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QUALITY OF THE *LONGISSIMUS LUMBORUM* MUSCLE IN CROSSBRED FATTENERS FED DIETS SUPPLEMENTED WITH PROBIOTIC, PREBIOTIC, AND SYNBIOTIC*

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A b s t r a c t

This study aimed to evaluate the quality of the *longissimus lumborum* muscle in PLW×PL pigs fed diets supplemented with a probiotic, a prebiotic and a synbiotic. The study material comprised the *longissimus lumborum* (*LL*) muscle sampled from fattening pigs. The animals were fed complete feed rations according to the following scheme: control group (I) – no feed additives; group II – 0.3% EM Bokashi; group III – 3% inulin; and group IV – 0.3% EM Bokashi + 3% inulin. The pigs were fattened until they reached an average body weight of approximately 112 kg. The inclusion of feed additives in the diets did no affect carcass muscularity or fatness ($p > 0.05$). Supplementation with inulin and EM Bokashi (group IV) significantly reduced muscle pH at 45 min and 2 h *post-mortem* compared to group II. No significant effect of the feeding strategy was observed on the electrical conductivity, water holding capacity or the *LL* muscle tenderness. However, the highest drip loss and muscle tenderness were recorded in pigs fed diets supplemented with inulin. The muscles from pigs in groups I and II were darker in colour (L*), but less saturated in red and yellow hues than the *LL* muscle from pigs in groups III and IV ($p \leq 0.05$). A significantly higher intramuscular fat (IMF) content (1.73% and 1.67%) was recorded in the muscles of pigs

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fed diets with EM Bokashi or inulin, respectively, compared to the control group (1.28%). Simultaneously, the *LL* muscle from pigs receiving the prebiotic-supplemented diet contained significantly less cholesterol than that from groups II and IV. The higher IMF levels in the *LL* muscle of pigs fed inulin or EM Bokashi contributed to a significantly ($p \leq 0.05$) increased content of oleic, saturated, and monounsaturated fatty acids compared to that of control pigs. Based on these findings, the inclusion of 3% inulin in complete feed rations for fattening pigs is recommended, as it resulted in the lowest cholesterol level and most favourable fatty acid profile in the *longissimus lumborum* muscle.

Introduction

Meat is a source of high-quality proteins, minerals (zinc, selenium, iron, and phosphorus), B-group vitamins, and fatty acids, and plays an important role in the human diet (KUNACHOWICZ et al. 2020, MILCZAREK 2021, RYBARCZYK et al. 2021, ZDUŃCZYK et al. 2024). Despite the high nutritional value of red meat, studies (HERFORTH et al. 2019, DI et al. 2023, SHI et al. 2023) indicate that the consumption of meat products high in fat and cholesterol may be associated with an increased risk of cardiovascular, metabolic, and oncological diseases. Global pork consumption in 2021 was 32.5%, whereas poultry and beef consumption were 39.5% and 21.8%, respectively (OECD/FAO 2023). The quality and safety of pork are closely related to the health of humans. Therefore, improving pork quality and ensuring the safety of meat for consumers is crucial.

Research (SOBOLEWSKA and GRELA 2014, PEREIRA PINTO et al. 2019, WANG et al. 2019, GRELA et al. 2021, ZHOU et al. 2025) has shown that modifying the composition of pigs' diets by introducing bioactive components such as probiotics, prebiotics, or synbiotics may affect not only growth performance, but also carcass composition and the physicochemical properties of meat. Probiotics are a live beneficial microorganisms which, confer health benefits to the host, when administered in adequate amounts (FAO/WHO 2001). CHEN et al. (2005) and TUFARELLI et al. (2017) demonstrated that supplementation of pig diets with additives containing microorganisms improves digestion, enhances animal health status, and boosts weight gain. However, the effects of probiotics on the physicochemical properties of pork meat remain inconclusive. Some researchers have confirmed the positive impact of probiotics on meat quality (LIU et al. 2013, SUO et al. 2012 BALASUBRAMANIAN et al. 2018), whereas others (RYBARCZYK et al. 2016, CHANG et al. 2018) have not observed beneficial interactions.

Probiotics are commonly combined with prebiotics in livestock feeding (GRELA et al. 2021, LEE et al. 2009, RINGSEIS and EDER 2022, SCOTT et al. 2017). According to the latest consensus of The International Scientific Association for Probiotics and Prebiotics (ISAPP), prebiotics are dietary

substrates that are utilised by beneficial microorganisms (*Bifidobacteria* and *Lactobacillus*) in the gastrointestinal tract (GIT), thereby enhancing host health and preventing disease (SCOTT et al. 2017, PATTERSON et al. 2010). Inulin is a feed additive that exhibits prebiotic activity (ROBERFROID 2007, KIERNAN et al. 2023). Inulin is a polymer that contains oligosaccharides and polysaccharides. It is a type of fructan mixture found in a wide variety of plants (chicory roots, Jerusalem artichoke, dandelion, and elecampane). However, in industrial applications, it is most commonly extracted from chicory roots (ROBERFROID 2007, VAN BEKKUM et al. 2008). The degree of polymerisation of inulin fructans can range from approximately 2 to 60. Fructooligosaccharides (FOS) is obtained via the enzymatic hydrolysis of inulin, which reduces the degree of polymerisation (CHIKKERUR et al. 2020). The degree of polymerisation directly influences the physical properties of compounds. The higher the degree of polymerisation of inulin, the greater its gel-like behaviour, with longer chains having lower solubility (FRANCK 2002). Inulin passes through the upper digestive tract unchanged and reaches the lower gastrointestinal tract, where it undergoes anaerobic fermentation by bacteria. The fermentation products are short-chain fatty acids (SCFAs), including acetic, propionic, and butyric acids. It has been shown that butyrate serves as a primary energy source for colonocytes and provides protection against colorectal cancer and inflammation (FLINT et al. 2012). NOWAK et al. (2012) reported that an increase in the production of volatile fatty acids may help regulate cholesterol levels, as well as support the absorption of calcium, iron, and magnesium. Furthermore, other studies (DELZENNE and KOK 1999, WILLIAMS 1999) have demonstrated that inulin has beneficial effects on lipid metabolism in both humans and animals. ZHOU et al. (2025) suggest that maternal inulin supplementation during gestation mitigates offspring hepatic lipid deposition through butyrate-mediated epigenetic regulation, where microbial-derived butyrate from inulin fermentation inhibits HDAC activity, enhances histone acetylation levels, and upregulates fatty acid β-oxidation gene expression. The inclusion of inulin in animal diets may contribute to improved growth performance, increased villi length, and reduced levels of skatole, indole, and cresol (JENSEN and HANSEN 2006, HANSEN et al. 2006, GRELA et al. 2013, WANG et al. 2019) as well as affect the carcass composition and pork meat quality (SOBOLEWSKA and GRELA 2014, WANG et al. 2019, GRELA et al. 2021).

Probiotics may enhance the beneficial effects of prebiotics on biological systems (ALLOUI et al. 2013, MARKOWIAK and ŚLIŻEWSKA 2017), and their simultaneous inclusion in the diets of monogastric animals may result in a synergistic effect on growth rate (SHIM et al. 2005, LEE et al.2009) and meat quality.

Therefore, this study aimed to evaluate the quality of the *longissimus lumborum* muscle in PLW×PL pigs fed diets supplemented with EM Bokashi, inulin, or a combination of EM Bokashi and inulin.

Materials and Methods

Animals, slaughter and carcass treatment

The experiment was performed according to the recommended EU Directive 2010/63/EU for animal experimentation. The investigation was carried out on 80 barrows (20 animals in each group) derived from Polish Large White × Polish Landrace crossbred fatteners. The animals of the each group (I, II, III and IV) were fattened (for different number days) from starting an average body weight of 30.5 kg (±1.5 kg) to 112 kg (±5 kg). The fatteners were kept on the same farm (Mazovia district, Poland) in a non-bedding system with unrestricted access to water and were fed *ad libitum* with Grower 1 up to 60 kg, Grower 2 from 60 kg to 90 kg, and then up to 112 kg with Finisher. The rations were isoprotein, isoenergetic, and balanced in accordance with nutritional recommendations (NRC 2021). The animals were divided into four equinumerous feeding groups as follows: group I (control) receiving complete feed mixtures without probiotic or prebiotic, group II – complete feed + 0.3% EM Bokashi, group III – complete feed + 3% inulin, and group IV – complete feed + 0.3% EM Bokashi + 3% inulin (Table 1).

EM Bokashi probiotic contained a complex of effective microorganisms, such as *Saccharomyces cerevisiae* ($3.3 \cdot 10^5$ CFU/ml IFO 0203), *Lactobacillus casei* (1 k 2 $1.95 \cdot 10^7$ CFU/ml ATCC 7469), and *Lactobacillus plantarum* (1 k 2 1.95×10^7 CFU/ml ATCC 8014). Chicory inulin contained approximately 92% inulin with DP ≥ 10 and 8% other carbohydrates (glucose, fructose, and sucrose).

After the fattening period, all pigs were loaded in small groups by qualified personnel into transport vehicles. Fatteners were transported 30 km to the slaughterhouse at night and rested for 2 h in lairage pens, following density standards and with constant access to water. At the slaughter line, lean meat content, backfat, and muscle thickness were measured using a Sydel CGM optic-needle apparatus, and hot carcase weight (HCW) was measured immediately afterwards (accuracy up to 0.1 kg). The carcasses were then chilled in a blast-cooling tunnel and stored at 4°C for up to 24 h after slaughter.

Table 1

Ingredients and chemical composition of the pig diets

Item	Grower 1				Grower 2				Finisher			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Ingredients:												
Barley	23.9				21.5				20.5			
Triticale	24.78				29.71				29.71			
Wheat	12.6				8.6				5.8			
Corn	7.0				10.0				14.9			
wheat bran	1.0				2.5				3.5			
non-GMO soybean meal	11.68				8.16				5.18			
Sunflower meal	1.0				1.0				1.0			
DDGS	5.0				5.0				5.0			
Rapeseed meal	5.0				6.0				7.0			
Sunflower oil	2.1				1.5				1.3			
Mineral-vitamin supplements (e.g., limestone, 1-Ca-pfosphate, salt, etc.), amino acids, premix	2.94	2.91	2.94	2.91	3.03	3.0	3.03	3.0	3.11	3.08	3.11	3.08
Corn starch	3.0	3.0	-	-	3.0	3.0	-	-	3.0	3.0	-	-
EM Bokashi	-	0.3	-	0.3	-	0.3	-	0.3	-	0.3	-	0.3
Inulin	-	-	3.0	3.0	-	-	3.0	3.0	-	-	3.0	3.0
Total	100	100	100	100	100	100	100	100	100	100	100	100
Nutritive value per 1 kg of diet:												
Crude protein [g]	170				160				150			
Lysine [g]	11.6				10.7				9.80			
Methionine [g]	4.0				3.6				3.4			
Crude fibre [g]	41				46				50			
Ca [g]	7.6				6.8				6.0			
P [g]	5.5				4.7				4.1			
Na [g]	1.3				1.1				1.0			
Metabolic energy [MJ]	13.1				13.0				12.9			

Explanations: DDGS – dry distillers grains with solubles

Meat quality attributes

Both pH and EC measurements were performed directly in hanging half-carcasses in the *longissimus lumborum* muscle (*LL*) behind the last rib (from 35 min. to 24 h *post-mortem*) while remaining meat quality attributes were measured in meat samples taken at the last rib and 1^{st}–4^{th} lumbar vertebra (after 24 h of chilling). Each muscle sample was separated from

the bone, external fat, and epimysium, packed in polyethylene bags, placed in cooling boxes (below 4°C for approximately 1 h), transported to the laboratory, and stored at 4°C in refrigerators. Four slices were cut from each carcase: three slices (2-cm thick) were used to determine pork quality attributes, while the remaining slice was used to evaluate the proximate composition, fatty acid profile, and cholesterol content.

Muscle pH and electrical conductivity (EC) were measured after 45 min of storage (pH_{45}), 2 (pH_2), and 24 hours *post-mortem* (pH_{24}) directly in meat plants using a temperature-compensating pH meter pH-Star and conductometer LF-star with a frequency of 1.2 kHz, respectively. Both apparatuses were calibrated prior to measurement (the pH meter was standardised using pH 7 and 4.6 buffer solutions. The electrodes were placed crosswise on the muscle fibres.

Meat colour was measured at 24h *post-mortem* after 10 min. blooming period in the CIE $L^*a^*b^*$ system: L^* – lightness, a^* – redness, and b^* – yellowness (CIE 2007) with a Minolta portable chroma meter with a 50 mm aperture. Two illuminant/observer combinations were applied: illuminant C (average daylight) and standard observer 2°, and illuminant D65 (daylight) and standard observer 10°, as recommended by HONIKEL (1998) for the measurement of meat colour. The instrument was standardised using a white calibration plate with the following coordinates: $Y = 92.80$, $x = 0.3175$, and $y = 0.3333$. In the measuring system used, L^* denotes psychometric colour saturation, which is a spatial vector, and a *and b *are trichromatic coordinates (a *is a positive value that corresponds to red, its negative corresponds to green, positive b^* corresponds to yellow, and negative b^* corresponds to blue). The colour parameters a^* and b^* were used to calculate chroma (C^*) and hue (h°) using the formulas used by MILCZAREK and OSEK (2019).

Drip loss (DL) was determined according to the method described by PRANGE et al. (1997). Meat samples (approximately 100 g) were cut from carcasses 24 h *post-mortem*, weighed, and placed in plastic bags. After storage at 4°C, the samples were weighed again at 24 and 48 h. Drip loss [%] was calculated as the difference in sample weight before and after storage with respect to the initial weight.

Water absorption, expressed as water holding capacity (WHC), was determined using GRAU and HAMM'S (1952) method, as modified by POHJA and NINIVARRA (1957), based on the amount of free water (expressed in %) lost by the meat sample placed on the filter paper pressed between two glass plates. The infiltration area (cm^2) was measured using a mechanical planimeter HAFF-Planimeter No. 313.

Cooking loss was assessed as follows: samples of known weights (approximately 100 g) were placed in hot water for approximately 30 min. Upon reaching a temperature of 72°C, all samples were cooled to room

temperature (21°C), dried, and weighed. Cooking loss was calculated as the difference between the sample weights before and after thermal treatment with respect to the initial weight. After 24 h of storage at 4°C, the shear force was measured using a Stable Micro Systems TA.XT Express Enhanced with a Warner–Bratzler knife according to PN-ISO NORM 11036:1999 (1999). Three cuboids (1.0 cm in diameter) were cut from each meat sample along the muscle fibres, measured, and expressed as mean values.

Proximate chemical composition, fatty acid profile, cholesterol, and energy value of muscle

The following proximate chemical compositions were measured in the raw and ground meat samples according to the official methods of analysis of the AOAC (2003): moisture content by oven-drying samples to a constant weight (950.46), crude protein content by the classical Kjeldahl method (981.10), and intramuscular fat content by petroleum ether extraction (960.39) using a Soxhlet apparatus. Based on proximate composition and energetic value of protein (5.75 kcal · g^{-1}) and fat content (9.46 kcal · g^{-1}), the energetic value of *longissimus lumborum* muscle was estimated according to Atwater energy equivalents (MILCZAREK and OSEK 2016).

Sample preparation for the determination of total cholesterol content (extraction, separation of unsaponifiable fraction, preparation of trimethylsilyl sterol ethers) and chromatographic analysis with mass spectrometry (GCMS) were performed according to the Polish Standard PN-EN 12228:2002 (2002) using an Agilent 8890 GC apparatus.

The fatty acid profile of the lipid fraction was determined according to FOLCH et al. (1957) by gas chromatography (GC-FID) of methyl esters using a Perkin Elmer Clarus 580 gas chromatograph with a flame ionisation detector (air-hydrogen). A CP-Sil 88 capillary column (60 m × 0.25 mm × 0.20 µm) was used for the analysis. The injector temperature was 260°C, the detector temperature was 260°C, and the column temperature was 140°C (initial) and 240°C (final). Helium was used as the carrier gas at a flow rate of 0.5 ml per minute. The fatty acids were calculated using chromatogram peak areas. Although the total fatty acid profile was determined, only fatty acids with values ≥0.1% were included, reflecting the apparatus' detection limit.

Statistical analysis

The obtained results were statistically analysed using STATISTICA SOFTWARE VER. 13.1 (2019). The normality of the data distribution was tested using the Shapiro–Wilk test. The calculated parameters included measures of location (arithmetic mean) and dispersion (standard error of the mean), and data were analysed using one-way analysis of variance. The model is expressed as follows:

$$y_i = \mu + a_i + e_i$$

where:

y_i – the measured i^{th} trait
μ – the overall population mean
a_i – the analysed factor effect of the i^{th} trait
e_i – the random error.

The significance of the differences between the means was evaluated using Tukey's post hoc multiple range test. Statistical significance was assumed to exist when the probability was less than 0.05.

Results and Discussion

The introduction of EM Bokashi, inulin, or both additives combined into the diets for PLW×PL crossbred pigs had no significant effect ($p > 0.05$) on warm carcase weight, muscularity, longissimus lumborum muscle height, and backfat thickness (Table 2).

Table 2

Slaughter carcass value

Traits	Experimental groups				*p*-value	SEM
	I	II	III	IV		
Hot carcass weight [kg]	81.04	81.81	82.22	82.02	0.257	0.887
Lean meat content [%]	56.84	57.17	57.99	58.45	0.341	0.348
Backfat thickness [mm]	56.70	57.40	58.25	59.75	0.373	0.640
Muscle thickness [mm]	14.55	15.30	15.75	15.55	0.118	0.533

Explanations: group I – control (complete feed mixtures without additives); group II – fed complete mixtures with 0.3% EM Bokashi; group III – fed complete mixtures with 3% inulin; group IV – fed complete mixtures with 0.3% EM Bokashi + 3% inulin
SEM – standard error of the mean

Several researchers (CHANG et al. 2018, RYBARCZYK et al. 2020, 2021, ZHOU et al. 2025) have assessed the slaughter value of pigs fed diets with probiotics, prebiotics, and synbiotics. According to CHANG et al. (2018) and RYBARCZYK et al. (2020), no statistical differences in the lean meat content were noted between the experimental groups. In addition, ZHOU et al. (2025) found that 1.5% inulin inclusion resulted in no statistical differences in lean meat content; however, the authors observed a slight increase in backfat thickness. However, in the study by RYBARCZYK et al. (2021), the addition of 0.3% EM Bokashi to the Naïma x P-76 diet resulted in a statistically higher lean meat content (57.01% vs. 54.75%), higher *longissimus lumborum* muscle thickness (57.88 vs. 57.01%), and a decrease in backfat thickness (19.64% vs. 16.54%).

Supplementation of the fatteners' diet with inulin and EM Bokashi (group IV) significantly ($p \leq 0.05$) reduced muscle pH at 45 min and 24 h *post-mortem* compared with pigs fed diets supplemented with EM Bokashi alone (Table 3).

Table 3

Physicochemical traits of *longissimus lumborum* muscle ($N = 80$)

Traits	Experimental groups				*p*-value	SEM
	I	II	III	IV		
Acidity of the muscles						
pH_{45}	6.21*ab*	6.28*a*	6.16*b*	6.15*b*	< 0.05	0.023
pH_{24}	5.64*a*	5.56*ab*	5.53*b*	5.58*ab*	< 0.05	0.013
Electrical conductivity						
EC_2	3.61	3.14	3.28	3.89	0.101	0.117
EC_{24}	3.91	3.49	3.43	3.75	0.508	0.126
Colour						
L^*_{24}	51.62*b*	51.45*b*	53.91*ab*	54.36*a*	< 0.05	0.386
a^*_{24}	8.77*b*	8.51*b*	12.17*a*	12.46*a*	< 0.05	0.378
b^*_{24}	-0.63*b*	-0.77*b*	1.81*a*	2.48*a*	< 0.05	0.280
$C^*_{24} = [(a^*)^2 + (b^*)^2]^{0.5}$	8.83*b*	8.58*b*	12.53*a*	12.97*a*	< 0.05	0.410
$h°_{24} = \log(b^*/a^*)$	-0.08*b*	-0.10*b*	0.09*a*	0.15*a*	< 0.05	0.020
Drip loss	3.56	3.06	3.54	3.07	0.283	0.123
Cooking loss [%]	34.09	33.81	31.46	33.90	0.084	0.420
Water holding capacity WHC [cm^2]	5.68	6.42	6.89	6.43	0.121	0.178
Shear force [N/kg]	18.25	17.01	19.67	18.30	0.325	0.502

Explanations: group I – control (complete feed mixtures without additives); group II – fed complete mixtures with 0.3% EM Bokashi; group III – fed complete mixtures with 3% inulin; group IV – fed complete mixtures with 0.3% EM Bokashi + 3% inulin
a, *b* – statistically significant at $p \leq 0.05$, SEM – standard error of the mean

Dietary probiotics and prebiotics have the potential to improve pork quality traits (LIU et al. 2013, RYBARCZYK et al. 2021). However, the mechanisms by which they modify the quality traits are not fully understood. Probiotics and prebiotics may exert beneficial effects on meat quality through the gut-muscle axis by modulating the gut microbiota, producing beneficial metabolites, competitively excluding pathogenic microorganisms, and modulating the immune system of the host (CHEN et al. 2022, WEN et al. 2024). There are several potential mechanisms by which probiotics and prebiotics may influence meat quality via the gut-muscle axis. These include skeletal muscle metabolism, transformation of muscle fibre type, and intramuscular fat deposition (WEN et al. 2024).

Post-mortem pH decline plays a crucial role in determining of pork quality. Normally, in the *longissimus* muscle, pH declines from 7.2–7.4 in living muscle to 5.7–5.5 at 24 h after slaughter. Muscles with rapid *post-mortem* glycolysis exhibit a pH lower than 5.8 at 1 h after slaughter (SCHEFFLER and GERRARD 2007). In this study, the observed pH values in all experimental groups were within the range typical for normal meat across all measurements; however, pigs supplemented with EM Bokashi (II) produced pork with a higher pH at 45 min and 2 h in comparison with group III i IV. At 24 h *post-mortem,* the lowest pH value was noted in group III (pigs fed with 3% inulin). However, it should be stated that all experimental treatments (II, III, and IV) showed a tendency to lower muscle acidity compared to the control group (I).

SUO et al. (2012) noted that the addition of *Lactobacillus plantarum* ZJ316 increased pH measured at 45 min. after slaughter and lowered shear force and texture. Additionally, RYBARCZYK et al. (2016) showed that 0.3% EM Bokashi addition increased pH measured 24 hours after slaughter (5.59 vs. 5.66); however, it also increased drip loss (3.7% vs 2.5%) and cooking loss (31.02% vs. 28.57%). CHANG et al. (2018) found that *Lactobacillus plantarum* ($2.5 \cdot 10^7$ CFU/mL) statistically lower pH value; however, no adverse effect on WHC was found by the cited authors, which was also conferment in this study. RESZKA et al. (2020) showed that pigs fed a standard diet with soybean meal and probiotic had lower WHC than those from the control group and reported no effect of EM Carbon Bokashi on ultimate pH (pH_{48}), although both control and probiotic supplemented pigs displayed low pH_{48} (5.1–5.2).

No statistically significant effect ($p > 0.05$) of the feeding strategy was observed on the electrical conductivity, drip loss, cooking loss, and water holding capacity (WHC) of the *longissimus lumborum* muscle (Table 3). However, the highest drip loss was recorded in pigs fed diets supplemented with inulin (group III). Simultaneously, the muscles of pigs fed diets containing inulin exhibited the greatest hardness ($p > 0.05$).

According to the aforementioned studies, the effect of prebiotics, such as inulin supplementation, on water distribution in pork remains inconclusive. ROSENVOLD and ANDERSEN (2003) reported that the loins of pigs supplemented with high doses of inulin (25%) had lower drip loss than those in the control group. In contrast, ALUWE et al. (2013) showed that supplementation with 7% inulin increased the drip loss from pork loins. PRZYBYLSKI et al. (2019) showed that supplementation of inulin (7% in diet) had no significant effect on drip loss, although loins from inulin fed pigs for 40 days displayed higher drip loss (by 1.4 pp.). Other studies have shown no effect of inulin supplementation on drip loss (HANSEN et al. 2008, WANG et al. 2019, GRELA et al. 2021). In this study, low drip loss values (< 4% according to BERTRAM et al. 2000) measured 48 h after slaughter were observed, regardless of the experimental group. However, a slight decrease in its value (c.a. 0.5%) was noted for the experimental groups in which 0.3% EM Bokashi was used (II – 0.3% EM Bokashi and IV – 0.3% EM Bokashi and 3% inulin). Moreover, no statistical differences were observed in the WHC among the experimental groups. However, the addition of probiotics and synbiotics (II, III, and IV) tended to increase their values. This finding is contradictory to that of JUKNA et al. (2005), JIANG (2011), LIU et al. (2013), and GRELA et al. (2021) showed that the addition of *Saccharomyces cerevisiae, Lactobacillus casei, Lactobacillus acidophilus, Streptococcus faecium*, and *Bacillus subtilis* to pig diets statistically improved the water holding capacity. However, RYBARCZYK et al. (2020) showed that 0.5% EM® probiotic (*Saccharomyces cerevisiae*, *Lactobacillus casei,* and *Lactobacillus plantarum*) increased drip loss by 2-3 percentage points, cooking loss, and electrical conductivity at 2 and 24 h *post-mortem*. Additionally, the authors noted that the addition of probiotics at 0.3% did not influence the aforementioned traits. The tendency to decrease shear force in group II (0,3% EM Bokashi) was complementary to the results noted by GRELA et al. (2021). The authors found lower shear force (by 17%, $p \leq 0.05$) in pork fed with the addition of prebiotics. In addition, PEREIRA PINTO et al. (2019) reported that the addition of 6% inulin significantly lowered the shear force and chewiness. However, ZHOU et al. (2025) noted that inulin did not influence shear force. In conclusion, drip loss is an important quality cue for consumers, although it is less important in the decision-making process than fat cover and colour (NGAPO et al. 2007, VERBEKE et al. 2010, FONT-I-FURNOLS and GUERRERO 2014, NGAPO et al. 2017). In general, consumers prefer pork with minimal or no drip, which is perceived as a sign of higher meat quality (FONT-I-FURNOLS and GUERRERO 2014, NGAPO et al. 2017). Thus, pork from pigs supplemented with inulin or synbiotic fits well within the preferences of consumers.

Muscle from pigs fed diets without additives or supplemented with EM Bokashi were darker (L*) but less saturated ($p \leq 0.05$) in red (a*) and yellow (b*) hues than those from pigs receiving diets supplemented with inulin or inulin + EM Bokashi (Table 3). The *longissimus lumborum* muscles of pigs in groups III and IV featured significantly ($p \leq 0.05$) higher colour saturation (C*) than those of pigs in groups I and II. Similarly, hue angle (h°) values were significantly higher in muscles from groups II and IV in comparison with muscles from pigs fed diets supplemented solely with the probiotic (group II).

The lack of effect of EM Bokashi supplementation in the diets of PLW×PL fatteners on the colour parameters (L*,a*,b*) of the *longissimus lumborum* muscle is consistent with the findings of RYBARCZYK et al. (2016), who demonstrated that 0.3% EM Bokashi included in the diet of Naïma×P-76 crossbreds did not result in differences in lightness or colour saturation in the red and yellow directions. In a subsequent study, RYBARCZYK et al. (2020) reported that the meat of pigs supplemented with 0.5% EM® probiotic (containing *Saccharomyces cerevisiae*, *Lactobacillus casei*, and *Lactobacillus plantarum*) was characterised by higher red colour saturation (a*) than that of both the control group and the group supplemented with 0.3% probiotic. In a study by JIANG (2011), the addition of a probiotic preparation containing *Phaffia rhodozyma* significantly increased the redness (a*) of the meat colour of fatteners. Other studies have shown that the administration of probiotics (*L. plantarum*) to pigs enhanced the antioxidant activity in meat, which was due to an increase in the concentration of vitamin C (CHANG et al. 2018). It should be mentioned that vitamin C is characterised by very good antioxidant properties and increasing its concentration in meat improves meat colour and persistence (WHEELER et al. 1996). RYBARCZYK et al. (2020) claimed that the lactic acid bacteria (LAB) dosage had a significant effect on the gut microbiota through a significant increase in LAB count and a decrease in the number of *Enterobacteria*, which might be relating to the changes in *LL* muscle quality, especially in the traits associated with water holding capacity and meat colour-chromatic characteristics (a*, b*, C*, h°).

The inclusion of inulin or inulin + EM Bokashi in pig diets resulted in meat with a lighter colour (L*) and more intense red (a*) and yellow (b*) hues than the meat of pigs receiving control diets or diets with an added probiotic (Table 3). The colour of fresh meat has a crucial effect on consumers' purchasing decisions. However, consumers' expectations for pork colour vary widely by region and culture (ALTMANN et al. 2023). In Europe, most consumers prefer lighter but redder meat (NGAPO et al. 2010, JAWORSKA et al. 2009). Thus, pork from pigs supplemented with inulin or synbiotics may be more preferable to consumers. The results partially support the findings of GRELA et al. (2021), who also observed a lighter colour and increased yellow

hue in the meat of pigs fed a diet containing inulin, although with a decrease in redness. In turn, SOBOLEWSKA and GRELA (2014) demonstrated that the type of inulin used in pig diets affects meat colour parameters, as raw loin from pigs fed diets with inulin obtained by water-alcohol extraction, compared to other pig groups (inulin obtained by water extraction, powdered Jerusalem artichoke, or powdered chicory), was characterised by the lightest colour (L*) and the highest saturation in the yellow direction (b*). ZHOU et al. [13] did not confirm the effect of a 1.5% inulin addition to pig diets on meat colour parameters.

The addition of probiotics (EM Bokashi), prebiotics (inulin), or synbiotics (EM Bokashi + inulin) to the diets of fattening pigs did not affect ($p > 0.05$) the proximate composition (dry matter, crude ash, and crude protein) of the muscle, except for crude fat (Figure 1).

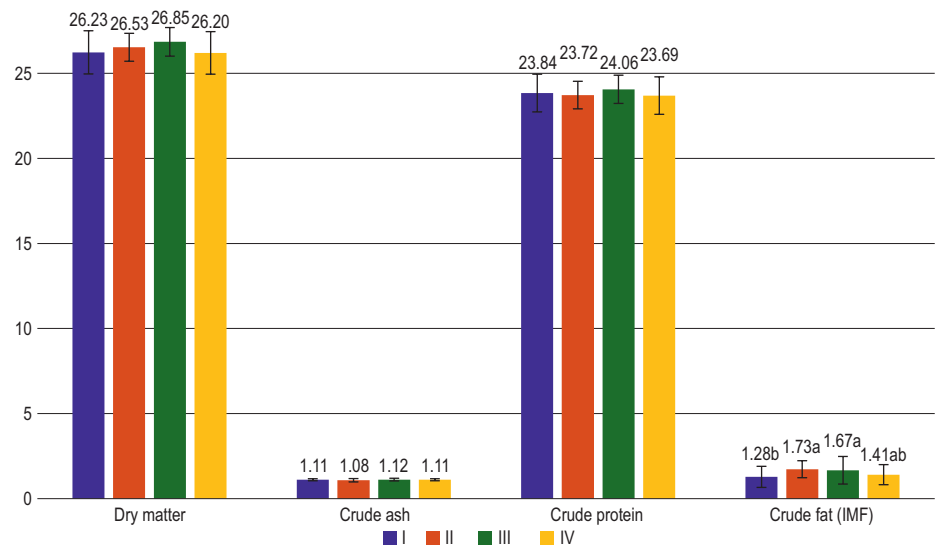

Fig. 1. Proximate chemical composition [%]

The crude fat content was significantly ($p \leq 0.05$) higher in the muscles of pigs fed diets with EM Bokashi (group II) and inulin (group III) than that in the control pigs.

From a human nutrition perspective, fat is a carrier of flavour and a source of saturated fatty acids (MILCZAREK 2021, ZDUŃCZK et al. 2024). Crude fat also determines the culinary usefulness of meat; for the *longissimus dorsi* muscle, the optimal IMF content ranges from 1.5 to 3.5% (WOOD et al. 1994). In this study, the analysis of the effect of the applied pig feeding regime on the nutritional value of the *longissimus dorsi* muscle confirmed

that the crude fat content was the most variable (1.28–1.73%). BREWER (1998) found that meat with IMF content between 1.5 and 3.5% was characterised by higher flavour intensity and juiciness than meat with low (<1.5%) IMF content. Only the muscles of fatteners receiving diets supplemented with EM Bokashi and inulin showed fat levels within the aforementioned range, which may be preferred by most consumers. In Europe, fat content is the most important cue in consumers' choice, preferably with slightly visible fat (including subcutaneous fat cover and intramuscular fat), thus increasing their purchase intention (VERBEKE et al. 2010, FONT-I-FURNOLS and GUERRERO 2014, FONT-I-FURNOLS et al. 2012, DE ARUJO et al. 2022). However, BREWER et al. (2001) reported that chops with less than 2.5% IMF had higher overall acceptability and purchase intention than those with higher IMF content.

RYBARCZYK et al. (2016, 2019, 2020) found that the inclusion of EM Bokashi probiotics (0.3%) or BioPlusYC (0.4%) in diets fed to fatteners did not significantly affect the fat content of meat. However, 0.5% share reduced intramuscular fat compared to the control and 0.3% probiotic-supplemented groups [55]. GRELA et al. (2021) demonstrated that supplementation with a probiotic (*Lactococcus lactis*, *Carnobacterium divergens*, *Lactobacillus casei*, *Lactobacillus plantarum*, *Saccharomyces cerevisiae*) reduced (2.09% vs. 2.22%) intramuscular fat content in the *longissimus lumborum* muscle compared to the control group.

Likewise, in the present study, GRELA et al. (2021) noted a similar content of basic components in the muscle tissue of fatteners fed diets supplemented with inulin, except for the IMF level. Inulin addition increased its content, whereas probiotic reduced.

The feed additives used in the diets of fattening pigs did not affect the energy value of the evaluated *longissimus lumborum* muscle (Table 4).

The amount of energy in the muscle ranged from 149.21 to 154.14 kcal/100 g and was attributed to the nutrient content, especially intramuscular fat (IMF). Due to the muscle's low IMF level, its energy value was lower than that reported by MILCZAREK and OSEK (2016), MILCZAREK et al. (2019) and KUNACHOWICZ et al. (2020).

Animal-origin products, including pork meat, are a source of cholesterol in the human diet (KUNACHOWICZ et al. 2020). KUNACHOWICZ et al. (2020) state that the cholesterol content in pork ranges from 60 to 72 mg/100 g. Lower cholesterol content (52.48–59.48 mg/100 g) was found in the *longissimus dorsi* muscle of PLW × PL crossbreds. The inclusion of probiotics, prebiotics, or synbiotics in the diets of fatteners did not affect the cholesterol content of the *longissimus lumborum* muscle. However, significantly lower amounts (52.48 mg/100 g) of this component were found in the muscle of pigs receiving diets with inulin compared to those fed with EM Bokashi

Table 4

Energy value, cholesterol and fatty acids profile of muscles ($N = 80$)

Traits	Experimental groups				p-value	SEM
	I	II	III	IV		
Energy value [kcal/100 g]	149.21	152.76	154.14	149.53	0.219	0.878
Cholesterol [mg/100 g]	53.72*ab*	59.26*a*	52.48*b*	59.48*a*	<0.05	0.884
Fatty acids [g/100 g]						
Palmitic acid (C16:0)	0.30	0.40	0.36	0.33	0.983	0.015
Stearic acid (C18:0)	0.19	0.25	0.22	0.22	0.788	0.009
Oleic acid (C18:1n9c)	0.46*b*	0.65*a*	0.62*a*	0.49*b*	<0.05	0.127
Linoleic acid, LA (C18:2n6c)	0.19	0.20	0.23	0.20	0.367	0.009
SFA	0.48*c*	0.67*a*	0.63*a*	0.55*b*	<0.05	0.027
UFA	0.81*b*	1.06*a*	1.04*a*	0.86*ab*	<0.05	0.040
MUFA	0.52*b*	0.79*a*	0.76*a*	0.61*ab*	<0.05	0.034
PUFA	0.26	0.26	0.28	0.24	0.399	0.012
Omega-3	<0.10	<0.10	<0.10	<0.10	1.000	1.000
Omega-6	0.23	0.26	0.27	0.23	0.526	0.011
Omega-7	0.14	0.13	0.15	0.13	0.356	0.005
Omega-9	0.46	0.66	0.63	0.51	0.580	0.028

Explanations: group I – control (complete feed mixtures without additives); group II – fed complete mixtures with 0.3% EM Bokashi; group III – fed complete mixtures with 3% inulin; group IV – fed complete mixtures with 0.3% EM Bokashi + 3% inulin
IMF – intramuscular fat; SFA – saturated fatty acids; UFA – unsaturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids
a, *b* – statistically significant at $p \leq 0.05$, SEM – standard error of the mean

(59.26 mg/100 g) or EM Bokashi + inulin (59.48 mg/100 g). RYBARCZYK et al. (2016) found a significantly lower cholesterol level (71.91 mg/100 g) in the muscle of Naïma × P-76 pigs fed a diet with 0.3% EM Bokashi compared to the muscle of pigs from the control group (74.50 mg/100 g). In contrast, GRELA et al. (2013) demonstrated that supplementing pig diets with inulin and garlic water extract significantly reduced the cholesterol content in the *longissimus dorsi* muscle.

The muscles of pigs fed diets supplemented with inulin or EM Bokashi contained significantly ($p \leq 0.05$) higher amounts of oleic acid, saturated fatty acids (SFA), and unsaturated fatty acids (UFA), including monounsaturated fatty acids (MUFA), than those of the control pigs.

From a human nutrition perspective, a beneficial increase in the share of unsaturated fatty acids (UFA) and a decrease in saturated fatty acids (SFA) were observed in the muscles of pigs fed control diets or diets with inulin compared to those fed rations supplemented with EM Bokashi or EM Bokashi

+ inulin. Moreover, the evaluated bioactive additives had no effect on omega-3 and omega-6 fatty acid levels. However, GRELA et al. (2013) found higher levels of omega-3 and omega-6 fatty acids in the *longissimus dorsi* muscle of pigs fed diets supplemented with inulin and garlic extract. Additionally, GRELA et al. (2021) reported a more favourable n6/n3 polyunsaturated fatty acid ratio in the muscle of pigs receiving diets supplemented with a probiotic (*Lactococcus lactis, Carnobacterium divergens, Lactobacillus casei, Lactobacillus plantarum,* and *Saccharomyces cerevisiae*) than that in the meat of fattening pigs from the control group.

Conclusions

In conclusion, it must be stated that the inclusion of 0.3% EM Bokashi, 3% inulin, and 0.3% EM Bokashi + 3% inulin in the diets of PLW × PL crossbreds did not affect carcass value and allowed for the production of meat with desirable physicochemical properties.

From the consumer nutrition perspective, the inclusion of 3% inulin in complete feed rations for fattening pigs is recommended, as it resulted in the lowest the cholesterol level (52.48 mg/100g) and the most favourable fatty acid profile in the *longissimus lumborum* muscle. Both of the above-mentioned impacts, that is, on the physicochemical and dietary value, can be considered factors influencing consumers' willingness to purchase, due to increased awareness of a healthy diet and a potential decrease in diseases of affluence, which may also attract greater interest from processors.

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