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FERMENTED ORGANIC MEAT PRODUCTS AS A SOURCE OF BENEFICIAL MICROBES - INDUSTRIAL CASE STUDY

S u m m a r y

Background. Fermented organic meat products constitute a constantly growing segment of functional foods. The study aimed to assess the microbial status of organic functional fermented meat products obtained under industrial conditions, especially in terms of the presence of lactic acid bacteria, as well as safety confirmation. The products were evaluated immediately after production and 90 days of refrigerated storage. The research material consisted of 48 fermented organic meat products (pork necks, sausages, loins and hams). The microbiological quality was assessed based on the count of aerobic mesophilic total flora, lactic acid bacteria, yeast/mold, as well as *Staphylococcus aureus*, *Enterobacteriaceae*, *Escherichia coli* using TEMPO® method, and the presence of *Salmonella* spp. and *Listeria* spp. using the plate method.

Results and conclusions. As a result of the research, it was found that the tested fermented meats were characterized by a high number of aerobic mesophilic total flora. Depending on the type of product, different numbers of lactic acid bacteria, yeast and mold were found. Bacteria from the *Enterobacteriaceae* family were also counted, and in some meats, the presence of *Salmonella* spp. and *Listeria* spp. was found. Depending on the type of product, a significant improvement or deterioration of microbiological quality was observed during refrigerated storage. This is typical of organic products due to variation in the quality of organic raw materials, as well as the lack of additives in organic meat production. At the same time, these products can be a good source of beneficial microorganisms in human diet, due to high number of lactic acid bacteria.

Keywords: microbiological assessment; fermentation; safety; probiotics; functional products

Introduction

Meat and meat products constitute one of the main ingredients of the diet of most people in the world. They are a source of energy, protein, vitamins and minerals, fatty acids and essential amino acids, as well as beneficial bacteria that enrich human gut

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microbiota. Although some authors consider meat as a diet component that negatively affects the richness and quality of gut microbiota, wider clinical study analyses suggest that the type of meat product consumption has a significant impact on microbiota changes [12, 29]. Moreover, fermented food consumption, including fermented meat products, can favorably modify gut microbiota [25].

Fermented meats are an important and increasingly popular food segment. They are characterized by a rich taste and aroma, and their production uses meat from various animals. Lactic acid fermentation involves the intracellular enzymatic process of converting sugars into lactic acid, which takes place in anaerobic conditions. Fermentation processes can take place in uncontrolled conditions, using natural microbiota. They are then difficult to monitor, and the appropriate course of the process is defined by many environmental factors. Often, the products that are created are not of appropriate quality, and it is difficult to obtain standardised product batches [16]. Controlled fermentation is carried out using highly selected microorganisms with precisely defined and stable characteristics. The key role in meat fermentation is played by lactic acid bacteria, as well as yeast and mold [3, 15].

Moreover, people's needs and expectations towards high-quality food have changed in recent years. Consumers want food that is healthier, sustainable, organic, and at the same time affordable (although we are willing to pay a bit more for "better" food). The use of preservatives is also not perceived positively [21]. An alternative to the use of additional substances may be various product manufacturing technologies [15]. The use of techniques such as cold smoking, drying, fermentation, acidification and pickling prevents the growth of harmful microorganisms [18]. Functional food is defined as “food containing an ingredient with functions for health and officially approved to claim their physiological effects on the human body” [1]. Fermented meat products as functional foods can be considered in two ways. The first is the strategy of increasing health-promoting ingredients in the product [5, 20, 23], such as probiotics. The second way is to reduce or eliminate the presence of unfavorable ingredients, such as nitrites and nitrates, phosphates, monosodium glutamate, colorings or flavorings [30].

During industrial production, and especially in organic production, it is difficult to obtain meat products of the same, appropriate and repeatable quality. This production is less efficient. Organic meat must come from animals raised possibly in the most natural conditions, with their physiological and behavioral needs met, and their feed must consist of organic raw materials. Despite clearly defined breeding rules, the production of organic meat can be difficult due to the diversity of raw materials, which also translates into the diversity of the quality of the final products [27]. The study aimed to assess the microbial status of organic functional fermented meat products obtained under industrial conditions, especially in terms of the presence of lactic acid bacteria, as well as safety confirmation.

Materials and methods

The research material consisted of 48 organic industrial fermented meat products: 5 pork necks (marked with symbols P1-P5), 19 sausages (S1-S19), 12 loins (L1-L12) and 12 hams (H1-H12). The characteristics of the tested fermented meats are presented in Table 1. These were various types of products: steamed and smoked, raw organic pork and/or organic beef, without additives, with the addition of organic acid whey or with the addition of probiotic bacteria. The products were produced using traditional methods in organic meat plants in Poland (Podkarpackie and Kujawsko-Pomorskie Province). After the production, the meat products were vacuum-packed in a multi-layer foil made of polyamide and polyethylene, and stored at 4 °C. Microbiological tests were carried out immediately (0) and after 90 days (90) of refrigerated storage.

Preparation of the samples

Each type of product was tested by taking three independent samples of fermented meat products from three production batches. Next, 25 g of the meat product was weighed into a sterile bag with a side filtration system (BagFilter® 400P, Interscience, France), and 225 cm^3 of buffered peptone water (BTL, Łódź, Poland) was added. Then, the samples were homogenized for 5 min in a paddle homogenizer (Stomacher Lab-Blender 400, Gemini B.V., Netherlands).

The pH measurement

A 10 g meat sample and 50 cm^3 of distilled water were homogenized using a Bamix SwissLine M200 (Sławno, Poland) for 1 min [20]. Then, pH values were measured using a FiveEasy F20 pH-meter with an LE438 electrode (Mettler-Toledo GmbH, Greifensee, Switzerland). The measurements were taken three times at 20 °C.

Quantitative microbial counting with TEMPO® system

Tests were carried out according to the attached manufacturer's instructions (bioMérieux, Marcy l'Etoile, France). The 3.9 cm^3 of sterile deionized water was added to the dehydrated microbiological media in glass bottles. Next, 0.1 cm^3 of the homogenized sample was added to each bottle. The samples were then identified and the bottle ID was linked to the TEMPO® card ID. The homogenized samples were placed in a filling rack in TEMPO® Filler. The number of microorganisms was examined using dedicated reagents (bioMérieux): TEMPO® AC (aerobic mesophilic total flora, REF 411113), TEMPO® LAB (lactic acid bacteria, REF 80071), TEMPO® YM (yeast/mold, REF 80001), TEMPO® STA (*Staphylococcus aureus*, REF 80002), TEMPO® EB

Table 1. Characteristics of the tested organic fermented meat products

Tabela 1. Charakterystyka badanych ekologicznych fermentowanych produktów mięsnych

Symbol / Symbol	Product / Produkt	pH value / Wartość pH	Details / Szczegóły
P1	Steamed pork neck / Baleron parzony	pH = 5.71±0.02	Smoked and steamed pork neck, 1 % curing salt and 1 % salt Chemical composition (g/100 g): protein – 17.2, total fat – 27.3, moisture – 53.4; / Baleron wędzony i parzony, 1 % soli peklującej i 1 % soli Skład chemiczny (g/100 g): białko – 17,2, tłuszcz – 27,3, wilgotność – 53,4;
P2-P5	Steamed pork neck with acid whey / Baleron parzony z serwatką kwasową	pH = 5.41±0.02	Smoked and steamed pork neck, 2 % sea salt and 2 % acid whey Chemical composition (g/100 g): protein – 22.9, total fat – 19.5, moisture – 57.1; / Baleron wędzony i parzony, 2 % soli morskiej i 2 % serwatki kwasowej Skład chemiczny (g/100 g): białko – 22,9, tłuszcz – 19,5, wilgotność – 57,1;
S1-S4	Steamed sausage / Kiełbasa parzona	pH = 5.29±0.01	Beef-pork sausage, medium minced, steamed, 1.2 % curing salt and 1.2 % salt Chemical composition (g/100 g): protein – 20.7, total fat – 19.6, moisture – 55.8; / Kiełbasa wołowo-wieprzowa, średnio rozdrobniona, parzona, 1,2 % soli peklującej i 1,2 % soli Skład chemiczny (g/100 g): białko – 20,7, tłuszcz – 19,6, wilgotność – 55,8;
S5-S7	Steamed sausage with acid whey / Kiełbasa parzona z serwatką kwasową	pH = 5.05±0.01	Beef-pork sausage, medium minced, smoked, and steamed, 2.0 % sea salt and 2 % acid whey Chemical composition (g/100 g): protein – 21.1, total fat – 16.4, moisture – 60.7; / Kiełbasa wołowo-wieprzowa, średnio rozdrobniona, wędzona i parzona, 2,0% soli morskiej i 2% serwatki kwasowej Skład chemiczny (g/100 g): białko – 21,1, tłuszcz – 16,4, wilgotność – 60,7;
S8-S11	Raw sausage with acid whey / Surowa kiełbasa z serwatką kwasową	pH = 5.30±0.15	Pork sausage, medium minced, raw, 2.8 % sea salt, 0.6 % glucose, and 5 % acid whey; / Kiełbasa wieprzowa, średnio rozdrobniona, surowa, 2,8 % soli morskiej, 0,6% glukozy i 5 % serwatki kwasowej;
S12-S13	Raw sausage / Surowa kiełbasa	pH = 4.98±0.00	Pork sausage, medium minced, raw, 2.8 % sea salt, 0.6 % glucose, and 5 % water; / Kiełbasa wieprzowa, średnio rozdrobniona, surowa, 2,8 % soli morskiej, 0,6 % glukozy i 5% wody;

S14-S19	Raw sausage with probiotics / Surowa kiełbasa z probiotykami	pH = 4.68±0.00	Medium minced sausage, pork, smoked, long-ripened Ingredients: pork, spices, curing salt, probiotic bacteria *L. rhamnosus* LOCK900; / Kiełbasa średnio rozdrobniona, wieprzowa, wędzona, długo dojrzewająca Składniki: wieprzowina, przyprawy, sól peklująca, bakterie probiotyczne *L. rhamnosus* LOCK900;
L1	Steamed smoked loin / Polędwica parzona wędzona	pH = 5.68±0.04	Smoked, steamed pork loin, 1.5 % curing salt Chemical composition (g/100 g): protein – 29.0, total fat – 3.7, moisture – 67.0; / Polędwica wieprzowa wędzona, parzona, 1,5 % soli peklującej Skład chemiczny (g/100 g): białko – 29,0, tłuszcz – 3,7, wilgotność – 67,0;
L2-L3	Steamed loin with acid whey / Polędwica parzona z serwatką kwasową	pH = 5.65±0.11	Smoked pork loin, steamed, 1.5 % sea salt and 10 % acid whey Chemical composition (g/100 g): protein –32.7, total fat – 3.7, moisture – 65.1; / Wędzona polędwica wieprzowa, parzona, 1,5 % soli morskiej i 10 % serwatki kwasowej Skład chemiczny (g/100 g): białko –32,7, tłuszcz – 3,7, wilgotność – 65,1;
L4-L12	Raw loin with probiotics / Surowa polędwica z probiotykami	pH = 4.96±0.06	Smoked pork, long-matured loin; Ingredients: pork meat, spices, sodium ascorbate, curing salt, probiotic *L. rhamnosus* LOCK900; / Wędzona polędwica, długo dojrzewająca; Składniki: mięso wieprzowe, przyprawy, askorbinian sodu, sól peklująca, , bakterie probiotyczne *L. rhamnosus* LOCK900;
H1	Steamed smoked beef ham / Szynka wołowa parzona wędzona	pH = 5.78±0.01	Beef ham, smoked, steamed, 1.5 % curing salt Chemical composition (g/100 g): protein – 32.7, total fat – 1.5, moisture – 66.8; / Szynka wołowa, wędzona, parzona, 1,5 % soli peklującej Skład chemiczny (g/100 g): białko – 32,7, tłuszcz – 1,5, wilgotność – 66,8;
H2-H3	Steamed beef ham with acid whey / Szynka wołowa parzona z serwatką kwasową	pH = 5.52±0.01	Beef ham, smoked, steamed, with 1.5 % sea salt and 10 % acid whey Chemical composition (g/100 g): protein – 32.2, total fat – 2.4, moisture – 64.9; / Szynka wołowa, wędzona, parzona, 1,5 % soli morskiej i 10 % serwatki kwasowej Skład chemiczny (g/100 g): białko – 32,2, tłuszcz – 2,4, wilgotność – 64,9;
H4-H5	Steamed smoked pork ham / Szynka wieprzowa parzona wędzona	pH = 5.75±0.02	Smoked, steamed pork ham, 1.5 % curing salt Chemical composition (g/100 g): protein – 29.4, total fat – 7.4, moisture – 63.3; / Szynka wieprzowa wędzona, parzona, 1,5 % soli peklującej Skład chemiczny (g/100 g): białko – 29,4, tłuszcz – 7,4, wilgotność – 63,3;
H6-H8	Steamed pork ham with acid whey / Szynka wieprzowa parzona z serwatką kwasową	pH = 5.68±0.07	Smoked pork ham, steamed, 1.5 % sea salt and 10 % acid whey Chemical composition (g/100 g): protein – 26.2, total fat – 12.5, moisture – 61.6; / Szynka wieprzowa wędzona, parzona, 1,5 % soli morskiej i 10 % kwaśnej serwatki Skład chemiczny (g/100 g): białko – 26,2, tłuszcz – 12,5, wilgotność – 61,6;

H9-H12	Raw pork ham with probiotics / Szynka wieprzowa surowa z probiotykami	pH = 5.60±0.05	Smoked pork, long-matured ham; Ingredients: pork meat, spices, sodium ascorbate, curing salt, probiotic *L. rhamnosus* LOCK900; / Wieprzowa wędzona szynka długo dojrzewająca; Składniki: mięso wieprzowe, przyprawy, askorbinian sodu, sól peklująca, bakterie probiotyczne *L. rhamnosus* LOCK900;

Explanatory notes / Objaśnienia:

Curing salt means a curing mixture of 99.5 % NaCl, 0.5 % $NaNO_2$. Salt means refined table salt (~99.7 % NaCl; 0.003 % KIO_3). Sea salt means coarse sea salt (97.0 % NaCl, 1.50 % water, 1.00 % $MgSO_4$, 0.30 % $MgCl_2$, 0.05 % $CaSO_4$, 0.02 % KCl; other minerals). /

Sól peklująca oznacza mieszankę peklującą składającą się z 99,5 % NaCl, 0,5 % $NaNO_2$. Sól oznacza sól kuchenną (~99,7 % NaCl; 0,003 % KIO_3). Sól morska oznacza gruboziarnistą sól morską (97,0 % NaCl, 1,50 % wody, 1,00 % $MgSO_4$, 0,30 % $MgCl_2$, 0,05 % $CaSO_4$, 0,02 % KCl; inne minerały)

(*Enterobacteriaceae*, REF 80003) and TEMPO® EC (*Escherichia coli*, REF 80004). The reading was done in TEMPO® Reader. The time to obtain results depended on the test used and was for AC incubation at 30 ± 1 °C for 40 ÷ 48 h; LAB incubation at 30 ± 1 °C for 40 ÷ 48 h; YM incubation at 25 ± 1 °C for 72 ÷ 76 h; STA incubation at 37 ± 1 °C for 24 ÷ 27 h; EB incubation at 35 ± 1 °C for 22 ÷ 27 h; EC incubation at 37 ± 1 °C for 24 ÷ 27 h. Microbial count results were presented as log CFU/g (±standard deviation).

Since there are currently no TEMPO® tests available for the detection of *Salmonella* spp. and *Listeria* spp., it was decided to conduct testing using the plate count method.

Qualitative microbiological analysis – the presence of Salmonella spp.

The presence of *Salmonella* spp. was determined according to ISO 6579-1:2017/Amd.1:2020 [13] with minor modifications. First, the sample was pre-enriched in buffered peptone water (BTL) at 37 °C for 18 h. Then, 0.1 cm^3 of the homogenized sample was added to 10 cm^3 of RVS broth (Rappaport-Vassiliadis Soya Peptone Broth; Oxoid Ltd., Basingstoke, United Kingdom) and incubated at 42 °C for 24 h. Subsequently, 0.1 cm^3 of the sample was inoculated onto XLD agar (Xylose Lysine Deoxycholate agar; Oxoid Ltd.) and incubated at 37 °C for 24 h. The presence of *Salmonella* spp. was confirmed on BGA (Brilliant Green Agar; Oxoid Ltd.) by incubating the plates at 37 °C for 18 h.

Qualitative microbiological analysis – the presence of Listeria spp., including Listeria monocytogenes

The presence of *Listeria* spp., including *Listeria monocytogenes*, was determined by ISO 11290-1:2017 [14]. Each time, 25 g of the product was pre-enriched in 225 cm^3 of half-Fraser broth (Biomaxima, Lublin, Poland) and incubated at 30 °C for 24 h. Then, 0.1 cm^3 of the sample was transferred to 10 cm^3 of Fraser broth (Biomaxima) and incubated at 37 °C for 24 h. Next, 0.1 cm^3 of the sample was inoculated on ALOA (Agar *Listeria* according to Ottaviani and Agosti, Biomaxima) and incubated at 37 °C for 24 h. *Listeria monocytogenes* was detected on ALOA as blue-green colonies with an opaque halo. The presence of *Listeria* spp. was confirmed on PALCAM agar (Oxoid Ltd.) by incubating the plates at 37 °C for 48 h.

Statistical analysis

All analysis tests were carried out in three repetitions, at time 0 (immediately after production) and day 90 (after 90 days of storage). The analysis of the test results was performed using a one-way analysis of variance (ANOVA) at $p < 0.05$. Tukey's HSD post-hoc test was used for comparative analysis of mean values. The Statistica 13.1 software was used for analyses (TIBCO Software Inc., Palo Alto, USA).

Results

Fermented pork necks

Table 2 presents the microbiological analysis of steamed pork neck (P1) and steamed pork necks with the addition of acid whey (P2 ÷ P5). Based on the research conducted, it was found that the pork necks were of good microbiological quality. The total microbial count was 4.00 ÷ 8.26 log CFU/g, and no coagulase-positive *Staphylococcus* was observed. Bacteria from the *Enterobacteriaceae* family, including *E. coli*, were recorded in pork neck without the addition of whey (P1) immediately after production. The steamed P1 pork neck was characterized by a relatively high number of *Enterobacteriaceae* bacteria compared to the pork necks with added acid whey. This was probably due to the acidification of the pork necks by the addition of acid whey, which is responsible for, among other things, lowering the pH and antimicrobial properties of acid whey [24]. This phenomenon was observed in the case of the pork neck

Table 2. Number of microbial cells of organic fermented pork necks during storage
Tabela 2. Liczba komórek mikroorganizmów w ekologicznych fermentowanych baleronach w trakcie przechowywania

Symbol / Symbol	Time [days] / Czas [dni]	Count of microorganisms [log CFU/g] / Liczba mikroorganizmów [log CFU/g]					
		AC	LAB	YM	STA	EB	EC
P1	0	8.23±0.03^{aC}	6.61±0.56^{aD}	4.71±0.42^{aB}	<1.00^{aA}	3.70±0.62^{aB}	3.00±0.00^{bB}
	90	8.26±0.23^{aD}	8.15±0.34^{bC}	4.79±0.23^{aB}	<1.00^{aA}	5.00±0.00^{bB}	<1.00^{aA}
P2	0	4.00±0.24^{aA}	6.16±0.73^{aD}	4.79±0.21^{aB}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	4.00±0.10^{aA}	7.60±0.50^{bC}	4.79±0.31^{aB}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
P3	0	6.36±0.31^{aB}	3.60±0.53^{aC}	<1.00^{aA}	<1.00^{aA}	3.00±0.00^{bB}	<1.00^{aA}
	90	7.00±0.12^{aC}	4.90±0.10^{bB}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
P4	0	6.78±0.47^{aB}	2.88±0.43^{aB}	<1.00^{aA}	<1.00^{aA}	2.84±0.54^{bB}	<1.00^{aA}
	90	6.90±0.36^{aC}	4.40±0.21^{bB}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
P5	0	4.24±0.21^{aA}	1.64±0.56^{aA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	5.68±0.32^{bB}	2.80±0.53^{bA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}

Explanatory notes / Objaśnienia:
Different lowercase letters ($^{a-b}$) mean significant differences among groups at different storage times ($p < 0.05$); Different uppercase letters ($^{A-D}$) mean significant differences among groups at different products at the same time ($p < 0.05$); AC, aerobic mesophilic total flora; LAB, lactic acid bacteria; YM, yeast/mold; STA, coagulase-positive staphylococci (*Staphylococcus aureus*); EB, *Enterobacteriaceae*; EC, *Escherichia coli*; < 1.00 - below the limit of quantification; /
Różne małe litery $^{(a-b)}$ oznaczają istotne różnice między grupami przy różnym czasie przechowywania ($p < 0,05$); Różne duże litery $^{(A-D)}$ oznaczają istotne różnice między grupami przy różnych produktach w tym samym czasie ($p < 0,05$); AC, całkowita tlenowa mezofilna flora; LAB, bakterie fermentacji mlekowej; YM, drożdże/pleśnie; STA, gronkowce koagulazo-dodatnie (*Staphylococcus aureus*); EB, *Enterobacteriaceae*; EC, *Escherichia coli*; < 1,00 - poniżej granicy oznaczalności;

P2 ÷ P5, whose pH was lower (5.41) than the one of the pork neck P1 (5.71). Interestingly, P1 pork neck had a higher number of lactic acid bacteria (6.61 ÷ 8.15 log CFU/g) than the P2 ÷ P5 pork necks, which had the addition of acid whey (rich in LAB). Perhaps the pH of the pork necks with added acid whey was too low to maintain the LAB count at a higher level. Quite high numbers of yeast and mold were recorded in the P1 and P2 pork necks (4.71 ÷ 4.79 log CFU/g). Interestingly, the low number of lactic acid bacteria in the case of the pork necks P3 ÷ P5 corresponds to the absence of yeast and mold cells (level below the detection limit). An increase in the number of AC was observed during storage, but this increase was not always statistically significant. In the case of P1, a significant deterioration in microbiological quality was observed during 3 months of storage (EB = 5.00 ± 0.00 log CFU/g). In general, it can be concluded that the addition of acid whey can improve the microbiological quality of pork necks, especially in terms of enterobacteria.

Fermented sausages

Table 3 shows the number of microbial cells in the tested fermented sausages. Steamed sausages without the addition of whey (S1 ÷ S4) and those with the addition of acid whey (S5 ÷ S7) were characterized by good microbiological quality. Aerobic mesophilic total flora was 3.05 ÷ 9.12 log CFU/g. In the sausages S2 and S6, immediately after production, a high number of bacteria from the *Enterobacteriaceae* family was observed, the number of which decreased significantly to < 1.00 log CFU/g after 3 months of storage ($p < 0.05$). Coagulase-positive staphylococci and *E. coli* were not recorded in all samples S1-S7. The number of lactic acid bacteria was 2.00 ÷ 8.69 log CFU/g. In the case of S2, S5, S6 and S7 sausages, 2.33 ÷ 5.65 log CFU/g yeast and mold were observed. Sausages fermented without and with added acid whey did not differ. Acid whey did not affect the number of microorganisms. Raw sausages (S12-S13) and raw sausages with probiotics (S14 ÷ S19) were characterized by a lower pH value (4.98 and 4.68, respectively) compared to steamed sausages (5.05 ÷ 5.29) and raw sausages with acid whey (5.30). Raw sausages (S8 ÷ S19) were characterized by a high number of aerobic mesophilic total flora (4.14 ÷ 9.87 log CFU/g). In the case of some sausage samples (S9, S10, S12 ÷ S14), bacteria from the *Enterobacteriaceae* family were recorded in the number of 1.34 ÷ 5.00 log CFU/g, and in the case of S13, also *E. coli* (1.00 ÷ 2.00 log CFU/g). However, the number of *Enterobacteriaceae* is still at an acceptable level, especially since it decreases during storage. It should be remembered that raw sausages are not subjected to any heat treatment. Therefore, enterobacteria can develop on their surface, as well as in the meat filling. The tested sausages were characterized by a high number of lactic acid bacteria, especially after 3 months of storage (6.02 ÷ 9.69 log CFU/g). A particularly high number of LAB was recorded in sausages with probiotics, which, after storage, exceeded even 8 log CFU/g.

This proves that sausages are a good matrix for the development of probiotic LAB. Quite a large number of yeast and mold was observed in raw sausages, which is typical of this type of product [22].

Table 3. Number of microbial cells of organic fermented sausages during storage
Tabela 3. Liczba komórek mikroorganizmów w ekologicznych fermentowanych kiełbasach w trakcie przechowywania

Symbol / Symbol	Time [days] / Czas [dni]	Count of microorganisms [log CFU/g] / Liczba mikroorganizmów [log CFU/g]					
		AC	LAB	YM	STA	EB	EC
S1	0	4.00 ± 0.05^{aA}	4.08 ± 0.22^{aB}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{Aa}$
	90	4.10 ± 0.14^{aA}	4.60 ± 0.25^{aB}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
S2	0	7.78 ± 0.19^{aC}	6.67 ± 0.42^{aC}	5.65 ± 0.29^{aD}	$<1.00^{aA}$	5.00 ± 0.00^{bC}	$<1.00^{Aa}$
	90	7.71 ± 0.14^{aC}	8.69 ± 0.30^{bD}	5.40 ± 0.38^{aD}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
S3	0	7.00 ± 0.10^{aC}	6.28 ± 0.14^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	9.12 ± 0.22^{bD}	8.28 ± 0.30^{bD}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
S4	0	5.95 ± 0.26^{bB}	5.65 ± 0.27^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	3.05 ± 0.23^{aA}	6.65 ± 0.13^{bC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
S5	0	4.48 ± 0.45^{aA}	2.50 ± 0.43^{aA}	4.04 ± 0.07^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	4.45 ± 0.12^{aA}	2.00 ± 0.05^{aA}	4.08 ± 0.13^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
S6	0	8.88 ± 0.16^{bD}	7.33 ± 0.21^{aD}	2.33 ± 0.19^{aB}	$<1.00^{aA}$	5.00 ± 0.00^{bC}	$<1.00^{aA}$
	90	6.78 ± 0.13^{aB}	8.18 ± 0.04^{aD}	2.56 ± 0.07^{aB}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
S7	0	6.49 ± 0.40^{aB}	4.00 ± 0.13^{aB}	3.63 ± 0.16^{aB}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	6.23 ± 0.08^{aB}	6.00 ± 0.40^{bC}	2.34 ± 0.22^{aB}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
S8	0	4.47 ± 0.22^{aA}	2.25 ± 0.22^{aA}	4.56 ± 0.30^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	4.30 ± 0.18^{aA}	7.43 ± 0.24^{bD}	4.56 ± 0.25^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
S9	0	8.17 ± 0.22^{aD}	7.91 ± 0.16^{aD}	1.95 ± 0.07^{aB}	$<1.00^{aA}$	5.00 ± 0.45^{bC}	$<1.00^{aA}$
	90	8.20 ± 0.10^{aC}	9.69 ± 0.19^{bE}	1.00 ± 0.00^{aA}	$<1.00^{aA}$	3.08 ± 0.08^{aC}	$<1.00^{aA}$
S10	0	6.23 ± 0.18^{aB}	7.69 ± 0.01^{aD}	2.81 ± 0.18^{bB}	$<1.00^{aA}$	4.57 ± 0.31^{bC}	$<1.00^{aA}$
	90	5.00 ± 0.00^{aB}	8.23 ± 0.15^{aD}	$<1.00^{aA}$	$<1.00^{aA}$	3.43 ± 0.23^{aC}	$<1.00^{aA}$
S11	0	8.20 ± 0.10^{bD}	7.57 ± 0.10^{aD}	2.59 ± 0.03^{bB}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	6.23 ± 0.16^{aB}	6.56 ± 0.18^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
S12	0	8.08 ± 0.07^{aD}	7.92 ± 0.30^{aD}	2.33 ± 0.29^{bB}	$<1.00^{aA}$	5.00 ± 0.09^{bC}	$<1.00^{aA}$
	90	7.99 ± 0.01^{aC}	8.48 ± 0.15^{aD}	$<1.00^{aA}$	$<1.00^{aA}$	2.18 ± 0.17^{aB}	$<1.00^{aA}$
S13	0	6.46 ± 0.09^{aB}	5.68 ± 0.07^{aC}	1.99 ± 0.04^{aB}	$<1.00^{aA}$	4.68 ± 0.02^{bC}	2.00 ± 0.00^{aA}
	90	8.00 ± 0.50^{bC}	6.02 ± 0.08^{aC}	2.32 ± 0.14^{aB}	$<1.00^{aA}$	1.40 ± 0.10^{aB}	1.00 ± 0.00^{aA}
S14	0	8.26 ± 0.06^{aD}	8.57 ± 0.08^{aE}	6.86 ± 0.21^{bE}	$<1.00^{aA}$	3.00 ± 0.09^{bB}	$<1.00^{aA}$
	90	8.23 ± 0.17^{aC}	8.41 ± 0.16^{aD}	4.00 ± 0.28^{aC}	$<1.00^{aA}$	1.34 ± 0.21^{aB}	$<1.00^{aA}$
S15	0	6.76 ± 0.11^{aB}	6.87 ± 0.31^{aC}	3.12 ± 0.21^{bB}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	8.67 ± 0.18^{bD}	8.13 ± 0.07^{bD}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$

S16	0	4.14±0.05^{aA}	6.99±0.01^{aC}	4.54±0.11^{bC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	9.12±0.19^{bD}	9.00±0.09^{bE}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
S17	0	8.10±0.18^{aD}	6.00±0.35^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	9.87±0.03^{bD}	7.13±0.09^{aD}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
S18	0	6.50±0.16^{aB}	6.12±0.01^{aC}	2.20±0.24^{aB}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	7.86±0.26^{aC}	8.43±0.12^{bD}	2.00±0.03^{aB}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
S19	0	9.34±0.23^{aE}	7.35±0.30^{aD}	3.14±0.25^{aB}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	9.36±0.15^{aD}	7.38±0.12^{aD}	3.80±0.48^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}

Explanatory notes / Objaśnienia:
Different lowercase letters ($^{a-b}$) mean significant differences among groups at different storage times ($p < 0.05$); Different uppercase letters ($^{A-E}$) mean significant differences among groups at different products at the same time ($p < 0.05$); AC, aerobic mesophilic total flora; LAB, lactic acid bacteria; YM, yeast/mold; STA, coagulase-positive staphylococci (*Staphylococcus aureus*); EB, *Enterobacteriaceae*; EC, *Escherichia coli*; < 1.00 - below the limit of quantification; /
Różne małe litery $^{(a-b)}$ oznaczają istotne różnice między grupami przy różnym czasie przechowywania ($p < 0{,}05$); Różne duże litery $^{(A-E)}$ oznaczają istotne różnice między grupami przy różnych produktach w tym samym czasie ($p < 0{,}05$); AC, całkowita tlenowa mezofilna flora; LAB, bakterie fermentacji mlekowej; YM, drożdże/pleśnie; STA, gronkowce koagulazo-dodatnie (*Staphylococcus aureus*); EB, *Enterobacteriaceae*; EC, *Escherichia coli*; < 1,00 - poniżej granicy oznaczalności;

Fermented loins

Steamed and smoked loins (L1 ÷ L3) were characterized by low microbiological quality (Table 4). A high number of aerobic mesophilic total flora was found (6.60 ÷ 9.57 log CFU/g), and a high number of bacteria from the *Enterobacteriaceae* family (3.43 ÷ 6.23 log CFU/g) was observed throughout the entire storage period. The steamed loins had significantly different pH values than the loins with probiotics (5.65 ÷ 5.68 and 4.96, respectively), which affected the microbiological quality. The lower pH in the L4 ÷ L12 loins eliminated enterobacteria, which were observed in significant numbers in the L1 ÷ L3 loins. The high AC count may also be due to the high LAB counts (6.78 ÷ 7.74 log CFU/g) and yeast and mold (2.22 ÷ 4.48 log CFU/g). In turn, raw loins with the addition of probiotics (L4 ÷ L12) were characterized by excellent microbiological quality throughout the entire storage period (Table 4). A high number of aerobic mesophilic total flora (7.00 ÷ 9.76 log CFU/g), a high number of LAB (6.12 ÷ 8.98 log CFU/g), and yeast and mold (< 1.00 ÷ 6.46 log CFU/g) were noted. This is the typical microbiota of these products. In the case of the L4-L12 loins, no coagulase-positive staphylococci, enterobacteria or *E. coli* were detected. All the tested fermented loins had a LAB count above 6 log CFU/g after production and throughout the refrigerated storage period, which indicates the high health value of these products.

Table 4. Number of microbial cells of organic fermented loins during storage.
Tabela 4. Liczba komórek mikroorganizmów w ekologicznych fermentowanych polędwicach w trakcie przechowywania.

Symbol / Symbol	Time [days] / Czas [dni]	Count of microorganisms [log CFU/g] / Liczba mikroorganizmów [log CFU/g]					
		AC	LAB	YM	STA	EB	EC
L1	0	8.58 ± 0.14^{aB}	6.78 ± 0.47^{aA}	4.32 ± 0.12^{bC}	$<1.00^{aA}$	4.23 ± 0.22^{aB}	$<1.00^{aA}$
	90	8.60 ± 0.14^{aB}	7.74 ± 0.12^{aA}	2.22 ± 0.00^{aB}	$<1.00^{aA}$	4.32 ± 0.08^{aB}	$<1.00^{aA}$
L2	0	9.57 ± 0.04^{bC}	6.78 ± 0.13^{aA}	4.32 ± 0.19^{bC}	$<1.00^{aA}$	5.85 ± 0.42^{bC}	$<1.00^{aA}$
	90	7.32 ± 0.11^{aA}	7.74 ± 0.00^{aA}	2.87 ± 0.11^{aB}	$<1.00^{aA}$	4.32 ± 0.08^{aB}	$<1.00^{aA}$
L3	0	8.56 ± 0.10^{bB}	7.40 ± 0.31^{aB}	4.48 ± 0.15^{aC}	$<1.00^{aA}$	6.23 ± 0.25^{bD}	$<1.00^{aA}$
	90	6.60 ± 0.05^{aA}	7.60 ± 0.02^{aA}	4.00 ± 0.30^{aC}	$<1.00^{aA}$	3.43 ± 0.02^{aA}	$<1.00^{aA}$
L4	0	7.00 ± 0.12^{aA}	7.63 ± 0.05^{aB}	6.46 ± 0.21^{bD}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	8.69 ± 0.06^{bB}	7.00 ± 0.15^{aA}	4.45 ± 0.19^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
L5	0	8.12 ± 0.05^{aB}	7.68 ± 0.29^{aB}	4.35 ± 0.21^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	9.24 ± 0.09^{bC}	7.99 ± 0.09^{aB}	4.68 ± 0.10^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
L6	0	7.80 ± 0.40^{aA}	6.99 ± 0.02^{aA}	4.87 ± 0.17^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	9.76 ± 0.27^{bC}	7.14 ± 0.19^{aA}	5.02 ± 0.09^{aD}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
L7	0	8.43 ± 0.12^{aB}	8.14 ± 0.10^{aC}	4.00 ± 0.28^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	9.45 ± 0.19^{bC}	8.64 ± 0.21^{aB}	5.12 ± 0.15^{aD}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
L8	0	9.17 ± 0.16^{aC}	8.96 ± 0.11^{aC}	6.12 ± 0.18^{aD}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	9.34 ± 0.12^{aC}	8.98 ± 0.12^{aB}	5.87 ± 0.10^{aD}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
L9	0	8.16 ± 0.08^{aB}	6.12 ± 0.23^{aA}	2.10 ± 0.13^{aB}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	8.60 ± 0.06^{aB}	6.18 ± 0.05^{aA}	3.46 ± 0.02^{aB}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
L10	0	8.98 ± 0.09^{aB}	6.78 ± 0.14^{aA}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	8.98 ± 0.13^{aB}	7.02 ± 0.10^{aA}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
L11	0	8.04 ± 0.05^{aB}	6.12 ± 0.12^{aA}	4.34 ± 0.10^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	8.50 ± 0.13^{aB}	6.82 ± 0.12^{aA}	4.56 ± 0.01^{aC}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
L12	0	8.16 ± 0.17^{aB}	6.73 ± 0.14^{aA}	2.20 ± 0.12^{aB}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$
	90	8.75 ± 0.05^{aB}	6.99 ± 0.01^{aA}	3.00 ± 0.00^{aB}	$<1.00^{aA}$	$<1.00^{aA}$	$<1.00^{aA}$

Explanatory notes / Objaśnienia:
Different lowercase letters ($^{a-b}$) mean significant differences among groups at different storage times ($p < 0.05$); Different uppercase letters ($^{A-D}$) mean significant differences among groups at different products at the same time ($p < 0.05$); AC, aerobic mesophilic total flora; LAB, lactic acid bacteria; YM, yeast/mold; STA, coagulase-positive staphylococci (*Staphylococcus aureus*); EB, *Enterobacteriaceae*; EC, *Escherichia coli*; < 1.00 - below the limit of quantification; /
Różne małe litery $^{(a-b)}$ oznaczają istotne różnice między grupami przy różnym czasie przechowywania ($p < 0,05$); Różne duże litery $^{(A-D)}$ oznaczają istotne różnice między grupami przy różnych produktach w tym samym czasie ($p < 0,05$); AC, całkowita tlenowa mezofilna flora; LAB, bakterie fermentacji mlekowej; YM, drożdże/pleśnie; STA, gronkowce koagulazo-dodatnie (*Staphylococcus aureus*); EB, *Enterobacteriaceae*; EC, *Escherichia coli*; < 1,00 - poniżej granicy oznaczalności;

Fermented hams

Table 5 presents the quantitative microbiological assessment of beef and/or pork hams. Steamed smoked beef hams (H1 ÷ H3) were of very good microbiological quality, and their microbiota was typical of this type of product. In the case of hams, there were no such large differences in pH (5.52 ÷ 5.78), with a slightly higher pH noted in the case of steamed hams without added acid whey or probiotics. This is understandable due to the presence of lactic acid bacteria in the remaining hams, which additionally acidify the environment. The number of aerobic mesophilic total flora was 5.86 ÷ 8.00 log CFU/g. A high number of LAB and yeast and mold (5.59 ÷ 6.64

Table 5. Number of microbial cells of organic fermented hams during storage. /
Tabela 5. Liczba komórek mikroorganizmów w ekologicznych fermentowanych szynkach w trakcie przechowywania.

Symbol / Symbol	Time [days] / Czas [dni]	Count of microorganisms [log CFU/g] / Liczba mikroorganizmów [log CFU/g]					
		AC	LAB	YM	STA	EB	EC
H1	0	6.00±0.10^{aB}	6.51±0.03^{aB}	4.30±0.10^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	5.86±0.15^{aA}	6.64±0.13^{aA}	4.04±0.05^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
H2	0	6.88±0.34^{aB}	5.99±0.02^{aB}	5.69±0.10^{aD}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	6.59±0.23^{aB}	6.00±0.00^{aA}	5.01±0.04^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
H3	0	8.00±0.00^{aD}	5.59±0.06^{aB}	4.69±0.11^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	7.03±0.08^{aB}	6.20±0.13^{aA}	4.18±0.11^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
H4	0	7.10±0.05^{aC}	6.90±0.06^{aB}	3.78±0.41^{aC}	<1.00^{aA}	1.00^{aA}	<1.00^{aA}
	90	8.26±0.14^{aC}	7.15±0.10^{aA}	3.15±0.15^{aB}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
H5	0	7.18±0.02^{aC}	6.53±0.24^{aB}	3.30±0.02^{aC}	<1.00^{aA}	4.20±0.13^{bC}	4.00±0.00^{bB}
	90	7.20±0.16^{aB}	7.40±0.13^{aA}	3.30±0.03^{aB}	<1.00^{aA}	2.48±0.02^{aB}	<1.00^{aA}
H6	0	6.85±0.05^{bB}	6.70±0.00^{aB}	4.10±0.17^{aC}	<1.00^{aA}	1.30±0.10^{aB}	<1.00^{aA}
	90	5.28±0.13^{aA}	6.68±0.09^{aA}	3.74±0.07^{aB}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
H7	0	5.85±0.07^{aB}	6.38±0.02^{aB}	5.00±0.00^{aD}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	5.60±0.15^{aA}	6.04±0.04^{aA}	4.68±0.00^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
H8	0	4.30±0.04^{aA}	6.26±0.02^{aB}	4.93±0.06^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	4.48±0.04^{aA}	8.32±0.03^{bB}	4.94±0.13^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
H9	0	8.15±0.13^{aD}	6.70±0.07^{aB}	7.14±0.02^{bE}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	8.15±0.07^{aC}	7.15±0.00^{aA}	3.52±0.03^{aB}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
H10	0	9.14±0.00^{aD}	7.02±0.03^{aB}	4.54±0.37^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	9.27±0.17^{aC}	7.04±0.03^{aA}	5.00±0.20^{aC}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
H11	0	8.18±0.03^{aD}	6.02±0.28^{aB}	2.02±0.08^{aB}	<1.00^{aA}	2.00±0.20^{aB}	<1.00^{aA}
	90	8.24±0.09^{aC}	6.06±0.07^{aA}	3.12±0.10^{aB}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
H12	0	4.56±0.04^{aA}	3.60±0.22^{aA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}
	90	7.16±0.10^{bB}	6.50±0.00^{bA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}	<1.00^{aA}

Explanatory notes / Objaśnienia:
Different lowercase letters ($^{a-b}$) mean significant differences among groups at different storage times ($p < 0.05$); Different uppercase letters ($^{A-D}$) mean significant differences among groups at different products at the same time ($p < 0.05$); AC, aerobic mesophilic total flora; LAB, lactic acid bacteria; YM, yeast/mold; STA, coagulase-positive staphylococci (*Staphylococcus aureus*); EB, *Enterobacteriaceae*; EC, *Escherichia coli*; < 1.00 - below the limit of quantification; /
Różne małe litery $^{(a-b)}$ oznaczają istotne różnice między grupami przy różnym czasie przechowywania ($p < 0,05$); Różne duże litery $^{(A-D)}$ oznaczają istotne różnice między grupami przy różnych produktach w tym samym czasie ($p < 0,05$); AC, całkowita tlenowa mezofilna mikrobiota; LAB, bakterie fermentacji mlekowej; YM, drożdże/pleśnie; STA, gronkowce koagulazo-dodatnie (*Staphylococcus aureus*); EB, *Enterobacteriaceae*; EC, *Escherichia coli*; < 1,00 - poniżej granicy oznaczalności;

and 4.04 ÷ 5.69 log CFU/g, respectively) was noted. *Staphylococcus*, *Enterobacteriaceae* and *E. coli* counts were below the limit of quantification (< 1.00 log CFU/g). There were no significant differences in the number of microorganisms during storage ($p > 0.05$). Steamed smoked pork hams (H4 ÷ H8) were also of good microbiological quality, except the H5 ham, which had a relatively high number of *Enterobacteriaceae* and *E. coli* bacteria (4.20 ± 0.13 and 4.00 ± 0.00 log CFU /g, respectively). However, a statistically significant reduction in the number of these bacteria was noted during 3 months of storage ($p < 0.05$). Raw pork hams (H9-H12) also had high numbers of aerobic mesophilic total flora (4.56 ÷ 9.27 log CFU/g) and lactic acid bacteria (3.60 ÷ 7.15 log CFU/g). No significant differences were found in the number of microorganisms during storage ($p > 0.05$).

Presence of Salmonella spp. and Listeria spp.

One case of *Salmonella* spp. was recorded in pork necks (P1 ÷ P5) immediately after production (20 %). Sausages (S1 ÷ S19) were of poorer quality, with three cases of *Salmonella* spp. detected immediately after production (15.8 %) and one after storage (5.3 %). *Listeria* spp. was also detected in one sausage (5.3 %), but *Listeria monocytogenes* was not found. In addition, *Salmonella* spp. was detected in loins (L1 ÷ L12) and hams (H1 ÷ H12), with one and two cases, respectively (8.3 and 16.7 %). It should be noted that *Salmonella* spp. or *Listeria* spp. bacteria appeared in the meat samples with the addition of acid whey. Acid whey is a by-product of cheese production. The whey used to produce the products was not pasteurized and could have been a source of undesirable bacteria.

It can be concluded that the microbiological quality of fermented meats depends on many factors, including the quality of raw materials, the environment and the production method. It can also be stated that among the fermented products tested, the best microbiological quality was found in raw loins and raw hams with probiotics. It can therefore be assumed that the greatest impact on inhibiting the growth of undesirable microorganisms was exerted by added probiotics.

Table 6. Presence of *Salmonella* spp. and *Listeria* spp. in the organic fermented meat products during storage. /
Tabela 6. Obecność *Salmonella* spp. i *Listeria* spp. w ekologicznych fermentowanych produktach mięsnych w trakcie przechowywania.

Symbol / Symbol	*Salmonella* spp. / *Salmonella* spp.		*Listeria* spp. including *L. monocytogenes* / *Listeria* spp. w tym *L. monocytogenes*	
	Number of cases/number of products [%] at time / Liczba przypadków/liczba produktów [%] w czasie			
	0	90	0	90
P1-P5	1/5 (20 %)	0/5 (0 %)	0/5 (0 %)	0/5 (0 %)
S1-S19	3/19 (15.8 %)	1/19 (5.3 %)	1/19 (5.3 %)*	0/19 (0 %)
L1-L12	1/12 (8.3 %)	0/12 (0 %)	0/12 (0 %)	0/12 (0 %)
H1-H12	2/12 (16.7 %)	0/12 (0 %)	0/12 (0 %)	0/12 (0 %)

Explanatory notes / Objaśnienia:
**Listeria monocytogenes* was not detected. / *Nie wykryto bakterii *Listeria monocytogenes*.

Discussion

This manuscript presents the results of microbiological studies of organic fermented meat products. The products were obtained from independent production batches. Fermented meats are characterized by a high number of aerobic mesophilic total flora. Most of the products were characterized by a high number of LAB and yeast and/or mold. Depending on the type of product, various numbers of bacteria from the *Enterobacteriaceae* family were obtained, including bacteria *E. coli*, as well as coagulase-positive staphylococci. Fermented sausages are products with a high degree of fragmentation, which facilitates maintaining a high number of LAB [17] and yeast [31], but also facilitates the growth of undesirable bacteria, such as enterobacteria or staphylococci. For example, in Galician chorizo sausage [22], the number of *Staphylococcus* was as much as 4.82 log CFU/g, and the number of *Enterobacteriaceae* was 2.98 log CFU/g. In a few cases, the presence of *Listeria* spp. including *L. monocytogenes* was observed in fermented sausages [22]. The number of LAB in the analyzed loins was high and amounted to 6.12 ÷ 8.98 log CFU/g, while the raw loins cited from the literature [19, 20] amounted to 6.11 ÷ 7.12 log CFU/g.

The production of meat products is difficult due to the diversity of raw meat materials. Additionally, the standardization of products is also hindered by the organic origin of meat raw materials. These are characterized by a different quality from conventional raw meat materials. Organic raw materials are characterized by greater susceptibility to microbiological spoilage because antibiotics are not used in animal breeding. They are also characterized by lower efficiency due to the lack of growth hormones in animal nutrition. All these features significantly affect the quality of the final products [27]. The use of LAB and/or their metabolites has become a great solution in the preservation of food [2], including meat products [26].

The adequate concentration of probiotic bacteria is considered as 10^6 CFU/g, and 100 g of food portion possesses a therapeutic effect [11]. In the present study, not all fermented products contained probiotic bacteria; however, all of the products contained a large number of LAB, which are generally recognized as safe [4] and are considered by many authors as beneficial [8, 10]. Although there are no guidelines regarding the necessary concentration of LAB in fermented meat products. The comparison of our research results with literature data leads to the conclusion that the number of LAB fluctuated, however, mostly reaching approximately 10^6 CFU/g. That might be too low concentration to observe the therapeutic effect; however, it should be taken into consideration that fat and proteins of meat products could have a protective effect in the gastrointestinal tract. It is well documented that a solid state of food, as well as higher fat and protein concentration, caused better survivability of beneficial bacteria during gastrointestinal passage, allowing them to pass into the large intestine where they can act, modulating the gut microbiota and influencing human health [28].

The production method has a major impact on the final microbiological quality of fermented products. On the one hand, products subjected to heat treatment should be characterized by better microbiological quality due to the elimination of spoilage and pathogenic microorganisms. On the other hand, they can contribute to faster spoilage of the product due to accelerated oxidative processes. The degree of fragmentation of the products also has an impact on quality. In the case of sausages, the meat filling itself can be a source of undesirable microorganisms. Unfortunately, research indicates a higher detection of pathogenic microorganisms in organic animal production. In our research, the presence of *Salmonella* spp. pathogens was observed immediately after production (time 0) in seven products. As determined in Commission Regulation (EC) No. 2073/2005 [7] of 15 November 2005 on microbiological criteria for foodstuffs, food safety criteria are subject to Annex I. Chapter 1. Food safety criteria point to: Ready-to-eat foods able to support the growth of *L. monocytogenes*, other than those intended for infants and for special medical purposes for *L monocytogenes* following EN/ISO 11290-2 and EN/ISO 11290-1 (This criterion has been further updated in Regulation 2024/2895 [6]), Minced meat and meat preparations intended to be eaten raw for *Salmonella* following EN/ISO 6579, and Chapter 2. Process hygiene criteria point to: Meat preparations for *E. coli* following ISO 16649-1 or 16649-2 [7]. Referring to the Commission Regulations, these products should not be placed on the market due to the presence of *Salmonella* spp. In the case of *E. coli* bacteria, no major deficiencies were found (except for one sausage and one ham). According to the publication by Rossi et al. [23], fermented sausages are a source of *Salmonella* serovars and *L. monocytogenes*. According to EFSA BIOHAZ [9], *L. monocytogenes* is the main microbiological threat to ripening meat that should be taken into account. In our research, one case of *Listeria* spp. was recorded (no *L. monocytogenes* was found).

Unfortunately, an emerging problem is the presence of pathogenic bacteria, which are difficult to eliminate, especially in the case of raw-ripened meats. The presence of *Salmonella* spp. in raw sausages is the result of surface contamination of fresh meat with these bacteria. The grinding and mixing processes used during sausage production favor the growth of these bacteria. Appropriate processing hygiene determines the health and safety of products, as well as the quality of the product [21].

Conclusions

1. The study assessed the microbiological quality of 48 different organic fermented meat products (pork necks, sausages, loins and hams) that were manufactured under industrial conditions. Based on the research conducted, it was found that organic fermented meats were characterized by different microbiological qualities.
2. A common feature is a high number of total viable counts, as well as lactic acid bacteria, yeast and mold. Some raw products had a higher number of enterobacteria, which is understandable because they are not subjected to typical heat treatment.
3. Interestingly, the source of undesirable microorganisms could be unpasteurized acid whey, which was added to some of the products. In turn, the addition of probiotic bacteria significantly improved the microbiological quality of the products.
4. The key factors in ensuring the proper health safety of fermented meat products are the appropriate quality of organic meat raw materials and the proper hygiene of the product processing process, including refrigerated storage.
5. Fermented meat products are an excellent source of beneficial LAB and can be a good supplement to the microbiota in the diet. LAB have the physiological ability to produce bioactive compounds during fermentation, which additionally enrich these products while ensuring health safety.

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FERMENTOWANE EKOLOGICZNE PRODUKTY MIĘSNE JAKO ŹRÓDŁO POŻYTECZNYCH MIKROBÓW – STUDIUM PRZYPADKÓW PRZEMYSŁOWYCH

S t r e s z c z e n i e

Wprowadzenie. Fermentowane ekologiczne produkty mięsne stanowią stale rosnący segment żywności funkcjonalnej. Celem badania była ocena stanu mikrobiologicznego ekologicznych funkcjonalnych fermentowanych produktów mięsnych uzyskanych w warunkach przemysłowych, pod kątem obecności bakterii fermentacji mlekowej, a także potwierdzenia ich bezpieczeństwa zdrowotnego. Produkty oceniano bezpośrednio po produkcji i po 90 dniach przechowywania w warunkach chłodniczych. Materiał badawczy stanowiło 48 fermentowanych ekologicznych produktów mięsnych (balerony, kiełbasy, polędwice i szynki). Jakość mikrobiologiczna została oceniona na podstawie liczby całkowitej tlenowej mezofilnej flory, bakterii fermentacji mlekowej, drożdży/pleśni, a także *Staphylococcus aureus, Enterobacteriaceae*, *Escherichia coli* z wykorzystaniem metody TEMPO® oraz obecności *Salmonella* spp. i *Listeria* spp. z wykorzystaniem metody płytkowej.

Wyniki i wnioski. W wyniku badań stwierdzono, że badane wędliny fermentowane charakteryzowały się dużą liczbą całkowitej tlenowej mezofilnej flory. W zależności od rodzaju produktu stwierdzono różną liczbę bakterii fermentacji mlekowej, drożdży i pleśni. Zanotowano również bakterie z rodziny *Enterobac-*

teriaceae, a w niektórych produktach mięsnych stwierdzono obecność *Salmonella* spp. i *Listeria* spp. W zależności od rodzaju produktu zaobserwowano znaczną poprawę lub pogorszenie jakości mikrobiologicznej podczas przechowywania w warunkach chłodniczych. Jest to typowe dla produktów ekologicznych ze względu na zmienność jakości surowców ekologicznych, a także brak substancji dodatkowych w produkcji ekologicznej. Jednocześnie produkty te mogą być dobrym źródłem pożytecznych mikroorganizmów w diecie człowieka, ze względu na wysoką liczbę bakterii fermentacji mlekowej.

Słowa kluczowe: ocena mikrobiologiczna; fermentacja; bezpieczeństwo; probiotyki; produkty funkcjonalne