Hindawi
Journal of Food Quality
Volume 2019, Article ID 5313496, 8 pages
https://doi.org/10.1155/2019/5313496

Research Article

Effects of Marinating Breast Muscles of Slaughter Pheasants with Acid Whey, Buttermilk, and Lemon Juice on Quality Parameters and Product Safety

Anna Augustyńska-Prejsnar,[1] Małgorzata Ormian,[1] Paweł Hanus,[2] Maciej Kluz,[3] Zofia Sokołowicz,[1] and Mariusz Rudy[4]

[1]*University of Rzeszow, Faculty of Biology and Agriculture, Department of Animal Production and Poultry Products Evaluation, 35-959 Rzeszów, Poland*
[2]*University of Rzeszow, Faculty of Biology and Agriculture, Department of Food Technology and Human Nutrition, 35-959 Rzeszów, Poland*
[3]*University of Rzeszow, Faculty of Biology and Agriculture, Department of Bioenergetics and Food Analysis, 35-959 Rzeszów, Poland*
[4]*University of Rzeszow, Faculty of Biology and Agriculture, Chair of Agricultural Processing and Commodity Science, 35-959 Rzeszów, Poland*

Correspondence should be addressed to Anna Augustyńska-Prejsnar; augusta@ur.edu.pl

Received 22 February 2019; Accepted 17 April 2019; Published 19 May 2019

Guest Editor: Lara Morán

Along with the growth of the group of consumers paying attention to the relationship between diet and health, there is a trend of interest in natural products and the possibility of their use in meat processing. Raw material used for the study was the breast muscles of pheasants (*Phasianus colchicus*), which were marinated for 24 hours with acid whey, buttermilk, and lemon juice. Physical parameters (marinade absorption, pH, WHC, colour, shear force, texture profile analysis (TPA), and thermal losses) and microbiological parameters (the number of mesophilic aerobic bacteria, Enterobacteriaceae, *Pseudomonas* spp., and lactic acid bacteria) of the nonmarinated and marinated muscles (raw and roasted) were evaluated, and sensory analysis was made. The studies have shown that whey and buttermilk can be used as a natural marinade for marinating pheasant meat, as it ensures microbiological safety of the product and has a positive effect on tenderness (measured by shear force) and chewiness. In the sensory evaluation, it improves the juiciness and tenderness of the roast product and has obtained general acceptability.

1. Introduction

The growing interest in high-quality food makes consumers increasingly pay attention to pheasant meat. The meat of these birds has valuable nutritional, dietary, and sensory values. It is a rich source of protein and micronutrients (especially selenium and phosphorus) and contains small amount of fat with a low content of saturated fatty acids [1, 2]. Due to high levels of vitamins B_6 and B_{12} and niacin in pheasant meat, the meat of these birds can be similar to the meat of chickens, geese, or ducks [3, 4]. However, it still remains a niche product. The factors limiting the production and demand for pheasant meat are the seasonality of production and a small group of farms dealing with their breeding [5]. Consumers are increasingly looking for meat with good and health benefits and are willing to pay a higher price for unique high-quality products.

Meat marinating has been known for many years. The selection of marinade ingredients and marinating techniques are constantly improved so that the product obtained meets the expectations of consumers. Consumers are increasingly aware of diet-related health problems and

therefore demanding natural ingredients which are expected to be safe and health-promoting [6].

Juice of lemon (*Citrus limon*) is commonly used for culinary purposes around the world: used as a food preservative and often used for marinating meat to improve the juiciness and tenderness of meat [7, 8]. Lemon juice contains citric acid, L-ascorbic acid, sugars, proteins, and fibres, as well as B-group vitamins, beta-carotene, macro- and micronutrients, and biologically active ingredients, such as essential oils (mainly limonene), bioflavonoids, phytoncides, and pectins [9].

Acid whey and buttermilk are by-products of the dairy industry which are produced in large quantities during the production of cottage cheese and the production of butter using appropriate cultures of lactic acid bacteria. These products are a source of many valuable components: lactose, calcium and phosphorus compounds, organic acids (including high content of lactic acid), and vitamins [10]. Acid whey has a very high biological value and contains peptides and proteins (α-lactalbumin, β-lactoglobulin, immunoglobulin, bovine serum albumin (BSA), and lactoferrin), of which the most important are α-lactalbumin and β-lactoglobulin. They are characterized by a high nutritional value and have a strong antimicrobial and antioxidant effect [11]. The health and technological properties of whey proteins make it a unique raw material of the food industry. Whey contains high amounts of B-group vitamins (especially B_2 vitamin) and vitamin A and significant amounts of tryptophan and cysteine and mineral compounds [12]. Buttermilk is a dietetic product (fat content does not exceed 1%), distinguished by a high content of lecithin and B-group vitamins. Buttermilk is well tolerated in people with lactose intolerance. The protein content in the product is low but has a high biological value. By-products of the dairy industry, such as whey and buttermilk, are currently used in the production of functional foods and enjoy the interest of the meat industry and consumers in households. The results of the latest scientific research indicate the possibility of using acid whey for marinating beef and pork [12–18] to improve the sensory characteristics and tenderness and inhibit oxidative changes in the meat products. Vlahova-Vangelova et al. [19] showed the beneficial effect of marinating on organoleptic characteristics (smell and consistency) of broiler chicken meat. The lack of information in the scientific literature presenting the use of acid whey and buttermilk for marinating pheasant meat prompted the authors to undertake research in this field.

The aim of this study was to evaluate the use of acid whey, buttermilk, and lemon juice to marinate pheasant breast muscles and the effect on the quality parameters and product safety.

1.1. Practical Applications. Meat of pheasants has valuable nutritional values. The growing interest in high-quality food makes consumers pay attention to the meat of pheasants. The use of whey and buttermilk for marinating pheasant meat had a positive effect on the quality of the product, ensuring full health safety and consumer acceptance. Based on the research results, it can be concluded that acid whey and buttermilk can be used as a marinade for pheasant meat.

2. Materials and Methods

Research material for the study consisted of breast muscles obtained from 16-week-old pheasants (*Phasianus colchicus*). The pheasant carcasses were bought from local farms dealing with the rearing of pheasants. The birds were kept in partially roofed aviaries on a sand-gravel substrate. They were fed *ad libitum*, using in the first 4 weeks of life complete commercial feed mixtures containing 28.0% of total protein and 11.6 MJ of metabolic energy and up to 10 weeks mixtures containing 21.5% of protein and 12 MJ of metabolic energy. Above that age till the end of rearing, farm fodder was fed, i.e., wheat grains, maize, green forage of grasses and alfalfa, and crumbled carrot and pumpkin. 24 hours after slaughter, skinless breast muscles were manually trimmed from chilled carcasses [20]. Single breast muscles were used in the study. The control group (C) consisted of nonmarinated breast muscles ($n = 40$ left). Before marinating, the muscles were weighed with an accuracy of 0.01 g (balance type ED 423S-0CE, Sartorius Mechatronics, Poland) and individually labelled. The samples were stored at 4°C.

Three acidic marinades were used in the study, which were based on acid whey (W group), buttermilk (B group), and lemon juice (LJ group). The marinades were supplemented with sea salt (1.0%), cane sugar (1.0%), and, in the LJ group, distilled water. The marinades were prepared for 1 hour before using for the study and stored at 4°C. The acid whey and buttermilk came from a local producer of dairy products that were obtained directly from the quark and organic butter production line. The by-products of the dairy industry were subjected to the microbiological control at the manufacturer in accordance with the following standards: PN-EN 12322 : 2005 [21] and PN-EN ISO 11133 : 2014-07 [22], on the mediums *Salmonella-Shigella* Lab-Agar, Violet Red Bile with Lactose Lab-Agar, and Tryptocasein Soy Lab-Agar. The products have a quality control certificate and are on the market. Analysis of the chemical composition of whey and buttermilk was performed with the analyzer of the chemical composition of milk and products, Bentley B-150 (Bentley, USA). The whey contained 0.59% protein, 0.21% fat, 4.65% lactose, and 6.56% dry matter. Buttermilk contained 3.95% protein, 1.87% fat, 4.97% lactose, and 11.96% dry matter. The active acidity in the products was determined by the pH meter FiveEasy Plus FP20 (Mettler Toledo, Switzerland) equipped with an LE438 electrode with an integrated temperature sensor; the pH of the products was similar: whey 4.53 and buttermilk 4.51. The total acidity was determined in accordance with the guidelines of Jemaa et al. [23]: for whey, it was 0.49 (g of lactic acid/l), and for buttermilk, it was 0.87 (g of lactic acid/l). Fresh bio-lemon juice (pH 2.46 ± 0.32) was used which was squeezed by hand. The concentration of lemon juice was designed to correspond to the average pH (4.52) of whey and buttermilk. For this purpose, the fruits were scalded (3 minutes in boiling water), cut with a sterile knife, and filtered. Sea salt and cane sugar were purchased at the organic food store.

The process of marinating consisted in immersion of breast muscles—W group (n = 40), B group (n = 40), and LJ group (n = 40)—in the prepared marinade. The ratio of meat to marinade was set at 1 : 1 (meat : marinade). Samples from the groups were immersed in the marinade inside plastic containers. Breast meat was stored in a refrigerator for 24 hours at 4°C ± 1°C in atmospheric conditions. After the fixed marinating period, the samples were weighed again with an accuracy of 0.01 g.

Nonmarinated (C) and marinated (W and LJ) breast muscles were weighed with an accuracy of 0.1 g and processed using an electric oven at 180°C to achieve a temperature of 80°C ± 2°C inside the muscle sample. The temperature inside the muscles was measured with a digital thermometer with an external K-type thermocouple probe (Therma Plus, England).

To determine the marinade absorption, the control and marinated meat samples were weighed before and after marinating. The marinade absorption was calculated using the following formula: marinade absorption (%) = weight of sample after marinating (g) − weight of sample before marinating (g) × 100/weight of sample before marinating (g). The pH measurements of nonmarinated and marinated breast muscles were made using a dagger electrode, fitted with a pH meter (HI-99163, Hanna, Germany). The sample's water-holding capacity (WHC) determined using the Grau and Hamm [24] method was based on the amount of juice squeezed from it. The colour assessment of the cross-sectional surface of nonmarinated and marinated breast muscles was performed, based on the reflection method, using the Chroma Meter colorimeter (Konica Minolta, Osaka, Japan), fitted with a CR-400 head (ø = 11 mm), calibrated with a Konica Minolta calibration plate (observer 2°, illuminant D_{65}, $Y = 93.5$, $x = 0.3160$, and $y = 0.3324$). The reading of the measurement results was achieved in a CIELAB colorimetric system [25], with L^* (lightness), a^* (redness), and b^* (yellowness). Brittleness analysis and texture profile analysis (TPA) were performed on roast control and marinated meat samples. Brittleness was measured based on the shear force (F_{max}), using a Zwick/Roell testing machine BT1-FR1.OTH.D14 (from Zwick GmbH & Co. KG, Ulm, Germany), applying a wide-width Warner–Bratzler V-blade with a head speed of 100 mm·min^{-1} and a 0.2 N precut force. The cutting was carried out on cubes of control and marinated breast muscles with a cross section of 100 mm^2 and a length of 50 mm. Texture profile analysis (TPA) was performed with a CT3 25 texture analyzer (Brookfield, USA) equipped with a cylindrical probe with a diameter of 38.1 mm and a length of 20 mm. A test of double compression of samples to 50% of their height was performed [26]. The texture was determined on nonmarinated and marinated breast muscle samples in the form of 10 mm cubes. The speed of the roll during the test was 2 mm/s, while the gap between pressures was 2 s. The TPA parameters hardness (N), springiness (mm), gumminess (N), and chewiness (MJ) were calculated from the force-time curves recorded for each sample using Texture Pro CT [27]. To assess the post-heat treatment leakage, 30 g of meat samples was weighed, placed, and kneaded in 150 cm^3 beakers and weighed with an accuracy of 0.01 g (balance type ED 423S-0CE, Sartorius Mechatronics, Poland). The samples thus prepared were covered with polyethylene foil and heated in a water bath at 72 ± 2°C for 30 minutes and subsequently cooled [28]. The amount of post-heat treatment leakage is expressed based on the following formula: $W = [(m_1 - m_2) : (m_1 - m_0)] \times 100\%$, where W is the amount of posttherm al leakage (%), m_0 is the mass of the empty beaker (g), m_1 is the mass of the beaker with meat before thermal treatment (g), and m_2 is the mass of the beaker with meat after pouring out the leaked meat juice (g). Weight loss (%) was calculated based on the weight difference before and after heat treatment.

An amount of 10 g (10 cm^2) of the breast muscles was sampled using sterile scalpels and forceps, immediately transferred into a sterile stomacher bag, containing 90 mL of 0.1% peptone water (pH 7.0), and homogenized for 60 s in a stomacher at room temperature. Microbiological analyses were conducted by using standard microbiological methods. Anaerobic plate count (AC) was determined using Tryptocasein Soy Lab-Agar (TSA, Biocorp) after incubation for 48 h at 35°C under aerobic conditions. For *Pseudomonas* spp., 0.1 ml from serial dilutions of meat sample homogenates was spread onto the surface of *Pseudomonas* Isolation Agar (PIA, Oxoid). *Pseudomonas* spp. were counted after incubation for 48 h at 25°C. For lactic acid bacteria, Rogosa and Sharpe Agar (MRS, Oxoid, UK) was inoculated with a 1.0 ml of sample suspension. Inoculated plates were incubated for 48–78 h at 37°C in an aerobic atmosphere supplemented with carbon dioxide (5% CO_2). For Enterobacteriaceae, a 1.0 ml of sample was transferred into 10 ml of molten (45°C) Violet Red Bile Glucose Agar (VRBL, Biocorp). Inoculated plates were incubated at 37°C for 24 h. All plates were examined for typical colony types and morphology characteristics associated with each medium applied for incubation. All tested groups of bacteria were counted in triplicate. Sampling for microbiological assessment after heat treatment was carried out after 24 hours of cold storage in a cooling cabinet (FKv 36110, Liebherr, Germany) at 4°C ± 1°C.

The sensory quality of marinated and nonmarinated pheasant breast muscles was scaled using the method according to Baryłko-Pikielna and Matuszewska [29]. In order to conduct the sensory assessment, the heat-treated samples were cooled to 20°C ± 2°C and cut into 1.5 cm thick slices, perpendicular to the run of meat fibres. They were placed in disposable plastic boxes that were covered with lids. All samples for evaluations were coded individually and given in random order. The sensory evaluation was carried out by a 6-person evaluation team tested in terms of sensitivity and sensory fitness according to ISO 8586-2:2008 [30] and ISO 8587:2006 [31]. The evaluating persons had experience in assessing meat and meat products. A 5-point evaluation was applied with a defined value limit, including the following qualitative indices: odour intensity (very negative (typical) and very strong), flavour intensity (very negative, very sour (typical), and very desirable), odour desirability (not desirable and highly desirable), flavour desirability (not desirable and highly desirable), juiciness

(very dry and very juicy), and tenderness (very hard and very tender). All the evaluations were performed at a sensory laboratory that conformed to all the requirements of the relevant standard [32]. Between each sample test, assessors took a break for 30 s and rinsed their mouths using mineral water.

Results obtained were statistically analysed with the analysis of variance (ANOVA) using the Statistica 13.1 software package [33]. The arithmetic mean ($\overline{x}$) and standard deviation (SD) were determined. To indicate the significance of differences between means in groups, Tukey's post hoc test with a level of significance $p < 0.05$ was applied.

3. Results and Discussion

The study showed that the percent marinade absorption significantly ($p < 0.05$) differed among treatments. Marinade absorption ranged from 3.26 to 7.32%. Pheasant breast muscles marinated in buttermilk showed the highest absorption, while those marinated in the lemon juice the lowest absorption (Table 1). Differences in marinade absorption could be due to the density of marinades, differences in the osmotic pressure exerted by different marinade solutions, and also the marinades' pH. Many authors [8, 14, 16, 34, 35] indicate that the acidity of marinated meat depends on the pH of the marinade, as confirmed in the present study. The pH value of raw pheasant breast muscles marinated with acid whey and buttermilk was significantly ($p < 0.05$) lower than that of those marinated with lemon juice. This result was unexpected because the pH of the marinades used was the same. The difference in pH may have resulted from the microbial load of the dairy industry by-products that could produce lactic acid. Water-holding capacity of meat is the ability to maintain its own and added water. In the case of marinated meat, water absorption depends on the composition of the marinade [36]. Meat with higher water-holding capacity loses less juice during thermal processing, which may affect its juiciness. In the present study, it was shown that pheasant breast muscles marinated in buttermilk and whey were characterized by a higher ($p < 0.05$) water absorption, while those marinated in lemon juice by a lower absorption. Increase in the moisture content might be attributed to marinade absorption [37]. In the present study, it was shown that marinating significantly affected ($p < 0.05$) the brightening of colour of raw and heat-treated pheasant breast muscles (increase in parameter L^*) in comparison to nonmarinated muscles (Table 1). On the contrary, no significant differences ($p > 0.05$) of the brightness parameter L^* between the marinades used were found. The brightening of colour of the pheasant breast muscles marinated in acidic marinades could be due to decrease in its pH and a higher amount of extracellular water introduced into the meat during marinating. Serdaroğlu et al. [35] reported that L^* values increased when turkey meat samples were marinated in citric acid. According to these researchers, one possible reason for increased L^* values is that muscle proteins swell and light reflection alters at low pH and ionic strength, resulting in lighter colour. In the study by Vlahova-Vangelova et al. [19], the effect of whey marinade used on the surface colour of raw and grilled breast muscles of broiler chickens was not demonstrated. Kim [14], on the contrary, noted the effect of acid whey on the reduction of the L^* brightness parameter in a raw and heat-treated bovine marinated product. In the present study, it was found that marinating with whey and buttermilk caused a significant increase in yellow colour ($p < 0.05$) of raw pheasant muscles. This tendency was preserved after heat treatment with marinating in whey, while marinating in buttermilk caused an increase in the colour saturation towards red (Table 1). The reduction of the L^* brightness parameter could result from the participation of mineral compounds and sugars present in whey and buttermilk, possibly by alteration of the oxidation state of myoglobin. In the present study, it was shown that marinating had an effect ($p < 0.05$) on the amount of thermal drip, whereas no effect of the marinades used on this characteristic was noted ($p < 0.05$).

Health safety in microbiological terms can be defined as the absence of pathogenic organisms and toxins of microbiological origin in a specified quantity of food [17]. It should be strictly ensured for meat products marinated using natural marinades. In the conducted research, it was found that the use of acid whey and buttermilk for marinating significantly ($p < 0.05$) affected the inhibition of the number of mesophilic aerobic bacteria and *Pseudomonas* spp. in a raw marinated pheasant breast muscle (Table 2). It was also shown that marinating with whey and buttermilk effectively inhibited the growth of bacteria from the family Enterobacteriaceae. The pH reduction caused by organic acid (lactic) was the primary factor that affected the reduction of microorganisms. In an environment with acidic pH, the processes of multiplication of most microorganisms are slowed down [38]. From the microbiological perspective, the antimicrobial substances contained in acid whey and buttermilk, such as organic acids or whey proteins, were responsible for the inhibition of microbial growth. Moreover, it was shown that marinating raw pheasant muscles with the use of whey and buttermilk significantly ($p < 0.05$) contributed to an increase in the number of lactic acid bacteria compared to the control and marinating with the use of lemon juice (Table 2). The growth of lactic acid bacteria in the conducted research, their ability to control the environment and to compete with other microorganisms for amino acids or easily fermentable saccharides, could limit the possibilities for the development of saprophytic and pathogenic bacteria [10]. Vlahova-Vangelova et al. [19] proved that the concentration of acid whey and the time of marinating affected the increase in the population of lactic acid bacteria in the raw breast muscles of broiler chickens. The growth of lactic acid bacteria was noted by Wójciak et al. [15], Wójciak et al. [16], and Wójciak and Dolatowski [39] in a pork product marinated in whey and a model beef product with the addition of sea salt. In the microbiological assessment of pheasant meat after heat treatment and cold storage for 24 hours, no lactic acid bacteria and bacteria from the family Enterobacteriaceae were found (Table 2). It was shown, however, that marinating with whey and buttermilk inhibited the growth of aerobic bacteria and *Pseudomonas*

Table 1: Physical composition of nonmarinated and marinated slaughter pheasants.

Parameter	Nonmarinated	Marinated			SEM
	Group C	Group W	Group B	Group LJ	
Raw marinated					
Marinade absorption (%)	—	$5.07^{b} \pm 0.62$	$7.32^{a} \pm 0.78$	$3.26^{c} \pm 0.51$	0.03
pH	$6.11^{a} \pm 0.03$	$5.49^{c} \pm 0.04$	$5.47^{c} \pm 0.03$	$5.59^{b} \pm 0.08$	0.01
Water-holding capacity (%)	$22.59^{c} \pm 2.56$	$28.73^{a} \pm 2.86$	$30.33^{a} \pm 3.12$	$25.67^{b} \pm 3.56$	0.12
Colour					
L^* (lightness)	$52.10^{b} \pm 3.94$	$53.18^{a} \pm 3.16$	$53.84^{a} \pm 3.10$	$58.89^{a} \pm 2.92$	0.50
a^* (redness)	11.20 ± 1.20	11.86 ± 1.65	13.05 ± 1.05	10.86 ± 1.40	0.15
b^* (yellowness)	$4.68^{a} \pm 1.25$	$6.11^{b} \pm 1.52$	$5.92^{b} \pm 1.2$	$3.16^{c} \pm 0.92$	0.09
Marinated and roasting					
pH	$6.24^{a} \pm 0.03$	$5.81^{b} \pm 0.03$	$5.83^{b} \pm 0.02$	$5.86^{b} \pm 0.04$	0.08
Colour					
L^* (lightness)	$76.82^{a} \pm 3.79$	$80.04^{b} \pm 3.51$	$79.35^{b} \pm 1.86$	$80.42^{b} \pm 3.82$	0.42
a^* (redness)	10.82 ± 1.58	9.58 ± 2.10	10.86 ± 1.80	9.10 ± 1.45	0.12
b^* (yellowness)	$10.89^{b} \pm 2.02$	$12.10^{a} \pm 2.05$	$11.48^{b} \pm 1.89$	$9.68^{b} \pm 2.50$	0.28
Treatment leakage (%)	$16.50^{b} \pm 2.60$	$22.29^{a} \pm 2.86$	$23.51^{a} \pm 2.88$	$21.94^{a} \pm 3.85$	0.26

Data are expressed as arithmetic mean ± standard deviation ($\bar{x} \pm s$). Group C: control group, nonmarinated; group W: marinated in acid whey; group B: marinated in butter milk; group LJ: marinated in lemon juice. [a,b,c]Values in rows with different letters differ significantly ($p < 0.05$).

Table 2: Microbiologial composition of nonmarinated and marinated breast muscles of slaughter pheasants.

Parameter (log cfu.g^{-1})	Nonmarinated	Marinated			SEM
	Group C	Group W	Group B	Group LJ	
Raw marinated					
Mesophilic aerobic bacteria	$5.21^{a} \pm 0.04$	$3.46^{b} \pm 0.22$	$3.27^{b} \pm 0.33$	$5.24^{a} \pm 0.17$	0.06
Enterobacteriaceae	4.73 ± 0.01	—	—	4.80 ± 0.02	0.08
Pseudomonas spp.	$5.22^{a} \pm 0.03$	$3.72^{b} \pm 0.09$	$3.94^{b} \pm 0.01$	$5.32^{a} \pm 0.06$	0.09
Lactic acid bacteria	$3.04^{b} \pm 0.10$	$3.72^{a} \pm 0.15$	$3.69^{a} \pm 0.15$	$3.00^{b} \pm 0.12$	0.08
Marinated and roasting					
Mesophilic aerobic bacteria	$2.19^{a} \pm 0.16$	$1.42^{c} \pm 0.18$	$1.65^{b} \pm 0.49$	$1.77^{b} \pm 0.32$	0.03
Enterobacteriaceae	—	—	—	—	—
Pseudomonas spp.	$1.89^{a} \pm 0.58$	$1.35^{b} \pm 0.46$	$1.30^{b} \pm 0.26$	$1.62^{a} \pm 0.32$	0.02
Lactic acid bacteria	—	—	—	—	—

Data are expressed as arithmetic mean ± standard deviation ($\bar{x} \pm s$). Group C: control group, nonmarinated; group W: marinated in acid whey; group B: marinated in butter milk; group LJ: marinated in lemon juice. [a,b,c]Values in rows with different letters differ significantly ($p < 0.05$).

spp., increasing the microbiological safety of the product subjected to heat treatment. In the study by Wójciak et al. [16], it was proved that acid whey can be used effectively to improve microbiological quality without adversely affecting organic sausage quality.

Texture is an important sensory characteristic of muscle foods, such as pheasant and beef. Many studies [8, 14, 16, 17, 35, 40, 41] have indicated that the low meat pH after marinating has positive effects on the texture, which was confirmed in the present study (Table 3). In the instrumental evaluation of the texture of meat, the most commonly used parameter, interdependent with tenderness, is the value of the maximum shear force obtained by the Warner–Bratzler test. The analysis of measurements of the maximum shear force showed a significant ($p < 0.05$) effect of marinating using acidic marinades on the change of mechanical properties of raw and heat-treated meat. However, it was shown that the breast muscles marinated using whey and buttermilk were characterized by a smaller ($p < 0.05$) shear force as compared to those marinated with lemon juice. The results obtained by Ergezer and Gokce [40] showed that the use of lactic acid for marinating turkey breast muscles decreased the value of shear force compared to the control. Kim [14] did not confirm the effect of the use of acid whey in the process of marinating beef on the tenderness of meat measured by shear force. Texture profile analysis (TPA) takes into account the multiparameter properties of the product and mimics the conditions to which the material is subjected throughout the mastication process [27]. Meat texture analysis was based on the measurement of strains occurring during sample compression (Table 3). In the present study, it was shown that marinating had a beneficial effect ($p < 0.05$) on reduction of the hardness of roasted breast muscles of slaughter pheasants compared to the control. Significant statistical differences ($p > 0.05$) were not found between used marinades. The hardness results obtained for the control group coincide with those reported by Kotowicz et al. [2] for slaughter pheasants from aviary breeding. According to Kumar et al. [8], the acid breaks the transversal bounds of collagen, leading to the unstable structure loss of this connective tissue protein. According to Berge et al. [42], the mechanism of the

Table 3: Texture parameters (Warner–Bratzler test and texture profile analysis) of nonmarinated and marinated roasting breast muscles of slaughter pheasants.

Parameter	Nonmarinated	Marinated			SEM
	Group C	Group W	Group B	Group LJ	
Warner–Bratzler shear force (N)	$25.86^{a} \pm 2.86$	$18.26^{c} \pm 2.34$	$19.85^{c} \pm 1.98$	$21.48^{b} \pm 2.02$	0.42
Texture profile analysis (TPA)					
Hardness (N)	$24.48^{a} \pm 3.80$	$17.18^{b}c \pm 2.80$	$16.82^{b} \pm 2.56$	$18.29^{b} \pm 3.20$	0.20
Resilience	0.20 ± 0.05	0.18 ± 0.04	0.17 ± 0.06	0.19 ± 0.04	0.01
Cohesiveness	0.30 ± 0.06	0.23 ± 0.05	0.22 ± 0.05	0.29 ± 0.04	0.02
Springiness (mm)	$2.29^{a} \pm 0.30$	$1.41^{c} \pm 0.28$	$1.47^{c} \pm 0.32$	$1.76^{b} \pm 0.42$	0.08
Chewiness (MJ)	$18.02^{a} \pm 2.56$	$5.40^{c} \pm 1.86$	$5.11^{c} \pm 1.90$	$9.53^{b} \pm 2.56$	0.26

Data are expressed as arithmetic mean ± standard deviation ($\bar{x} \pm s$). Group C: control group, nonmarinated; group W: marinated in acid whey; group B: marinated in butter milk; group LJ: marinated in lemon juice. [a,b,c]Values in rows with different letters differ significantly ($p < 0.05$).

Table 4: Sensory properties of nonmarinated and marinated roasting breast muscles of slaughter pheasants.

Parameter (pt)	Nonmarinated	Marinated			SEM
	Group C	Group W	Group B	Group LJ	
Odour intensity	$4.20c \pm 0.42$	$4.48^{b} \pm 0.32$	$4.82^{a} \pm 0.48$	$4.59^{b} \pm 0.36$	0.06
Flavour intensity	$4.00^{c} \pm 0.50$	$4.82^{a} \pm 0.36$	$4.85^{a} \pm 0.40$	$4.64^{b} \pm 0.44$	0.08
Odour desirability	$4.34^{c} \pm 0.76$	$4.52^{b} \pm 0.46$	$4.58^{b} \pm 0.38$	$4.72^{a} \pm 0.50$	0.05
Flavour desirability	$4.10^{c} \pm 0.34$	$4.16^{c} \pm 0.40$	$4.88^{a} \pm 0.36$	$4.56^{b} \pm 0.51$	0.06
Juiciness	$4.12^{c} \pm 0.40$	$4.73^{a} \pm 0.38$	$4.73^{a} \pm 0.44$	$4.46^{b} \pm 0.32$	0.06
Tenderness	$3.80^{c} \pm 0.34$	$4.84^{a} \pm 0.32$	$4.80^{a} \pm 0.48$	$4.48^{b} \pm 0.40$	0.09
General acceptability	$4.10^{c} \pm 0.46$	$4.60^{b} \pm 0.38$	$4.80^{a} \pm 0.42$	$4.56^{b} \pm 0.48$	0.08

Data are expressed as arithmetic mean ± standard deviation ($\bar{x} \pm s$). Group C: control group, nonmarinated; group W: marinated in acid whey; group B: marinated in butter milk; group LJ: marinated in lemon juice. [a,b,c]Values in rows with different letters differ significantly ($p < 0.05$). Sensory scale: Odour and flavour intensity: 1, changed; 2: moderately changed; 3, typical, weak; 4, typical, strong; 5, typical, very strong. Odour and flavour desirability: 1, not desirable; 2, fairly desirable; 3, desirable; 4, very desirable; 5, highly desirable. Juiciness: 1, very dry; 2, dry; 3, slightly juicy; 4, juicy; 5, very juicy. Tenderness: 1, very hard; 2, hard; 3, slightly tender; 4, tender; 5, very tender.

tenderising action of acidic marinades is revealed to involve in the weakening of structures due to swelling of the meat and increased conversion of collagen to gelatine at low pH during cooking. In the present study, it was shown that marinating with the use of acid whey and buttermilk caused a significant ($p < 0.05$) decrease in springiness and chewiness compared to the muscles marinated with lemon juice and the control group. Ferysiuk et al. [12] showed that the combination of acid whey and sea salt also had a positive effect on the springiness parameter of the marinated pork product.

The results of the sensory evaluation (Table 4) indicate that the use of marinade has improved the sensory characteristics of pheasant breast muscles compared to the control group. It was shown that the muscles marinated with whey and buttermilk were characterized by significantly higher juiciness and tenderness and lower odour desirability as compared to the muscles marinated using lemon juice. Kim [14] also stated that the use of acid whey for marinating beef improved the tenderness and juiciness of the product compared to the control group. Vlahova-Vangelova et al. [19] showed a beneficial effect of whey marinating (50% whey and 50% water) on the hardness of broiler chicken meat subjected to grilling. In the present study, the buttermilk used for marinating had a beneficial effect on the desirability of flavour of the product that was highly rated by the evaluation panel, which indicates that the buttermilk ingredients had a positive effect on the flavour. On the contrary, the intensity of the flavour was rated the lowest in the product marinated using whey, which did not lower the acceptability of this characteristic in comparison to the nonmarinated pheasant muscles. In the study by Wójciak et al. [16], sensory evaluation revealed that the application of acid whey or set milk as a marinade in production of organic ripening beef enhances the feeling of good smell and sour taste which result from marinating and correctly conducted fermentation and ripening processes. Wójciak et al. [17] proved that the whey used for marinating maturing sausage caused a higher intensity of bitter taste, while the remaining sensory characteristics were rated high. Wójciak et al. [15], using whey and mustard seeds, gained the acidic smell of boiled sausage.

The lack of literature data on the use of buttermilk for marinating meat and the few studies related to the use of whey in marinating meat and products indicate the need to continue research in this area.

4. Conclusions

Based on the obtained results, it can be concluded that acid whey and buttermilk can be used as a pheasant meat marinade to obtain a high-quality product. In the sensory evaluation, marinating with whey and buttermilk increased the juiciness and tenderness of the product compared to those marinated in lemon juice and to the control group. The flavour desirability was rated the highest for the product marinated in buttermilk.

Pheasant meat is not an easy kind of meat for cooking or processing, but it was found that marinating with whey and buttermilk gives positive effect on tenderness as well as chewiness and springiness in the roast product. Marinating also ensured high microbiological quality of the raw and heat-treated product. Both acid whey and buttermilk can be used as a fully biologically safe ingredient in marinades for the meat of pheasant, providing a basis for further research on its use in marinating this kind of meat.

Data Availability

All the numerical data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

This research was funded by the Ministry of Science and Higher Education program "Regional Initiative of Excellence" for the years 2019-2020 (no. 026/RID/2018/19).

References

[1] C. Fernye, M. Erdélyi, Z. Ancsin, A. Bócsai, and M. Mézes, "Some chemical and physical characteristics of farmed pheasant hens (*Phasianus cholchicus*) breast meat," *Columella-Journal of Agricultural and Environmental Sciences*, vol. 4, no. 1, pp. 7–13, 2017.

[2] M. Kotowicz, K. Lachowicz, S. Lisiecki, M. Szczygielski, and A. Żych, "Characteristics of common pheasant (*Phasianus colchicus*) meat," *Archiv fur Geflügelkunde*, vol. 76, no. 4, pp. 270–276, 2012.

[3] D. Kokoszyński, Z. Bernacki, and W. Pieczewski, "Carcass composition and quality of meat from game pheasants (*P. colchicus*) depending on age and sex," *European Poultry Science*, vol. 78, 2014.

[4] A. Mieczkowska, D. Kokoszyński, R. Wasilewski, and Z. Bernacki, "Carcass composition and meat quality of common pheasants (*Phasianus colchicus colchicus*) depending on sex of birds," *Food Science Technology Quality*, vol. 21, no. 3(100), pp. 95–106, 2015, in Polish.

[5] P. Hofbauer, F. J. M. Smulders, M. Vodnansky, P. Paulsen, and W. R. El-Ghareeb, "A note on meat quality traits of pheasants (*Phasianus colchicus*)," *European Journal of Wildlife Research*, vol. 56, no. 5, pp. 809–813, 2010.

[6] J. Fernández-López, J. M. Fernández-Ginés, L. Aleson-Carbonell, E. Sendra, E. Sayas-Barberá, and J. A. Pérez-Alvarez, "Application of functional citrus by-products to meat products," *Trends in Food Science & Technology*, vol. 15, no. 3-4, pp. 176–185, 2004.

[7] G. S. Kumar-Philips, N. Murali, N. C. Rath, J. Marcy, and M. F. Slavik, "Effect of marinating chicken meat with lemon, green tea and turmeric against foodborne bacterial pathogens," *International Journal of Poultry Science*, vol. 11, no. 5, pp. 326–332, 2012.

[8] Y. Kumar, P. Singh, A. Pandey, V. K. Tanwar, and R. R. Kumar, "Augmentation of meat quality attributes of spent hen breast muscle (pectoralis major) by marination with lemon juice vis-a-vis ginger extract," *Journal of Animal Research*, vol. 7, no. 3, pp. 523–529, 2017.

[9] A. Lebiedzińska, J. Czaja, K. Petrykowska, and P. Szefer, "Evaluation of vitamin c content in fruit juices and nectars," *Bromatology and Toxicological Chemistry*, vol. 3, pp. 390–396, 2012, in Polish.

[10] Z. J. Dolatowski, "Processing innovative solutions in the field of processing to increase health values organic product of plant and animal products ecological methods: Research on optimization and development," Report on research for organic farming financed by the Ministry of Agriculture and Rural Development, 2017, in Polish. http://wnzck.sggw.pl/wp-content/uploads/2015/07/Batony-Raport-_15.11.2017.pdf.

[11] V. G. G. Chandrajith and G. A. D. V. Karunasena, "Applications of whey as a valuable ingredient in food industry," *Journal of Dairy & Veterinary Sciences*, vol. 6, no. 5, article 555698, 2018.

[12] K. Ferysiuk, K. Wójciak, and E. Solska, "Effect of acid whey as starter culture on selected physicochemical properties of fermented pork sausage," *World Scientific News*, vol. 93, pp. 23–31, 2018.

[13] M. Karwowska, K. M. Wójciak, and Z. J. Dolatowski, "The influence of acid whey and mustard seed on lipid oxidation of organic fermented sausage without nitrite," *Journal of the Science of Food and Agriculture*, vol. 95, no. 3, pp. 628–634, 2015.

[14] J. Kim, *Effects of Acid Whey Marination on Tenderness, Sensory and Other Quality Parameters of Beef Eye of Round*, Brigham Young University BYU Scholars Archive, Provo, UT, USA, 2018.

[15] K. M. Wójciak, M. Karwowska, and Z. J. Dolatowski, "Use of acid whey and mustard seed to replace nitrites during cooked sausage production," *Meat Science*, vol. 96, no. 2, pp. 750–756, 2014.

[16] K. M. Wójciak, P. Krajmas, E. Solska, and Z. J. Dolatowski, "Application of acid whey and set milk to marinate beef with reference to quality parameters and product safety," *Acta Scientiarum Polonorum Technologia Alimentaria*, vol. 14, no. 4, pp. 293–302, 2015.

[17] K. M. Wójciak, Z. J. Dolatowski, and D. Kołożyn-Krajewska, "Use of acid whey and probiotic strains to improve microbiological quality and sensory acceptance of organic fermented sausage," *Journal of Food Processing and Preservation*, vol. 39, no. 5, pp. 539–547, 2015.

[18] J. Stadnik and D. M. Stasiak, "Effect of acid whey on physicochemical characteristics of dry-cured organic pork loins without nitrite," *International Journal of Food Science & Technology*, vol. 51, no. 4, pp. 970–977, 2016.

[19] D. B. Vlahova-Vangelova, D. K. Balev, S. G. Dragoev, and G. D. Kirisheva, "Improvement of technological and sensory properties of meat by whey marinating," *Scientific Works of University of Food Technologies*, vol. 63, no. 1, pp. 7–13, 2016.

[20] J. Ziołecki and W. Doruchowski, *Evaluation Method of the Poultry Slaughter Value*, COBRD, Poznań, Poland, 1989, in Polish.

[21] P. N-EN 12322:2005, *In Vitro Diagnostic Medical Devices—Culture Media for Microbiology—Performance Criteria for Culture Media*, International Organization for Standardization (ISO), Geneva, Switzerland, 2005.

[22] PN-EN. ISO 11133:2014-07, *Microbiology of Food, Animal Feed and Water—Preparation, Production, Storage and Performance Testing of Culture Media*, International Organization for Standardization (ISO), Geneva, Switzerland, 2014.

[23] M. B. Jemaa, H. Falleh, M. A. Neves, H. Isoda, M. Nakajima, and R. Ksouri, "Quality preservation of deliberately contaminated milk using thyme free and nanoemulsified essential oils," *Food Chemistry*, vol. 217, pp. 726–734, 2017.

[24] R. Grau and R. Hamm, "Eine einfache Methode zur Bestimmung der Wasserbindung im Muskel," *Die Naturwissenschaften*, vol. 40, no. 1, pp. 29-30, 1953.

[25] CIE, *Supplement No 2 to: Recommendations on uniform color spaces—Color Difference Equations. Psychometric Color Terms. Commission International de Eclarage (1971) to 1-1, CIE Publication No 15 (E-1.3.1)*, CIE, Paris, France, 1976.

[26] M. C. Broune, "Texture profile analysis," *Food Technology*, vol. 32, no. 7, pp. 62–66, 1979.

[27] A. M. Herrero, J. A. Ordóñez, R. de Avila, B. Herranz, L. de la Hoz, and M. I. Cambero, "Breaking strength of dry fermented sausages and their correlation with texture profile analysis (TPA) and physico-chemical characteristics," *Meat Science*, vol. 77, no. 3, pp. 331–338, 2007.

[28] M. Mitek and M. Słowiński, *Selected Issues in Food Technology", Meat and Egg Technology*, Publisher SGGW, Warszawa, Poland, 2006, in Polish.

[29] N. Baryłko-Pikielna and I. Matuszewska, *Sensory Testing of Food. Basics—Methods—Application*, Publishing: Polish Society of Food Technologists, Wrocław, Poland, 2009, in Polish.

[30] ISO 8586-2:2008, *Sensory Analysis. General Guidance for the Selection, Training and Monitoring of Assessors*, International Organization for Standardization (ISO), Geneva, Switzerland, 2008.

[31] ISO 8587:2006, *Sensory Analysis. Methodology*, International Organization for Standardization (ISO), Geneva, Switzerland, 2006.

[32] PN-EN ISO 8589:2010, *General Guidelines for the Design of a Sensory Analysis Laboratory*, International Organization for Standardization (ISO), Geneva, Switzerland, 2010.

[33] Statsoft, Inc., *Statistica (Data Analysis Sofware System) Veriosion 31.1*, Statsoft, Inc., Poland, 2018.

[34] Y. Kumar, P. Singh, V. K. Tanwar, P. Ponnusamy, P. K. Singh, and P. Shukla, "Augmentation of quality attributes of chicken tikka prepared from spent hen meat with lemon juice and ginger extract marination," *Nutrition & Food Science*, vol. 45, no. 4, pp. 606–615, 2015.

[35] M. Serdaroğlu, K. Abdraimov, and A. Önec, "The effect of marinating with citric acid solutions and grapefruit juice on cooking and eating quality of Turkey breast," *Journal of Muscle Foods*, vol. 18, no. 2, pp. 162–172, 2007.

[36] S. Saad Latif, "Effect of margination on the quality characteristics and microstrure of chicken breast meat cooked by different methods," *Lucrari Stiinifice*, vol. 54, pp. 314–324, 2010.

[37] S. M. Yusop, M. G. O'Sullivan, J. F. Kerry, and J. P. Kerry, "Effect of marinating time and low pH on marinade performance and sensory acceptability of poultry meat," *Meat Science*, vol. 85, no. 4, pp. 657–663, 2010.

[38] C. Alvarado and S. McKee, "Marination to improve functional properties and safety of poultry meat," *Journal of Applied Poultry Research*, vol. 16, no. 1, pp. 113–120, 2017.

[39] K. M. Wójciak and Z. J. Dolatowski, "Evaluation of natural preservatives in combination with acid whey for use in fermented sausage," *Scientia Agricola*, vol. 73, no. 2, pp. 125–133, 2016.

[40] H. Ergezer and R. Gokce, "Comparison of marinating with two different types of marinade on some quality and sensory characteristics of Turkey breast meat," *Journal of Animal and Veterinary Advances*, vol. 10, no. 1, pp. 60–67, 2011.

[41] K. M. Wójciak, P. Kęska, A. Okoń, E. Solska, J. Libera, and Z. J. Dolatowski, "The influence of acid whey on the antioxidant peptides generated to reduce oxidation and improve colour stability in uncured roast beef," *Journal of the Science of Food and Agriculture*, vol. 98, no. 10, pp. 3728–3734, 2018.

[42] P. Berge, P. Ertbjerg, L. M. Larsen, T. Astruc, X. Vignon, and A. J. Møller, "Tenderization of beef by lactic acid injected at different times post mortem," *Meat Science*, vol. 57, no. 4, pp. 347–357, 2001.