*no. 2 (2025), pp. 101-112*
*ISSN 1857-0003 E-ISSN 2587-3202*

**DOI:** https://doi.org/10.55505/sa.2025.2.10
**UDC:** 637.5'692.05

# QUALITY AND SAFETY EVALUATION OF REFRIGERATED VACUUM-PACKED RABBIT MEAT

**Alisa PÎRLOG**[1], ORCID: 0000-0003-3937-8708,
**Diana CURCHI**[2], ORCID: 0009-0005-1700-9567,
**Liliana CANTEMIR**[1*], ORCID: 0009-0009-4555-9979,
**Veronica ROTARU**[1], ORCID: 0009-0007-9458-1131,
**Angela LUNCARI**[1], ORCID: 0009-0000-9517-1467

[1]*Technical University of Moldova, Republic of Moldova*
[2]*National Center for Animal and Plant Health and Food Safety, Republic of Moldova*
[*]*Corresponding author: Liliana CANTEMIR - e-mail: liliana.cantemir@mpasa.utm.md*

**Abstract.** This research investigates the quality and safety of vacuum-packed chilled rabbit meat. The study evaluates organoleptic, physico-chemical, and microbiological parameters of rabbit meat stored under vacuum conditions at 0-4 °C for a defined period. The results demonstrate that vacuum packaging effectively extends shelf life, preserving meat's safety and quality. After the full storage period (10 days, plus an additional 3-day reserve period), the meat maintained acceptable organoleptic characteristics, physicochemical stability, and microbiological safety. Laboratory analyses confirmed that chilled rabbit meat is safe for consumption and complies with all current regulatory requirements.

**Keywords:** *Food safety; Rabbit meat; Refrigeration; Vacuum packaging.*

**Rezumat.** Această cercetare investighează calitatea și siguranța cărnii de iepure refrigerate, ambalate în vid. Studiul evaluează parametrii organoleptici, fizico-chimici și microbiologici ai cărnii de iepure păstrate în condiții de vid, la temperatura de 0-4 °C, pe o perioadă determinată. Rezultatele demonstrează că ambalarea în vid extinde eficient durata de păstrare, menținând siguranța și calitatea cărnii. După întreaga perioadă de depozitare (10 zile, plus o perioadă suplimentară de rezervă de 3 zile), carnea și-a păstrat caracteristicile organoleptice acceptabile, stabilitatea fizico-chimică și siguranța microbiologică. Analizele de laborator au confirmat că carnea de iepure refrigerată este sigură pentru consum și respectă toate cerințele de reglementare în vigoare.

**Cuvinte-cheie:** *Siguranța alimentelor; Carne de iepure; Refrigerare; Ambalare în vid.*

## INTRODUCTION

In recent years, increasing focus has been placed on foods that have an extended shelf life, but also retain high nutritional value. Among the technologies used to preserve meat quality, vacuum packaging has proven to be particularly effective in maintaining both the sensory characteristics and nutritional value of rabbit meat. By limiting exposure to oxygen, vacuum packaging significantly reduces lipid oxidation and the proliferation of aerobic microorganisms, which are key factors responsible for meat

spoilage. Consequently, this preservation method extends the shelf life of rabbit meat and significantly reduces economic losses for both producers and distributors (Vissio et al., 2024; Racewicz et al., 2023).

Rabbit meat is distinguished by its exceptionally high nutritional value. From chemical, morphobiochemical, and technological perspectives, it is considered superior to the meat of many other farm animals. It is widely recognized as a dietary, white meat, recommended for individuals of all ages, particularly children, pregnant women, and people suffering from gastrointestinal, hepatic, or cardiovascular diseases. Notably, the protein content of rabbit meat exceeds that of mutton, beef, pork, and veal (Nollet & Toldra, 2006).

From an organoleptic standpoint, rabbit meat is appreciated for its juiciness, tenderness, and mild flavor, often compared to that of chicken. At the same time, it effectively meets nutritional requirements by providing high-quality protein while maintaining a low-fat content, especially in terms of saturated fatty acids. This characteristic is particularly beneficial for individuals affected by obesity or metabolic disorders.

In addition to its favorable protein and fat composition, rabbit meat is a valuable source of vitamins and minerals. It contains such vitamins as C, B6, B12, and PP, as well as essential minerals including iron, phosphorus, cobalt, manganese, fluorine, and potassium. Moreover, rabbit fat is characterized by a low melting point and high digestibility, making it nutritionally superior to the fat of beef, mutton, and pork (Hui, 2012)

Compared to chicken, rabbit meat contains significantly less sodium, approximately 2.7 times less cholesterol, and 2.4 times less cholesterol than veal. Regular consumption of rabbit meat contributes to maintaining optimal lipid levels and a balanced nutrient intake (Снегов, 2014). Age also influences meat composition; as rabbits mature, protein content increases while less valuable protein fractions decrease. (Toldra, 2022). The meat obtained from rabbits aged 4-5 months is considered optimal, as the protein quality index (the ratio of tryptophan to oxyproline) reaches its maximum during this period before gradually declining.

Rabbit meat contains 19 amino acids, including all essential amino acids required for human nutrition. The most important thing is that thermal processing does not alter the qualitative amino acid profile, affecting only their quantitative proportion (Devine & Dikeman, 2014). Of particular significance is the high content of lysine (10.43%), methionine (2.37%), and tryptophan (1.55%). Rabbit fat is white in color, has a dense consistency, begins to melt at 41-42° C, and solidifies at approximately 39° C. It is also richer in essential fatty acids compared to other farm animals.

Muscle tissue represents the most nutritionally valuable component of meat; therefore, a higher proportion of muscle tissue directly correlates with increased nutritional quality. Rabbit meat contains approximately 84-85 % muscle tissue, which is considerably higher than that found in cattle (57-62 %), horses (60-65 %), sheep (50-60 %), broilers (51-53 %), and pigs (40-52 %) (Рыгалова, et al., 2021; Sahoo & Kumar, 2021).

## MATERIALS AND METHODS

Rabbit meat samples were vacuum-packaged and stored under refrigerated conditions at a temperature of 0-4° C. The samples consisted of various commercial cuts obtained from rabbit carcasses, including whole carcasses, half-carcasses, legs, shoulders, chops, ribs, shoulder blades, and fillets. Individual vacuum-packed portions weighed between 0.3 and 1.5 kg.

The objective of the research was to evaluate the microbiological and physicochemical properties of vacuum-packed rabbit meat during 10 days of refrigerated stor-

age. Analyses were conducted at predefined intervals throughout the storage period. Physicochemical assessments included the determination of pH values, water-holding capacity, and evaporative mass losses. In addition, the proximate composition of the meat was analyzed by measuring protein, fat, and moisture content to assess changes in meat quality and stability during storage. Microbiological analyses were performed to evaluate the presence of major foodborne pathogens. The tested microorganisms included *Escherichia coli*, *Listeria monocytogenes*, and *Salmonella spp*., using standard microbiological methods appropriate for meat products.

## RESULTS AND DISCUSSIONS

The assessment of the quality and safety of vacuum-packed rabbit meat for shelf-life determination requires a comprehensive and dynamic evaluation of organoleptic, physicochemical, and microbiological indicators according to the applicable regulatory and normative documents.

In compliance with Government Decision (GD) no. 696 on the approval of the requirements for the production, import, and placing on the market of meat raw materials, as well as IT MD 67-40622912-01:2021, the following organoleptic indices were evaluated for all samples according to the established research protocol: external appearance, appearance in cross-section, odor, and color.

At the initial stage of storage (day 0), the chilled vacuum-packed rabbit meat samples, represented by various cuts of the rabbit carcass, exhibited characteristics consistent with high-quality fresh meat. The external surface was clean, free from foreign impurities, visible bloodstains, fluff, or remnants of viscera. The surface appeared glossy, with a vivid and natural coloration ranging from light pink to pink, without discoloration or stains. No exudate or drained liquid was observed inside the vacuum packaging.

In cross-section, the samples displayed well-developed muscle tissue with a slightly moist and glossy appearance. No hematomas, gray spots, or other defects were detected. The meat exhibited a firm and elastic consistency, with finger pressure marks disappearing rapidly, indicating good freshness. The color of the muscle tissue varied from pale pink to pink, corresponding to the normal characteristics of rabbit meat.

Upon opening the vacuum packaging, the meat released a pleasant, characteristic odor specific to fresh rabbit meat, with no detectable foreign or off-odors. These findings confirm that, at the beginning of the storage period, the vacuum-packed rabbit meat met all organoleptic quality criteria established by the current regulatory standards.

Thus, the chilled rabbit meat from all three batches at day 0 (immediately after refrigeration and vacuum packaging) met the requirements of the GD no. 696/2010 on the approval of the requirements for the production, import, and placing on the market of meat raw material, based on laboratory evaluation of organoleptic indicators.

Subsequently, the organoleptic assessments conducted after 3, 5, and 7.5-8 days of refrigerated storage at 0-4°C demonstrated that the quality characteristics of the chilled rabbit meat remained unchanged and continued to comply with the requirements of GD 696/2010 during the evaluated storage period.

Throughout storage, the rabbit meat samples (various carcass parts) exhibiteda clean, glossy surface with a bright, natural coloration ranging from light pink to pink, without blemishes, foreign impurities, visible bloodstains, fluff, or remnants or viscera. No exudate or drained liquid was observed inside the vacuum packaging. In cross-section, the samples displayed well-developed musculature, with a slightly moist and glossy appearance, free of hematomas and gray spots. The meat maintained a firm and

elastic consistency, with finger pressure marks disappearing rapidly. Upon opening the packaging, the meat released a pleasant odor characteristic of fresh rabbit meat, with no detectable foreign or off-odors.

***Table 1.*** *Organoleptic characteristics of vacuum-packed refrigerated rabbit meat*

| Index | Regulatory requirements (GD no.696/2010) | Results obtained (n=9) | Test method/ normative reference |
|---|---|---|---|
| External appearance | Whole carcasses, half carcasses, or quarter carcasses (front or rear half) must correspond to species, age, and fat cover. Carcasses, half-carcasses, and quarter-carcasses must bear the official stamp of the State Veterinary Service. | Surface clean, glossy, and shiny; vivid, natural coloration; free from stains, foreign impurities, visible bloodstains, fluff, and viscera residues; no exudate or drained liquid observed in the package. | GD No. 696/2010 |
| Color | Characterized by brightness, intensity, and hue specific to the species. | Muscle tissue color ranged from pale pink to pink, characteristic of fresh rabbit meat. | |
| Flavor (odor) | Determined by smell and taste; must be characteristic of fresh meat and free from foreign odors. | Upon opening the package and examining it cross-sectionally, a pleasant odor characteristic of fresh rabbit meat was detected; no foreign or off-odors were present. | |
| Consistency | Fresh meat must have a normal consistency (elastic, firm). Meat with extended storage may be firmer. Spoiled meat is excessively soft, flaccid, crumbly, or abnormally elastic. | Elastic and firm consistency; indentation caused by finger pressure disappeared rapidly, indicating good freshness. | |
| Integrity of carcass parts | Removal of muscle tissue, subcutaneous fat, bones, or other parts from carcasses, half-carcasses, or quarter-carcasses is not permitted; the presence of foreign meat or fat fragments is not allowed. | No removal of tissues or presence of foreign meat or fat fragments was observed in any sample. | GD No. 696/2010 |

After 10 days of refrigerated storage (the established shelf life) at 0-4°C, the organoleptic characteristics of rabbit meat from all three batches showed minor but noticeable changes. The meat surfaces were partially glossy and moist, without signs of stickiness, and retained a vivid, natural coloration ranging from light pink to pink, with no visible discoloration or spots. The consistency became moderately elastic, with finger pressure marks disappearing more slowly than at the initial storage stages. In cross-section, the muscle tissue exhibited no significant changes in color or consistency. Both the surface and cross-section maintained an odor characteristic of fresh rabbit meat, with no detectable foreign or off-odors.

After 13 days of refrigerated storage at 0-4°C, which corresponds to the recommended shelf life of 10 days plus an additional 3 days, based on a reserve coefficient of 1.3, the vacuum-packed rabbit meat from all three batches exhibited early signs of spoilage. Upon opening the packages, the meat emitted a slightly sour odor, characteristic of incipient spoilage. The consistency was partially elastic, with finger pressure marks disappearing slowly, while the color remained pink, with no gray or abnormal discoloration observed. Thus, chilled rabbit meat, vacuum-packed and stored at a temperature of 0-4°C, preserved its sensory characteristics (appearance, cross-sectional appearance, consistency, and odor) for up to 8 (eight) days, with no detectable changes in organoleptic properties.

Organoleptic evaluationof the chilled rabbit meat samples throughout the storage period demonstrated that the sensory quality was maintained s for 8 (eight) days at a temperature of 0-4°C. According to the assessed organoleptic indices, the samples complied with the requirements stipulated in the normative document GD no. 696/2010.

In addition to sensory assessment, the physico-chemical indices of vacuum-packed chilled rabbit meat were also evaluated. Meat quality is influenced by several factors, particularly the initial level of microbiological contamination and the pH value. It is well established that meat with pH exceeding 6.2 exhibits a reduced shelf life. Acidity is one of the main factors inhibiting the development of bacterial microflora, thereby delaying spoilage processes.

The concentration of hydrogen ions in meat is primarily determined by the glycogen content of the muscle tissue at the time of slaughter. In live muscle, the pH value typically ranges between 7,0-7,5. After slaughter, under normal post-mortem conditions, the pH value of the meat decreases relatively rapidly due to the glycolytic process, during which lactic acid is produced. As a result, the pH reaches its ultimate value of approximately 5.4-5.6 within 12-14 hours post-slaughter.

During refrigeration, as the temperature decreases, the pH value in the meat also decreases. Laboratory investigations show a decrease in pH value for all three batches of fish during the 13-day storage period. Initially, vacuum-packed rabbit meat had pH values ranging from 5.8 to6.0, which are specific for fresh meat 15-20 hours after slaughter and subsequent refrigeration at temperatures between -1° and +1°C, with an air circulation rate of 0.8-2.0 m/s.

Throughout storage at 0-4°C, a relatively pronounced decrease in pH was observed. After eight days of storage, pH values ranged from 5.6 to 5.8, while after thirteen days, the pH stabilized within the range of 5.5-5.7. These values indicate favorable conditions for maintaining meat quality and extending shelf life under vacuum-packed refrigerated storage.

***Table 2.*** *Physico-chemical indices of vacuum-packed refrigerated rabbit meat*

| Analyzed parameter | Regulatory requirements | Results obtained | | | DN to test method |
|---|---|---|---|---|---|
| | | Batch I (n=3) | Batch II (n=3) | Batch III (n=3) | |
| | | X ± Sx | X ± Sx | X ± Sx | |
| Protein mass fraction, %, min. | Min. 8,0 | 20,75 ± 0,03 | 21,31 ± 0,02 | 20,78 ± 0,03 | ISO 937 |
| Fat mass fraction, %, max. | De facto | 8,443 ± 0,015 | 8,150 ± 0,016 | 5,528 ± 0,012 | ISO 1443 |
| Chloride mass fraction, %, max. | De facto | 0,108 ± 0,004 | 0,118 ± 0,005 | 0,126 ± 0,007 | GOST 9957-73 |
| pH value, un. | De facto | 5,82 ± 0,08 | 5,83 ± 0,09 | 5,61 ± 0,04 | SM SR ISO 2917 |

* No specific maximum or minimum limits established by GD No. 696/2010 for these parameters in fresh rabbit meat.

The decrease in pH value after slaughter is primarily attributed to several post-mortem biochemical processes. One of the main mechanisms is the degradation of glycogen, whose concentration declines markedly following slaughter as it is converted into lactic acid. The accumulation of lactic acid leads to a progressive reduction in pH. The glycolytic process ceases once the pH reaches approximately 5.4-5.6, a range that is unfavorable for the activity of glycolytic enzymes.

Concomitantly with glycogen degradation, adenosine triphosphate (ATP) undergoes hydrolysis. ATP is broken down into adenosine monophosphate (AMP) and phosphoric acid, further contributing to the acidification of muscle tissue. As a result of these combined processes, the pH of meat gradually decreases from initial values of around 7.1 to approximately 5.6–5.8.

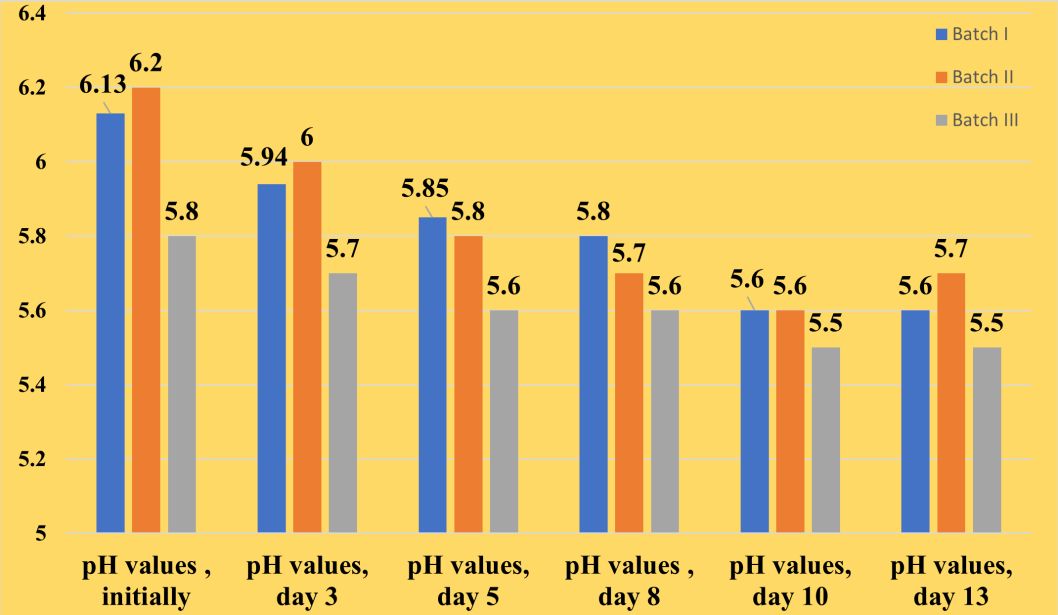


Figure 1. Changes in pH values during storage of vacuum-packed refrigerated rabbit meat

At this pH level, the enzymes of the glycolytic system become inactive, even though residual glycogen may still be present and capable of contributing to lactic acid production. Maintaining a sufficiently low pH and slowing the rate of environmental pH increase over an extended period has a favorable effect on the shelf life of chilled (refrigerated) meat. pH values within the range of 5,6-5,8 create conditions that inhibit or significantly slow the growth of microbial flora, thereby supporting the stability of the sensory indices of vacuum-packed chilled rabbit meat throughout storage.

Rabbit meat is characterized by a considerably lower fat content compared to other types of meat, which accounts for its reduced caloric value. At the same time, it is rich in high-quality protein and contains a higher concentration of essential amino acids, reported to be nearly twice that found in chicken or beef. Regarding lipid composition, the fat fraction of rabbit meat consists predominantly of saturated fatty acids, followed by monounsaturated fatty acids, with polyunsaturated fatty acids present in smaller proportions. As a result of the investigations carried out on the samples of chilled rabbit meat, it can be mentioned that in the examined batches, the fat content values ranged from 5.5 to 8.4 in all three batches. These values are of chilled rabbit meat used as raw material and are consistent with data reported in the specialized literature. Moreover, the results comply with the requirements specified in ISO 1443.

The chloride content determined in the analyzed samples of chilled rabbit meat showed low values, ranging from 0.10 to 0.13. Such values are specific and characteristic of rabbit meat as a raw material. Moreover, this parameter remained relatively stable, showing no significant variation between the analyzed batches.

With respect to the protein composition of rabbit meat, amongthe essential amino acids, tryptophan was present in high concentrations, while phenylalanine was found in the lowest amounts. Nevertheless, rabbit meat represents a rich source of high-quality protein, with a total protein content of approximately 19-20%, making it suitable and valuable for human consumption.

The evaluation of protein content in the examined batches of chilled rabbit meat demonstrated compliance with the regulatory requirements in force, which stipulate a minimum protein content of 8.0%. This condition was fulfilled by all three batches included in the study.

Accordingly, the results presented in Table 3.2 indicate average protein content values of 20.75% for Batch I, 21.31% for Batch IIand 20.78% for Batch III. These values are characteristic of rabbit meat and are consistent with species-specific composition data reported in the literature, while also conforming to the requirements of ISO 937.

***Table 3.*** *Evaluation of peroxidase activity in vacuum-packed refrigerated rabbit meat*

| Index | Regulatory requirements | Results obtained | | | DN to test method |
|---|---|---|---|---|---|
| | | Batch I (n=3) | Batch II (n=3) | Batch III (n=3) | |
| | | X ± Sx | X ± Sx | X ± Sx | |
| Peroxidase reaction | Positive reaction | Positive reaction | Positive reaction | Positive reaction | GOST 7702.1 |
| Positive reaction to peroxidase - characteristic for fresh meat | | | | | |

* A positive peroxidase reaction is characteristic of fresh meat and indicates minimal enzymatic degradation.

The peroxidase value of refrigerated, vacuum-packed rabbit meat is an important indicator of freshness. The investigations conducted onall the batches included in the study confirmed compliancewith the normative requirements in force for this category of products.

One of the key indicators of meat quality preservation is the peroxidase reaction. Peroxidase is an endogenous enzyme present in animal tissues that catalyzes the decomposition of peroxide compounds formed during metabolism processes. The principle of the test is based on the enzymatic breakdown of hydrogen peroxide, during which atomic oxygen is released. This oxygen rapidly oxidizes benzidine to parachinone diimine, which, in combination with benzidine residues, forms a blue-green compound that subsequently turns brown within a few seconds. This reaction is characteristic of fresh meat.

When the initially formed compound exhibits a blue-green coloration that slowly turns brown, the reaction is considered partially negative, indicatingquestionable freshness. In case of a negative reaction, the compound turns brown immediately, which is typical for spoiled meat.

Peroxidase activity is strongly influenced by pH, as follows:

- up to pH=6.0 the peroxidase reaction is positive;
- at pH=6,1-6,2 the peroxidase reaction is considered doubtful;
- at pH > 6,2 the peroxidase reaction is consistently negative.

For chilled, vacuum-packed rabbit meat, peroxidase reaction tests were performed on all 3 batches at each storage stage: initial, after 3, 5, 8, 10, and 13 days of storage. At all research stages of analysis, the peroxidase reaction remained positive, which is a characteristic reaction for fresh meat. This outcome is consistent with the pH values recorded during storage, which remained within the range of 5.5–5.8 up to 8, 10, and 13 days, providing favorable conditions for a positive peroxidase reaction.

***Table 4.*** *Assessment of the acid value (mg KOH/g) in vacuum-packed refrigerated rabbit meat*

| No. | Sample | Shelf life (days) | Regulatory requirements | Acid value mg KOH/g GOST 20235.1 | | |
|---|---|---|---|---|---|---|
| Batches under study | | | | Batch I | Batch II | Batch III |
| 1 | Vacuum-packed chilled rabbit meat | originally | – | 1,9 | 1,7 | 1,5 |
| | | 3 | | 2,1 | 1,9 | 1,5 |
| | | 5 | | 2,5 | 2,0 | 1,6 |
| | | 8 | | 2,6 | 2,2 | 1,7 |
| | | 10 | | 3,0 | 3,0 | 2,0 |
| | | 13 | | 3,2 | 3,5 | 2,0 |
| X ± Sx | | | | 2,550 ± 0,205 | 2,383 ± 0,289 | 1,717 ± 0,095 |

* Acid value (mg KOH/g) is an indicator of lipid hydrolysis; increasing values over storage time reflect gradual fat degradation.

The data presented in Table 4 demonstrate the acidity indices of vacuum-packed chilled rabbit meat, both by batch and by research period (originally, 3, 5, 8, 10 and 13 day).

***Table 5.*** *Evaluation of peroxide value (%) in vacuum-packed refrigerated rabbit meat*

| No. | Sample | Shelf life (days) | Regulatory requirements | Peroxide value, % GOST 34118 | | |
|---|---|---|---|---|---|---|
| Batches under study | | | | Batch I | Batch II | Batch III |
| 1 | Vacuum-packed chilled rabbit meat | originally | – | 0,024 | 0,023 | 0,022 |
| | | 3 | | 0,025 | 0,025 | 0,024 |
| | | 5 | | 0,027 | 0,028 | 0,026 |
| | | 8 | | 0,029 | 0,031 | 0,030 |
| | | 10 | | 0,032 | 0,033 | 0,032 |
| | | 1 | | 0,164 | 0,13 | 0,11 |
| X ± Sx | | | | 0,050 ± 0,023 | 0,045 ± 0,017 | 0,041 ± 0,014 |

* Peroxide value (%) is an indicator of lipid oxidation. Low values at initial and mid-storage stages indicate minimal oxidative deterioration, while increasing values after extended storage reflect the onset of oxidative spoilage.

During refrigerated storage, meat is susceptible to lipid oxidation, which represents one of the factors responsible for quality deterioration. These oxidative processes negatively affect sensory attributes such as flavor, texture, nutritional value, and color. Moreover, lipid oxidation products may act as substrates that promote protein oxidation, further compromising meat quality. The accumulation of oxidation products leads to undesirable organoleptic changes, including rancid odor and discoloration (yellowing) of the tissue. Depending on the nature of the influencing factors and storage conditions, lipid rancidity may occur through different mechanisms, namely:

- hydrolytic rancidity, expressed by the acid value, which results from the hydrolysis of lipids and the subsequent formation of free fatty acids;
- aldehydic (oxidative) rancidity, expressed by the peroxide value, resulting from the autocatalytic oxidation of fatty acids and leading to the formation of peroxides, aldehydes, and organic acids responsible for unpleasant rancid odor and taste.

According to GOST 20235.1, chilled rabbit meat is classified as fresh when the acid value does not exceed 2.25 mg KOH/g, while values between 2.25 and 9.0 mg KOH/g indicate relatively fresh or spoiled meat.

To monitor possible lipid oxidation processes, which may occur as a result of biochemical reactions, the peroxide value and acid value were determined in fat extracted from rabbit meat. Measurements were carried out at the initial stage (day 0) and after 8, 10, and 13 days of refrigerated storage for all three experimental batches (Figure 2). The experimental results indicated that the acid value represents the most sensitive and representative indicator of lipid oxidation processes in rabbit meat during refrigerated storage. In contrast, the peroxide value, which reflects the autocatalytic oxidation of fatty acids, showed low values ranging from 0.024 to 0.164%, suggesting a limited extent of oxidative deterioration. This observation is consistent with the fatty acid composition of rabbit meat, which, according to laboratory analyses, contains only 31.41% saturated fatty acids, compared to a markedly higher proportion of unsaturated fatty acids (68.59%). Furthermore, the comparatively higher acid value (1.5–3.5 mg KOH/g) relative to the peroxide value (0.024–0.164%) indicates that hydrolytic processes preceded oxidative reactions during storage. The progression of lipid oxidation was likely slowed by controlled storage conditions, including limited exposure to atmospheric oxygen, reduced light intensity, and maintenance of a stable refrigerated temperature between 0 and 4°C.

Thus, it was found that initially, the acidity index value was 1.5–1.7 mg KOH/g, insignificant for the fat content of 5.5–8.4% in the product. By the end of the 8-day storage period, the acid value increased slightly by 0–0.5 mg KOH/g, reaching 1.7–2.0 mg KOH/g, values that remained within the regulatory limits established by GOST 20235.1.

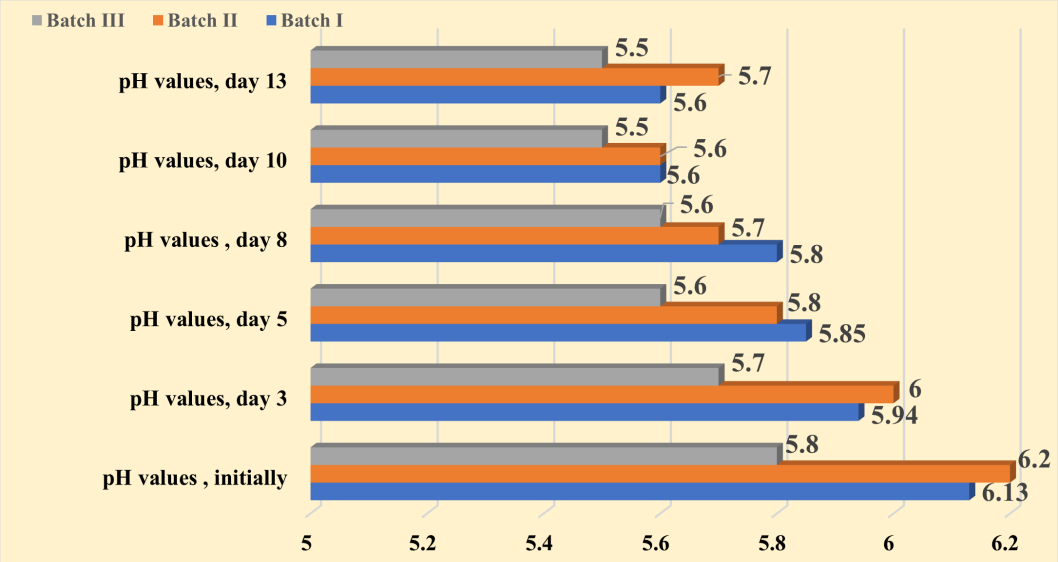


Figure 2. Variation of oxidation/peroxide indices during the shelf-life of vacuum-packed refrigerated rabbit meat

After 10 and 13 days of refrigerated storage, the acidity index values for BatchII exceeded the regulatory threshold of 2.25 mg KOH/g, reaching 3.0–3.5 mg KOH/g. Consequently, lipid oxidation processes in vacuum-packed refrigerated rabbit meat from Lot II can be considered to have initiated on the 10th day of storage. However, the exceedance was moderate and did not result in detectable deterioration of the product's sensory characteristics.

Overall, laboratory tests for determining lipid oxidation indices revealed that vacuum-packed refrigerated rabbit meat exhibits resistance to oxidative degradation for up to 8 days of storage. Throughout this period, under controlled temperatures of 0–4°C, lipid oxidation was not observed, as evidenced by the low acid values and their

minimal variation over time. These parameters did not negatively affect the appearance, aroma, or color of the product, confirming the stability of organoleptic properties during the 8-day storage period.

According to the research program, the refrigerated rabbit meat samples were further analyzed to determine safety and quality indices, including the determination of heavy metals (Pb, Cd), the results of which are presented in Table 6.

***Table 6.*** *Safety indices for vacuum-packed refrigerated rabbit meat*

| Index | Normative requirements | Results obtained | | | DN to test method |
|---|---|---|---|---|---|
| | | Batch I (n=3) | Batch II (n=3) | Batch III (n=3) | |
| | | X ± Sx | X ± Sx | X ± Sx | |
| Lead (Pb), mg/kg | max. 0,1 | 0,023 ± 0,004 | 0,045 ± 0,010 | 0,050 ± 0,006 | SM SR EN 14082:2006 |
| Cadmium (Cd), mg/kg | max. 0,05 | <0,005 | <0,005 | <0,005 | SM SR EN 14082:2006 |

* Both lead and cadmium concentrations in all batches were well below the maximum permissible limits, indicating that the meat is safe for consumption according to current regulatory standards.

The analysis demonstrated that refrigerated rabbit meat is safe and complies with the requirements of the current regulatory framework, specifically Government Decision No. 520/2010 on the approval of the sanitary regulations regarding contaminants in food products. Along with organoleptic, physicochemical, and safety indices, microbiological indices were also determined.

When meat is chilled and stored under refrigeration, microbiological processes may occur in the meat with significant intensity, potentially leading to quality deterioration. The most important factor determining the safety of raw meat is its initial level of microbial contamination. Contamination of carcasses and other slaughter products can occur through both endogenous and exogenous pathways.

Endogenous contamination of tissues and organs with microorganisms can occur during the animal's life or after slaughter. Bacteria originating from the intestinal tract can penetrate the animal's organs and tissues via the circulatory and lymphatic systems. Post-mortem endogenous contamination of slaughter products is possible when there is a delay in the removal of the gastrointestinal tract following slaughter.

Exogenous contamination of meat can occur at any stage of the technological processing, including bleeding, skinning, evisceration, scalding, or cleaning, especially when contaminated equipment is used or when personnel fail to observe proper hygiene practices.

Meat obtained from healthy, well-fed, and unstressed animals, under strict adherence to technological and sanitary requirements, is characterized mainly by superficial microbial contamination. Lowering the temperature of meat during refrigeration, as a preservation method, inhibits the vital activity of microorganisms and disrupts metabolic processes within microbial cells. As a result, the reproduction of thermophilic microorganisms is halted, while the activity of mesophilic microorganisms is significantly reduced.

In this context, an important practical task for the economic operator in extending the shelf life of refrigerated meat is to implement measures aimed at suppressing microbial development. These measures include:

- reducing the initial microbial contamination of raw materials;
- ensuring rapid cooling of the meat;

- carrying out regular sanitary treatment of refrigeration and storage facilities;
- using vapor-tight packaging materials;
- storing packaged meat under controlled environmental conditions;
- applying ozonation and ultraviolet irradiation in refrigeration rooms.

Based on these considerations and in accordance with the applicable normative documents, namely Government Decision No. 221 of 16.03.2009, Regulations on Microbiological Criteria for Food Products, microbiological investigations were conducted at the beginning of the storage period and subsequently after 3, 5, 8, 10, and 13 days of refrigerated storage.

To guarantee the microbiological safety and hygienic quality, all mandatory microbiological indices specified in Government Decision No. 221 were initially examined, and all samples were found to comply with the established criteria. During the storage period, additional microbiological indices with potential impact on product microflora and quality were monitored, such as coliform bacteria, total colony count, E. coli, and sulfite-reducing Clostridia.

Throughout the storage period, hygiene-related indicators in refrigerated meat, such as coliform bacteria and E. coli, were not detected.

The dynamics of changes in microbiological indices, specifically the totalcolony count at 30°C, were monitored throughout the storage period under the conditions specified by the producer. The colony count at 30°C showed only minor variations during the storage period and remained within the limits set by the applicable normative documents. This stability can be attributed to storage at low temperatures, which significantly slows down the growth of the product's microflora.

A decrease in the meat's pH value within the range of 5.5-6.0, along with the stability of this parameter during the storage period, created unfavorable conditions for microbial development, leading to reduced enzymatic activity and reproductive capacity of microorganisms.

Thus, following the evaluation of microbiological indices of vacuum-packed refrigerated rabbit meat, it was established that the products comply with microbiological criteria, and no significant changes in microflora were observed during storage. The results confirm that the meat remains microbiologically safe even after 8 days of storage at temperatures of 0-4°C.

## CONCLUSIONS

Based on the investigations conducted on the quality and safety indices of vacuum-packed refrigerated rabbit meat, the following conclusions can be drawn:

1. The organoleptic characteristics of refrigerated rabbit carcasses vacuum-packed and stored at a temperature of 0-4°C remained stable for a period of 8 days. No changes were observed in appearance, cross-sectional aspect, consistency, or odor, indicating good sensory quality throughout this storage interval.
2. The results of the physicochemical analyses (protein, fat, and chloride content) for samples from all three batches, assessed immediately after refrigeration and vacuum packaging, confirmed the high quality of the rabbit meat. The protein content (20.75%-21.31%) corresponds to the values indicated on the product label (11.2-21.2%, depending on the carcass part), while the fat content (5.5-8.1%) fell within the limits established by normative documents and was consistent with labeled values (6.3-19.0%). These findings demonstrate compliance with established quality requirements.
3. The evaluation of microbiological indices showed that vacuum-packed refrigerated rabbit meat complied with all applicable microbiological criteria. Throughout

the storage period, no significant changes in microflora were detected, and the products remained microbiologically safe for up to 8 days when stored at a temperature of 0–4°C.

4. Laboratory investigations confirmed that refrigerated rabbit meat meets the safety requirements stipulated in the current regulatory framework, particularly Government Decision No. 520/2010 concerning sanitary regulations on contaminants in food products.
5. With respect to shelf life, storage of vacuum-packedrabbit meat from all three batches for 13 days (including the initially requested period of 10 days, extended by an additional 3 days) at 0–4 °C revealed the onset of quality deterioration. Upon opening the vacuum packages, a slight sour odor characteristic of early spoilage was detected. The meat exhibited partially elastic consistency, with slow recovery after finger pressure, while the color remained pink, without gray discoloration or other abnormal pigmentation.

In conclusion, vacuum-packed refrigerated rabbit meat maintains acceptable organoleptic, physicochemical, and microbiological quality for up to 8 days when stored at 0–4 °C, confirming this period as a safe and optimal shelf life under the studied conditions.

## REFERENCES


1. DEVINE, C. & M. DIKEMAN, eds. (2014). *Encyclopedia of Meat Sciences*. 2nd edition, London: Academic Press, 1712 p. ISBN 978-0123847348.
2. HUI, Y., ed. (2012). *Handbook of meat and meat processing*. 2nd edition. Boca Raton: CRC Press, 943 p. ISBN 9781439836835.
3. NOLLET, L. & F. TOLDRÁ, eds. (2006). *Advanced technologies for meat processing*. 1st edition. Boca Raton: CRC Press Taylor & Francis Group, 483 p. ISBN 9780429135323.
4. RACEWICZ, P.; H. BIESIADA; M. MAJEWSKI; A. LUDWICZAK; M. STANISZ et al. (2023). Impact of packaging system on the microbial quality of chilled rabbit meat over 21 days of storage. *Animal Science Journal*, vol. 94 (1). DOI 10.1111/asj.13852.
5. SAHOO, J. & M. Kumar (2021). *Meat, poultry and fish technology*. Daya Publishing House, 851 p. ISBN 9789351308478.
6. TOLDRÁ, F., ed. (2022). *Lawrie's Meat Science*. 9th Edition. United Kingdom: Woodhead Publishing, 890 p. ISBN 978-032385408-5.
7. VISSIO, A.; A. GRYGIER; J. SKŁADANOWSKA-BARYZA; D. KMIECIK, M. STANISZ et al. (2024). Storage of Rabbit Meat in Vacuum Extends the Oxidative Stability of Fat. *European Journal of Lipid Science and Technology*, vol. 126 (12). Disponibil: https://doi.org/10.1002/ejlt.202400146.
8. РЫГАЛОВА, Е. А.; Е. А. РЕЧКИНА; К. А. ГЕРАЩЕНКО; Л. П. ШАРОГЛАЗОВА; Н. А. ВЕЛИЧКО (2021). *Переработка мяса птицы и кроликов*: Учебное пособие. Красноярск: КрасГАУ. 362 с.
9. СНЕГОВ, Александр (2014). *Самый полный справочник кролиководa*. Москва: АСТ, 320 p. ISBN 978-5-17-072559-5.



**Conflict of interests**
The authors declare no conflict of interests.

**Authors' contributions**
All authors contributed equally to this work. All authors read and approved the final manuscript. This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

**Paper history**
Received 02.09.2025; Accepted 23.11.2025