. Ahn, J. Y. – Kil, D. Y. – Kong, C. – Kim, B. G.: Comparison of oven-drying methods for determination of moisture content in feed ingredients. *Asian-Australasian Journal of Animal Sciences*, 27, 2014, pp. 1615–1622. DOI: 10.5713/ajas.2014.14305.
  18. Pouttu, P. – Puolanne, E.: A procedure to determine the water-binding capacity of meat trimmings for cooked sausage formulation. *Meat Science*, 66, 2004, pp. 329–334. DOI: 10.1016/S0309-1740(03)00107-4.
  19. ISO 2173:2003. Fruit and vegetable products. Determination of soluble solids – Refractometric method. Geneva : International Organization for Standardization, 2003.
  20. Joo, S.-T.: Determination of water-holding capacity of porcine musculature based on released water method using optimal load. *Korean Journal for Food Science of Animal Resources*. 38, 2018, pp. 823–828. DOI: 10.5851/kosfa.2018.e18.
  21. Ziv, C. – Fallik, E.: Postharvest storage techniques and quality evaluation of fruits and vegetables for reducing food loss. *Agronomy*, 11, 2021, article 1133. DOI: 10.3390/agronomy11061133.
  22. Azmi, A. F. M. – Roslan, W. N. H. W. – Rashid, A. Z. Z. A. – Ngoo, S. A. M. H. – Noor, M. H. M. – Rashid, M. A. – Saad, M. Z. – Adl, D. N. – Hassim, H. A.: Effects of adding soybean waste on growth performance and carcass quality in quails. *Advances in Animal and Veterinary Sciences*, 11, 2023, pp 1307–1312. DOI: 10.17582/journal.aavs/2023/11.8.1307.1312.
  23. Farouk, M. M. – Wieliczko, K. J. – Merts, I.: Ultra-fast freezing and low storage temperatures are not necessary to maintain the functional properties of manufacturing beef. *Meat Science*, 66, 2004, pp. 171–179. DOI: 10.1016/S0309-1740(03)00081-0.
  24. Gambuteanu, C. – Borda, D. – Alexe, P.: The effect of freezing and thawing on technological properties of meat: Review. *Journal of Agroalimentary Processes and Technologies*, 19, 2013, pp. 88–93. ISSN: 2069-0053 (print), 2068-9551 (online). <[https://journal-of-agroalimentary.ro/admin/articole/48037L15\\_Vol\\_19\\_1\\_2013\\_88-92.pdf](https://journal-of-agroalimentary.ro/admin/articole/48037L15_Vol_19_1_2013_88-92.pdf)>
  25. Jo, Y.-J. – Jang, M.-Y. – Jung, Y.-K. – Kim, J.-H. – Sim, J.-B. – Chun, J.-Y. – Yoo, S.-M. – Han, G.-J. – Min, S.-G.: Effect of novel quick freezing techniques combined with different thawing processes on beef quality. *Food Science of Animal Resources*, 34, 2014, pp. 777–783. DOI: 10.5851/kosfa.2014.34.6.777.
  26. Chwastowska-Siwiecka, I. – Kondratowicz, J. – Gugolek, A. – Matusiewicz, P.: Changes in the physicochemical properties of deep-frozen rabbit meat as dependent on thawing method. *Veterinarija ir Zootechnika*, 62, 2013, pp. 68–72. ISSN: 1392-2130. <<https://vetzoo.lsmuni.lt/data/vols/2013/62/pdf/siwiecka.pdf>>

Received 12 June 2024; 1st revised 10 July 2024; accepted 30 July 2024; published online 8 November 2024.