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Quality and safety of pork meat after cooling and treatment with lactic starters

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ABSTRACT

Cooling the pork half-carasses in a refrigerating chamber with showering had no significant impact on their surface temperature. Still, it reduced the core temperature of the meat in 1 hour after cooling compared with air-cooling. pH-value of all pork half-carasses that were subjected to cooling with the showering method, as well as the final processing of the pork with suspensions of *Lactobacillus sakei* and *Leuconostoc carnosum* in 1 hour and on the 4th day of storage in a chilled condition was within the limits typical for fresh and high-quality meat. The greatest weight loss of the pork half-carasses occurred during the first 24 hours when they were being cooled. The weight loss of the pork half-carasses in a chilled condition during 1 day when they were being cooled in a refrigerating chamber without the use of showering was 2.27%, when they were being cooled with the use of showering – 1.65%, when they were being cooled with the use of showering and final processing with SafePro® B-SF-43 (*Leuconostoc carnosum*) – 1.61% and SafePro® B-2 (*Lactobacillus sakei*) – 1.25% in comparison with the output of a hot carcass. Microorganism cultures of strains SafePro® B-SF-43 and SafePro® B-2, when they are applied at a dose of $10^6/\text{cm}^2$, had contributed to a colonization of the meat with the lactic-acid microorganisms and a significant decrease in the number of QMAFAnM in the neck and spine areas in 1 hour after cooling. *S. aureus*, *Salmonella* spp., and *L. monocytogenes* were not detected in the meat of the pork half-carasses in all processing options during 4 days of storage in a chilled condition.

Keywords: quality, safety, pork, storage, stiving

INTRODUCTION

A wide range of factors determines the quality and safety of pork: genetic potential, feeding and rearing conditions of pigs, and conditions of stunning, slaughtering, and post-slaughter ablation of pork carcasses [1], [2]. Nowadays, enterprises specializing in meat processing use many technologies to improve the quality of the final product due to the speed and method of animal slaughter, cooling, and further storage of the carcasses. At the same time, an important criterion is the sensory properties of the meat products that consumers prefer [3], [4].

In the last few years, research on pork cooling has focused on accelerated cooling to minimize carcass weight loss due to evaporation and rates of microbial contamination. Furthermore, the accelerated cooling of the pork carcasses can also be used to improve the physicochemical properties of the meat due to a decrease in metabolic rate, in particular, glycolysis in post-slaughter tissues. In turn, slowing glycolysis leads to less loss of droplet moisture in the muscles and less meat with PSE signs [5].

Understanding the mechanisms underlying the development of water loss in droplet evaporation when the pork carcasses are being cooled will make it possible to reduce the weight loss and preserve the meat quality. It is understood that early post-slaughter processes, including the reduction rate and extent of the pH value, the proteolysis, and even the protein oxidation, are the main processes influencing the moisture-holding capacity of the meat. The cell structures, including the intra- and extra-myofibrillar spaces, retain a significant part of the

muscle water. During the meat's ageing processes, the water's space, which is contained in the myofibrils, decreases, and the fluid can be displaced into the extra-myofibrillar spaces, where it is lost as droplets. The lateral reduction of the myofibrils during the stiffening can be transmitted throughout the cell if the proteins that bind the myofibrils together and the myofibrils with the cell membrane (such as desmin) are not degraded. Recent figures point to the fact that the degradation of key cytoskeletal proteins by calpain proteinases plays a certain part in determining the moisture-holding capacity of the muscles [6]. The microbial contamination of the meat, which occurs during the slaughtering of animals and subsequent operations of primary processing of the pork carcasses, also impacts this process. At the same time, exogenous and endogenous contamination with the bacteria occurs, the sources of which can be the skin cover, the contents of the alimentary tract, air, equipment, vehicles, tools, hands, clothes, and shoes of workers who have contact with the meat, as well as the water, which is used for the pork carcasses to be processed [7].

This microflora causes meat spoilage and can harm the consumer's body. The main human pathogens in terms of microbial hazards, which were found in the animal meat, include *E. coli*, *Salmonella* spp., *Campylobacter* spp., *Listeria monocytogenes*, *Clostridium botulinum/perfringens*, *Staphylococcus aureus* and *Bacillus cereus* [8], [9]. Several scientists attach particular importance to the cross-over contamination of meat products with pathogenic microorganisms, particularly *Listeria monocytogenes* [10], [11]. A significant number of chemicals, in particular, organic acids [12], bacteriocins, essential oils [13], as well as ionizing radiation, hydrostatic pressure, electric fields, sonication, and microwaves [14], are used to reduce the contamination risks of the meat with the microflora. However, these reduction methods of the microbial contamination of the meat have several disadvantages; firstly, they change the organoleptic properties, which affects this product's attractiveness to the consumer.

One of the promising reduction methods for the microbial contamination of the meat is using the microbial cultures of lactic acid microorganisms, which can produce the bacteriocins that can inhibit the growth and reproduction of various bacteria. The action mechanism of the bacteriocins is based on the ability to interact with the cell surface to increase the permeability of its membrane, suppress the formation of the cell wall components, and synthesize the nucleic acids and protein [15].

Among the most common and promising microorganisms capable of producing bacteriocins in the meat industry are bacteria of the genus *Lactobacillus*, in particular, *Lactobacillus sakei*. It is a facultative heterofermenter capable of producing alcohol or lactic acid from sugars. *L. sakei* is used in Europe to produce traditional dry sausages as a starter and can be used to preserve fresh meat [16]. Sakacin P, produced by *Lactobacillus sakei*, has antibacterial activity against *Listeria monocytogenes* and *Bacillus cereus* [17], [18]. The lactic acid microorganism *Leuconostoc carnosum*, which produces leucocin, is also widely known. Its effectiveness has been proven against developing *Listeria monocytogenes* in many meat products [19], [20].

Scientific Hypothesis

Cooling the pork half-carcasses with the use of stiving and final processing of the half-carcass surface by the suspensions of lactic-acid microorganisms *Leuconostoc carnosum* or *Lactobacillus sakei* will reduce the weight loss of the pork half-carcasses due to moisture evaporation and preserve the quality and safety of the meat when stored.

MATERIAL AND METHODOLOGY

Samples

The study material was the pork half-carcasses obtained after the primary processing in the LLC “Antonivsky meat-processing plant” conditions, Kyiv region, Ukraine. The animals were slaughtered in compliance with the current “Rules for pre-slaughter veterinary inspection of animals and veterinary-sanitary examination of meat and meat products” [21], good hygienic practice (GMP), after which the pork half-carcasses were transported to the specialized refrigerating chambers – the lactic acid microorganisms *Leuconostoc carnosum* and *Lactobacillus sakei* produced by Chr. Hansen (LLC “Chr. Hansen Ukraine”) was used for the study.

Chemicals

Media and diagnostic tests manufactured by HiMedia (India) were used for microbiological studies.

Medium M091 Plate Count Agar was used to determine QMAFAnM. For recovery and quantitative counting of the bacteria of the genus *Lactobacillus* – Lactobacillus MRS Agar M641, for recovery of pathogenic and non-pathogenic staphylococci – Baird Parker, Agar M043, for *Salmonella* – Bismuth Sulphite Agar M027 and Xylose Lysine Deoxycholate Agar M031, for *L. monocytogenes* – Agar Palcam, Agar Oxford.

Animals, Plants, and Biological Materials

For research, 20 heads of young fattening pigs of the large white breed aged 6 months, who were slaughtered from a private farm in the Kyiv region, Ukraine, were used. Pork half carcasses weighing 43-44 kg were selected to form groups in the experiment.

Instruments

pH meter for meat EZODO MP-103M Taiwan, GONDO'Electronic Co., Ltd.

Petrie dishes.

Disposable microbiological tubes.

Laboratory Methods

The weight of the pork half-carcasses was determined with the use of industrial scales TV4-1500 in the conditions of the meat-processing plant with an accuracy of 0.1 kg.

The washings from the surface of the pork half-carcasses in the neck and spine area were made to determine the quantity of mesophilic aerobic and facultatively anaerobic microorganisms (QMAFAnM), the bacteria of the genera *Salmonella* spp., *S. aureus*, *Lactobacillus*, *L. monocytogenes*, fungi, and mold. For this purpose, consistent nine-fold dilutions were prepared in a sterile physiological solution.

The quantity of the microorganism was determined in colony-forming units (CFU), and the results were expressed in lg CFU/cm² of the surface. The recovered microorganisms were identified by genus and species using current methods.

The meat of the slaughtered animals (color, smell, consistency, cooking test) was organoleptically evaluated according to DSTU 7992:2015 [22].

Description of the Experiment

Sample preparation: Meat sampling from slaughtered animals and preparation for microbiological tests were carried out according to the requirements of DSTU 8381:2015 [23]. Washings from the meat surface of the slaughtered animals, stored in the refrigeration chambers of the meat-processing plant, were sampled with a sterile swab according to the requirements of DSTU ISO 17604:2014 [24].

Number of samples analyzed: 10 half-carcasses of each group, 40 half-carcasses total. The parameters of the pork half-carcasses cooled in the refrigerating chamber (control 1) were compared with the pork half-carcasses, cooled in the refrigerating chamber with the use of stiving (control 2), cooled in the refrigerating chamber with the use of stiving, and processed with the starter of culture SafePro® B-SF-43 (*Leuconostoc carnosum*) (experimental 1), as well as cooled in the refrigerating chamber with the use of stiving and processed with the starter of culture SafePro® B-2 (*Lactobacillus sakei*) (experimental 2).

Number of repeated analyses: From 5 to 10 samples were used in each experiment.

Number of experiment replications: 1

Design of the experiment: The pork half-carcasses obtained after slaughtering were divided into 4 groups, each containing 10 half-carcasses (Table 1).

Table 1 Determination experiment scheme of a cooling effect on pork half-carcasses with stiving method.

Group	Experiment conditions
Control 1	Carcass abluition without showering
Control 2	Carcass abluition with showering
Experimental 1	Carcass abluition with stiving and processing by starter of culture SafePro® B-SF-43 (<i>Leuconostoc carnosum</i>) in a dose of 10 ⁶ /cm ²
Experimental 2	Carcass abluition with stiving and processing by a starter of culture SafePro® B-2 (<i>Lactobacillus sakei</i>) in a dose of 10 ⁶ /cm ²

Experimental groups 1 and 2 were processed with the microbial starters at the rate of 10⁶/cm² of the lactic acid microorganisms, which were applied to the surface of the pork half-carcasses after the end of the stiving process. All pork half-carcasses were stored in a refrigerator at 3 ± 1 °C. The study results were recorded in 1 hour after cooling, in a day, and on the 4th day of storage of the pork half-carcasses in refrigerators.

Statistical Analysis

The obtained results were statistically processed using the ANOVA program, and the table data are presented as x ± SD (mean ± standard deviation). The normality of data distribution was confirmed using the program R-3.6.3 for Windows. The difference between the groups was considered probable using the Tukey test at p ≤ 0.05 (considering the Bonferroni correction).

RESULTS AND DISCUSSION

The cooling rate of pork carcasses impacts the meat's sensory properties [25], [26]. The rapid decrease of the core temperature of the meat determines the intensity of post-slaughter metabolism [27] and the formation of volatile and non-volatile compounds in it, which create the aroma of the final product and its appeal to the consumer [28]. The temperature of the meat surface of the pork half-carcasses that were not subjected to stiving 1 hour after cooling probably did not differ from similar indicators of the pork half-carcasses that were cooled with stiving. At the same time, the core temperature of the pork half-carcasses was probably lower ($p \leq 0.05$) in the case of cooling with the use of stiving of both control group 2 and both experimental groups, in comparison with the data of the pork half-carcasses of control group 1 (Table 2).

Table 2 Temperature and pH-value of pork half-carcasses in 1 h after cooling, $\bar{x} \pm SD$, $n = 5$.

Group	The surface temperature of half-carcass, °C	The core temperature of half-carcass, °C	pH-value of meat, un.
Control 1	11.93 ± 0.60 ^a	28.12 ± 1.55 ^a	6.84 ± 0.05 ^a
Control 2	12.19 ± 1.33 ^a	24.66 ± 2.47 ^b	6.67 ± 0.13 ^a
Experimental 1	11.68 ± 0.75 ^a	24.60 ± 2.12 ^b	6.70 ± 0.13 ^a
Experimental 2	11.85 ± 1.24 ^a	23.82 ± 1.15 ^b	6.80 ± 0.11 ^a

Note: different letters of upper indices ^{a, b} indicates the values that were significantly different in one column of the table ($p \leq 0.05$) according to the comparison results with the use of the Tukey test.

Our data are compliant with the studies [29], which showed that jet cooling (stiving) significantly accelerates the decrease of the core temperature of the pork carcass muscles and can be combined with other cooling phases of the meat [30]. The pH value of the meat of all pork half-carcasses subjected to cooling with the stiving method 1 hour after cooling was within the limits characteristic of fresh and high-quality meat (see Table 2). The study results [31] point to the fact that the decreased rate of the pH value/temperature in the muscles of the slaughtered animals significantly impacts the proteolysis of the muscle protein by increasing the activity of proteases and degrading several proteins.

Reaching the cooling temperature of the carcass core meat up to 2 °C depends on its weight, and for this purpose, it is averagely necessary from 17 hours to more than 27 hours for a carcass weight of 95 kg if the carcass weight is more than 105 kg [32]. In our experiment, the weight of the pork carcass did not exceed 95 kg in all cases (Table 4), which did not require a longer cooling process for the pork half-carcasses.

The surface temperature and the core thickness of the pork half-carcasses on the 4th day of storage probably did not differ between the groups (Table 3).

Table 3 Temperature and pH-value of pork half-carcasses on the 4th day of storage, $\bar{x} \pm SD$, $n = 5$.

Group	The surface temperature of half-carcass, °C	The core temperature of half-carcass, °C	pH-value of meat, un.
Control 1	3.40 ± 0.32	3.30 ± 0.89	6.37 ± 0.17
Control 2	3.48 ± 0.15	3.24 ± 0.09	6.43 ± 0.29
Experimental 1	3.24 ± 0.22	3.62 ± 0.86	6.73 ± 0.22
Experimental 2	3.52 ± 0.31	3.80 ± 0.50	6.41 ± 0.29

It is known that the pH value of the meat has a significant impact on its tenderness [33], [34] in particular, through the regulation of the phosphorylation intensity of the muscle protein [35], [36]. On the 4th day of storage, the pH value of the pork meat did not depend on the cooling method of the pork half-carcasses, as well as on the processing of the half-carcass surface with the starters of the lactic-acid microorganisms, and was within the parameters of the quality meat in all cases. Organoleptic indicators: color, consistency, smell, transparency, and aroma of meat broth obtained from the pork half-carcasses of the control and experimental groups did not differ on the 4th day of storage. The meat was pink, characteristic of pork, quite dense and springy when cut, with a specific smell characteristic of fresh meat (Figure 1).



Figure 1 Storage of the experimental groups of pork half carcasses for 4 days in the refrigerator.

During the storage of the pork half-carcasses in the refrigerating chambers, the process of drying, which is associated with moisture loss in the meat. The cooling rate of the carcasses of the slaughtered animals significantly impacts their weight loss due to the droplet evaporation [37] and thus, on the economic indicators of meat production [38]. As can be seen from the obtained data, the average weight of the paired carcass did not differ between the control and experimental groups (Table 4).

Table 4 Weight of pork half-carcass when stored in a chilled condition, kg, $\bar{x} \pm SD$, $n = 10$.

Group	Paired carcass	In a day of storage	In 4 days of storage
Control 1	44.01 \pm 5.09	43.01 \pm 4.98	42.72 \pm 4.93
Control 2	42.95 \pm 6.20	42.26 \pm 6.31	41.89 \pm 6.16
Experimental 1	43.31 \pm 3.89	42.71 \pm 3.71	42.35 \pm 3.68
Experimental 2	44.80 \pm 4.20	44.24 \pm 4.16	43.96 \pm 4.12

The biochemical processes and structural changes that occur in the muscles during the first 24 hours after slaughter play an important role in the meat's final quality and taste properties and are affected by the cooling processes to which the carcasses are subjected after slaughter. For the pork, due to exposure to high muscle temperatures and low pH value, a faster cooling process is required to reduce the development of pale, soft, and exudative (PSE) pork with a recommended core muscle temperature of 10 °C at 12h and 2-4 °C by 24h. Cooling with stiving is a system in which chilled water is applied to the carcasses at the early stage of post-mortem cooling. It is used to control carcass shrinkage and to improve the cooling rate through evaporative cooling [39].

The greatest weight loss of the pork half-carcasses occurred during the first 24 hours when they were being cooled both without the use of stiving and with the use of stiving and the final processing of the pork half-carcasses with the suspensions of the lactic-acid microorganisms. The storage of the pork in a chilled condition for 1 day contributed to a decrease ($p \leq 0.05$) in the total half-carcass weight of control group 1 by 2.27%, control group 2 – by 1.65%, experimental group 1 – by 1.61%, and experimental group 2 – by 1.25%, in comparison with the output of the paired carcasses (Figure 2-5). Our experiment results comply with the data obtained for different cooling methods of the pork carcasses [40], as well as for cooling methods of the beef carcasses [41].

On the 4th day of storage of the pork in a chilled condition, the shrinkage of the pork half-carasses of control group 1 was 2.93%, control group 2 – 2.50%, experimental group 1 – 2.22%, and experimental group 2 – 1.87%, in comparison with similar indicators of the paired carcasses (Figure 2-5). Such difference ($p \leq 0.05$) in the moisture loss of the pork half-carasses is due to the accelerated cooling with the use of stiving and the decrease in the intensity of the moisture evaporation [42].

In the period from 1 to 4 days, the intensity of the weight loss of the pork half-carasses was in all cases lower ($p \leq 0.05$) than in the first 24 hours after slaughter (Figure 2-5). This is due to the achievement of the stable core temperature of the cooled half-carasses and the decrease in the intensity of the evaporation process in the refrigerating chamber.

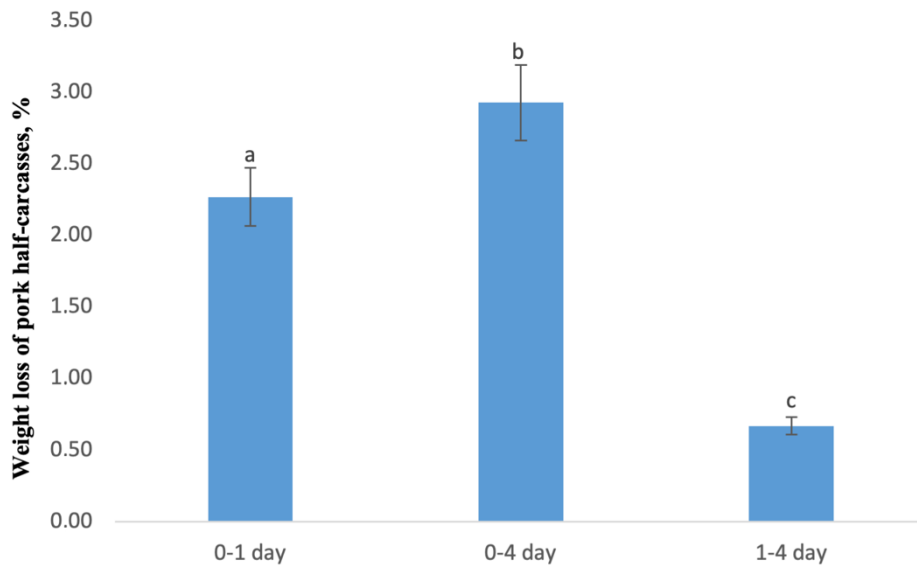


Figure 2 Weight loss of pork half-carasses during traditional cooling, $x \pm SD$, $n = 10$. Note: here and elsewhere, different upper indices ^{a, b, c} indicates the values that were significantly different in one column of the table ($p \leq 0.05$) according to the comparison results with the use of the Tukey test.

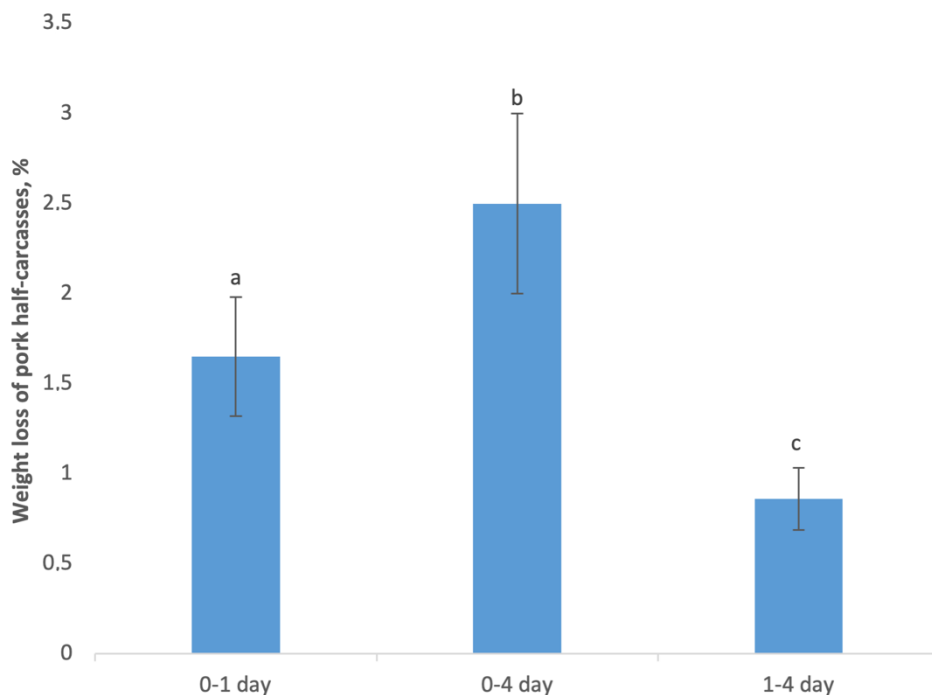


Figure 3 Weight loss of pork half-carasses after cooling with the use of stiving, $x \pm SD$, $n = 10$. Note: see Figure 2.

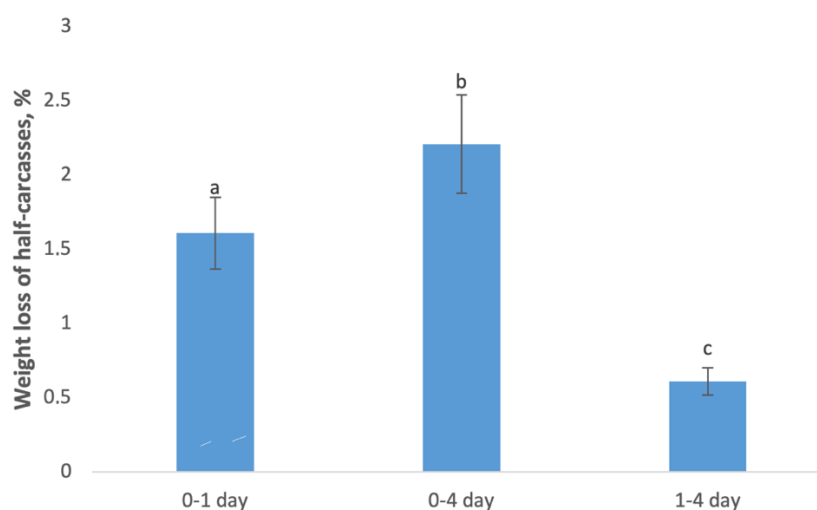


Figure 4 Weight loss of pork half-carasses after cooling with the use of stiving and final processing with suspension of culture *Leuconostoc carnosum* (SafePro® B-SF-43), $\bar{x} \pm SD$, $n = 10$. Note: see Figure 2.

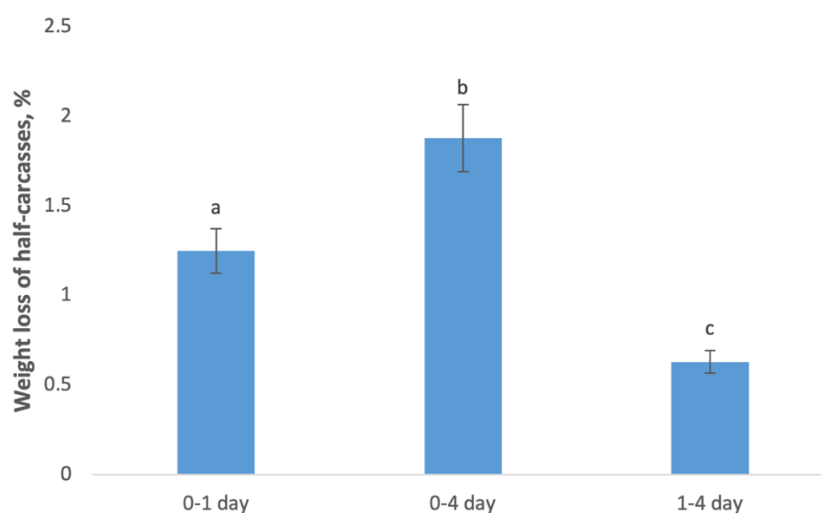


Figure 5 Weight loss of pork half-carasses after cooling with the use of stiving and final processing with suspension of culture *Lactobacillus sakei* (SafePro® B-2), $\bar{x} \pm SD$, $n = 10$. Note: see Figure 2.

It's worth mentioning that meat is the main product through which food-origin pathogenic microorganisms are spreading among people [43], [44] and depends on the observance of good hygiene practices at the enterprises for the production and circulation of meat products [45], [46]. Microbiological study data obtained from the neck and spine areas of the pork half-carasses 1 hour after cooling point to the fact that the pork of both the control and experimental groups met the requirements of the current regulations. However, QMAFAnM in the neck and spine areas of the pork half-carasses of the experimental groups was an order of magnitude lower ($p \leq 0.05$) in comparison with the control groups (Table 5). In this connection, it's worth mentioning that the main microorganisms in the pork meat samples of the experimental groups were the lactic acid bacteria, which were used to process these half-carasses. At the same time, the number of lactic acid bacteria was $<1 \log \text{CFU/cm}^3$ in the pork half-carasses of the control groups, which were cooled without stiving and with the use of stiving. This amount of the lactic-acid microorganisms in the meat of the pork half-carasses, which were subject to the final processing with the suspensions of the lactic-acid microorganisms, is associated with the ability of *Lactobacillus sakei* [47], [48] and *Leuconostoc carnosum* [49], [50] to withstand the temperature regime of the refrigerating chamber, the reduced pH-value of the meat and to use its nutritional ingredients for their development.

The initial contamination of the half-carasses with the mold fungi and yeast was practically at the same level in the meat samples of the control and experimental pork groups in the neck area. Still, in the spine area of both control pork groups, it exceeded ($p \leq 0.05$) the similar values of both experimental options, where the final processing of the pork half carcasses with the starters of the lactic acid microorganisms was used (Table 5).

Table 5 Microbiological indicators of pork half-carcasses in 1 h after cooling, $x \pm SD$, $n = 5$, log CFU/cm².

Group	QMAFAnM	Lactic-acid bacteria	Mold fungi and yeast
Neck			
Control 1	3.05 ±0.70 ^a	<1 ^c	0.58 ±0.11 ^a
Control 2	2.85 ±0.34 ^{ab}	<1 ^c	0.68 ±0.07 ^b
Experimental 1	2.33 ±0.33 ^b	5.67 ±0.96 ^a	0.56 ±0.04 ^a
Experimental 2	2.39 ±0.07 ^b	6.07 ±0.41 ^b	0.54 ±0.09 ^a
Spine			
Control 1	3.11 ±0.22 ^a	<1 ^c	0.68 ±0.11 ^b
Control 2	3.08 ±0.12 ^a	<1 ^c	0.73 ±0.13 ^b
Experimental 1	2.19 ±0.23 ^b	5.54 ±0.14 ^a	0.34 ±0.09 ^a
Experimental 2	2.39 ±0.21 ^b	5.98 ±0.18 ^b	0.34 ±0.08 ^a

Note: different upper indices ^{a, b, c} indicate the values that were significantly different in one column of the table within one sampling area ($p \leq 0.05$) according to the comparison results with the use of the Tukey test.

One of the promising directions of the safety provision of meat products is the use of natural antimicrobial agents in the technological process, in particular, bacteriocins, which are produced by lactic acid microorganisms [51], [52]. Therefore, the processing of the pork half-carcasses with the suspension of the lactic acid microorganisms, which are capable of forming these substances, makes it possible to predict the reduction in the spread risk of microbial pathogens in the meat. No pathogenic microorganisms, in particular, *S. Aureus*, *L. monocytogenes*, and *Salmonella* spp. were detected in the meat of the paired pork half-carcasses, as well as during 4 days of storage in a chilled condition, which indicates their safety for the consumer (Tables 5-6).

Table 6 Microbiological indicators of pork half-carcasses on the 4th day of storage, $x \pm SD$, $n = 5$, log CFU/cm².

Group	QMAFAnM	Lactic-acid bacteria	Mold fungi and yeast
Neck			
Control 1	3.63 ±0.26 ^a	2.50 ±0.29 ^a	2.30 ±0.12 ^a
Control 2	3.69 ±0.37 ^a	2.80 ±0.38 ^a	2.09 ±0.75 ^a
Experimental 1	3.75 ±0.56 ^a	5.17 ±0.35 ^b	1.84 ±0.75 ^a
Experimental 2	3.80 ±0.56 ^a	5.73 ±0.34 ^b	1.89 ±0.70 ^a
Spine			
Control 1	3.75 ±0.48 ^a	2.40 ±0.27 ^a	1.84 ±0.21 ^a
Control 2	3.66 ±0.52 ^a	2.39 ±0.27 ^a	1.79 ±0.17 ^a
Experimental 1	3.40 ±0.23 ^a	5.43 ±0.37 ^b	1.20 ±0.11 ^b
Experimental 2	3.62 ±0.60 ^a	5.82 ±0.54 ^b	1.24 ±0.08 ^b

Note: different upper indices ^{a, b} indicates the values that were significantly different in one column of the table ($p \leq 0.05$) according to the comparison results with the use of the Tukey test.

There was no significant difference in QMAFAnM on the 4th day of storage both in the washings from the meat surface of the experimental groups, which were subjected to the final processing with the suspension of the lactic-acid microorganisms and in the control groups of the pork half-carcasses, which were cooled without and with the use of striving. The quantity of the lactic acid bacteria on the surface of the pork half-carcasses did not differ significantly between the control groups, which indicates the absence of the influence of the stiving process on this indicator (Table 6).

At the same time, it's worth mentioning that the number of the lactic-acid bacteria in the washings from the neck and spine of the pork half-carcasses of the experimental groups, which were subjected to the final processing with the suspensions of the lactic-acid bacteria of strains SafePro[®] B-SF-43 and SafePro[®] B-2, was higher ($p \leq 0.05$) by almost 3 orders of magnitude, in comparison with both control groups. There was also an increase ($p \leq 0.05$) in the number of molds and yeasts in the meat of the pork half-carcasses of all experimental groups. Still, their number was significantly lower ($p \leq 0.05$) in the washings from the spine surface of the half-carcasses of the experimental groups.

This probably happened due to the processing of the pork half-carcasses with the microbial starters, the microorganisms that colonized the meat surface, and their ability to synthesize the bacteriocins [53], [54], microflora [55].

The effectiveness of using suspensions of lactic acid bacteria strains SafePro® B-2 (*Lactobacillus sakei*) and SafePro® B-SF-43 (*Leuconostoc carnosum*) for the processing of pork carcasses is also related to the ability of these microorganisms to ferment glucose and synthesize lactic acid, which lowers the pH value of the environment and acts as a preservative that prevents the development and reproduction of pathogenic microflora and microflora capable of causing meat spoilage. This, in turn, reduces the intensity of destruction of muscle fibers and increases the shelf life of pork in a chilled form [56]. At the same time, *Lactobacillus sakei* and *Leuconostoc carnosum* are facultative anaerobes that can withstand the temperature of 2 °C typical of a cold room, which allows their growth in such a nutrient-rich environment as meat.

Several studies have proven that *L. sakei* suppresses the growth of *Colletotrichum gloeosporioides*, *Botrytis cinerea*, *Penicillium expansum*, and *Aspergillus flavus* due to the synthesis of 3-phenyllactic acid. *L. carnosum* is known to be able to synthesize, in addition to lactic acid, hydrogen peroxide and more than 4 heat-stable bacteriocins, including leucocin, mesentericin B105, mesentericin Y105 and/or mesentericin-like protein. In addition, *L. carnosum* can synthesize aromatic four-carbon metabolites, such as acetoin and butanediol from pyruvate, making it promising for fermented meat products [57], [58]. In addition, *Lactobacillus sakei* and *Leuconostoc carnosum* strains SafePro® B-2 and SafePro® B-SF-43 do not form mucus, do not ferment starch, and withstand a significant concentration of table salt in an environment, which reaches 5-6%, which makes their use suitable for production of fermented sausage products, which contain pork.

Thus, the use of suspensions of lactic acid bacteria strains SafePro® B-2 (*Lactobacillus sakei*) and SafePro® B-SF-43 (*Leuconostoc carnosum*) is promising not only for processing pork half-carcasses but also for further study of the quality and safety of products made from this pork, their shelf life and appeal to consumers.

The study of the safety and quality of pork meat after cooling and treatment with lactic acid starters opens a wide range of promising directions for future research. Here are some ideas to explore:

Study of microbiological safety: Studies can focus on the detection and study of microorganisms on the surface of pork meat after treatment with lactic acid starters. It is important to investigate how these starter cultures affect the level of bacterial contamination and the safety of meat consumption.

Evaluation of meat quality: Research can be directed to evaluating the organoleptic properties (such as taste, aroma, and texture) of pork meat after treatment with lactic acid starters. This will help determine whether the meat retains its quality and appeal to consumers.

Study of effects on shelf life: Studies may include analyzing the shelf life of pork meat after treatment with lactic acid starters. This will help determine how effectively starter cultures increase the shelf life of meat and prevent it from spoiling.

Effectiveness of antimicrobial protection: It is important to investigate how effectively lactic acid starters reduce the risk of the spread of pathogenic microorganisms on the surface of pork meat and ensure its safety for consumption.

Development of new processing technologies: Research can be directed to developing new processing technologies for pork meat using lactic starters, which provide optimal results in terms of product quality and safety.

Consumer health impact studies: Research may include an analysis of the human health impact of consuming pork treated with lactic acid starters. This will help identify potential risks or benefits for consumers.

In general, research into the safety and quality of pork meat after cooling and treatment with lactic acid starters has great potential for developing new technologies that provide quality and safe meat for consumers.

CONCLUSION

Cooling of the pork half-carcasses in the refrigerating chamber with the use of stiving after 24 hours of storage reduces the weight loss of the pork half-carcasses by 0.62%, in combination with the final processing of the half-carcasses with the suspension of SafePro® B-SF-43 (*Leuconostoc carnosum*) – by 0.66% and SafePro® B-2 (*Lactobacillus sakei*) – by 1.02%, in comparison with the air cooling in the refrigerating chamber. Cooling of the pork half-carcasses in the refrigerating chamber with the use of stiving on the 4th day of storage makes it possible to reduce the shrinkage, on average, by 0.46%. The use of the lactic-acid starters of the microorganisms of strains SafePro® B-SF-43 (*Leuconostoc carnosum*) and SafePro® B-2 (*Lactobacillus sakei*) for the processing of the half-carcass surface reduces this indicator, on average, by 0.71% and by 1.06%. The microorganism cultures of strains SafePro® B-SF-43 (*Leuconostoc carnosum*) and SafePro® B-2 (*Lactobacillus sakei*) when applied to the surface of the pork half-carcasses at a dose of $10^6/\text{cm}^2$ contribute to the colonization of the meat with the useful lactic-acid microflora, which has a positive impact on the quality and safety indicators, and can be a promising technology element for extending the shelf life of the meat.

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