ŻYWNOŚĆ. Nauka. Technologia. Jakość, 2019, 26, 1 (118), 125 – 136

DOI: 10.15193/zntj/2019/118/278

ANNA AUGUSTYŃSKA-PREJSNAR, MAŁGORZATA ORMIAN,
ZOFIA SOKOŁOWICZ, ANNA ROGOWSKA

# EFFECT OF MARINATING BROILER CHICKEN MEAT WITH ACID WHEY ON PRODUCT QUALITY AND CONSUMER ACCEPTANCE

S u m m a r y

In the research study, acid whey was used to marinate chicken broiler meat. The raw material used in the research study consisted of breast muscles of broiler chickens (n = 90); they were marinated with the acid whey added (n = 30) and, comparatively, with a marinade with the addition of lemon juice (n = 30). The concentration of lemon juice was designed to correspond to pH of the acid whey (4.54). Non-marinated breast muscles were a control group (n = 30). The assessment of the raw and grilled product included a sensory assessment (pts) and the determination of the following: quality parameters (marinade absorption, pH and colour in the CIE L* a* b* system), nutritional value (protein, fat, mineral compounds in the form of ash), textural parameters (shear force as well as hardness, springiness, gumminess, chewiness). The research study showed that compared to marinating the breast muscles with lemon juice, marinating them using whey increased the uptake of marinade, advantageously ($p < 0.05$) affected tenderness (measured by a Warner-Bratzler shear force), hardness (assessed using a TPA texture profile analysis), the ash content of the raw and heat-treated product, the reduction in saturation of red (a*) and the increase in saturation of yellow (b*) in the general colour tone. In the sensory assessment, the marinating with the use of whey positively affected the juiciness and tenderness of the grilled product. Also an overall acceptability of the attributes analysed was reported. The results obtained allow to conclude that acid whey can be used as a natural marinade for broiler chicken meat.

**Key words:** broiler chicken meat, marinating, whey, lemon juice, quality

## Introduction

Poultry meat and products made from it are becoming more and more popular among consumers. With the growing interest in convenience food, the demand for marinated broiler chicken meat is increasing [30]. Marination is a simple procedure applied in order to improve the tenderness, juiciness and aroma of meat. The selection

*Dr inż. A. Augustyńska-Prejsnar, dr inż. M. Ormian, dr hab. inż. Z. Sokołowicz, prof. nadzw., mgr inż. A. Rogowska, Katedra Produkcji Zwierzęcej i Oceny Produktów Drobiarskich, Wydz. Biologiczno-Rolniczy, Uniwersytet Rzeszowski, ul. Zelwerowicza 4, 35-601 Rzeszów. Kontakt: augusta@ur.edu.pl*

of marinade ingredients is constantly being improved so that the product obtained meets the expectations of consumers [10, 17]. Synthetic additives used to marinate meat are not gaining consumer acceptance. Changes occurring in the diet and eating habits along with care for the heath and the growing consumer awareness cause consumers to increasingly utilise natural food additives, which, apart from the taste, have a beneficial effect on the functioning of human body [19, 31]. Consumers are more and more aware of diet-related health problems and therefore they demand natural ingredients, which are expected to be safe and health-promoting [8]. In the group of natural additives used to marinate meat it is possible to use, for example: natural fruit and vegetable acids, herbs and their extracts, sea salt and fermented milk beverages [18, 28]. Lemon juice is a common ingredient of meat marinades, it is used as a preservative and it improves sensory characteristics [20]. The interest of the meat industry is currently focused on the use of whey in the functional food production. Acid whey is a source of valuable nutrients such as: whey proteins (β-lactoglobulin, α-lactalbumin, immunoglobulin, bovine serum albumin (BSA) and lactoferrin), mineral compounds and lactic acid bacteria [27]. Acid whey has many physiological functions, i.a.: antifungal, antiviral, antibacterial, anticarcinogenic and anti-inflammatory; also it has a positive effect on the nervous system and the iron-binding capacity [17, 27, 32].

The results of the most recent scientific research indicate the possibility of using acid whey to marinate beef and pork [9, 15, 17, 28, 31, 33] in order to improve the sensory characteristics and health safety of the product. In order to meet the needs of consumers looking for new ingredients of marinades, it is proposed to use the acid whey as a natural additive to marinate meat of broiler chickens.

The objective of the research study was to evaluate the use of acid whey as a natural marinade additive to marinate breast muscles of broiler chickens in terms of their qualitative characteristics and consumer acceptance of the product.

## Material and methods

Breast muscles (*musculus pectoralis*) constituted the raw material for the study; they were obtained from 35-day-old ROSS 308 broiler chickens reared in the same production cycle. The chickens were slaughtered and dissected according to the industry standards set for the poultry slaughterhouses. The birds were mechanically slaughtered after they had been subjected to vet tests and a combined water-electricity stunning treatment. The parameters of the electric current delivered to stun the birds complied with Council Regulation (EC) No. 1099/2009 [24] on the protection of animals at the time of killing. Soon after the bleeding and scalding (56 ± 2 ºC), the birds were plucked and mechanically gutted. The carcasses were chilled in two stages: in water with temperatures of up to 16 ºC and, next, by an air-jet method to reach an in-meat temperature of 2 ºC. From the carcasses chilled a skinless breast meat was manu-

ally cut out. The tests were carried out on single breast muscles (n = 90, their mean weight being 200 ± 50g), which were transported in isothermal containers to the laboratory and stored in a refrigerator at 4 ºC for 6 h; they were weighed with an accuracy of 0.01 g and individually marked. The non-marinated breast muscles (n = 30) were a control group (group C).

Acid whey was purchased in a local farm, where dairy cattle are organically bred and where dairy organic products are produced. Fresh unpasteurized milk underwent a natural milk fermentation process. Afterwards it was heated to a temperature of approx. 40 ºC. After acid coagulation of milk, a protein curd precipitated and the whey was separated from the curd. The analysis of the chemical composition of whey was performed with an Analyzer of the Chemical Composition of Milk and Dairy Products, Bentley B-150 (Bentley, USA). For this purpose the whey was thoroughly mixed in a water bath at 40 ºC; the determination was made on the "whey" calibration in triplicate. The whey contained 0.86 % protein, 0.19 % fat, 5.12 % lactose and 7.17 % dry matter. The active acidity in the whey was determined by a pH-meter FiveEasy PLUS FP20 (Mettler Toledo, Switzerland) equipped with an LE438 electrode with an integrated temperature sensor; the pH value of the product was 4.54 ± 0.32.

A fresh lemon juice (pH 2.28 ± 0.41) was used; it was squeezed by hand. For this purpose the fruits were scalded (3 min in boiling water), cut with a sterile knife and filtered.

Two acidic marinades containing natural ingredients were prepared for marination. The first contained acid whey as the main component (group W), in the second one a combination of lemon juice and distilled water was used (group LJ). The concentration of lemon juice was designed to correspond to the mean pH value of acid whey (4.54 ± 0.32). The other natural ingredients of marinades were the same: sea salt (1.0 %), cane sugar (1.5 %), rapeseed oil (2.0 %), dried bear's garlic (0.3 %) and dried thyme (0.2 %). The marinades were prepared 2 h before use and stored at 4 ºC. The process of marinating consisted in immersing the breast muscles – group W (n = 30) and group LJ (n = 30) in the prepared marinade for 24 h. The ratio of meat to marinade was set at 1:1 (meat : marinade). The samples from the groups W and LJ were closed in sealed plastic containers and stored in a refrigerator at 4 ºC for 24 h. After the fixed marinating period the samples were weighed with an accuracy of 0.01 g.

The non-marinated and marinated breast muscles were subjected to grilling treatment in a fat-free grill pan until the temperature inside a sample reached 80 ± 2 ºC.

To determine the marinade uptake, the non-marinated and marinated meat samples were weighed before and after marination. The marinade uptake was calculated based on the weight of meat samples before marination ($W_1$) and their weight after marination ($W_2$) according to the equation:

$$\text{Marinade uptake [\%]} = [(W_2 - W_1)/W_1] \times 100$$

The pH measurements of the non-marinated and marinated breast muscles were made using a dagger electrode, fitted with a pH meter (Hanna HI 99163, Germany). The weight loss [%] was calculated based on the weight difference before and after heat treatment. The colour assessment of the cross-sectional surface of non-marinated and marinated breast muscles was determined based on a reflection method using a Chrome Meter colorimeter (Konica Minolta Osaka, Japan) with a CR 400 head, with settings for illuminations compatible with a $D_{65}$ illuminator. The reading of the measurement results was achieved in a CIE LAB colorimetric system CIE LAB (CIE 1978), with L* (lightness), a* (redness) and b* (yellowness). The cutting was carried out on meat cubes; their cross section being 100 $mm^2$ and their length 50 mm. The content of nitrogen was determined using a Kjeldahl method (units from Foss Tecator, Hőganas, Sweden) and converted into proteins through multiplying it with a factor of 6.25. The fat content was determined using a Soxhlet method (Büchi Extraction System B-811 apparatus, Flawil, Switzerland). The dried at 105 ºC samples (5 ± 0,001 g) were subjected to extraction using the n-hexane as a solvent. The fat content was determined by weight after removing the solvent [22]. The total ash content was determined after the mineralization of 5 g of a meat sample at 550 - 650 ºC (a muffle Carbolite oven type AAF1100, Hope Valley, UK) was fully accomplished [23]. The tenderness was measured based on a shear force (Fmax) using a Zwick/Roell testing machine BT1-FR1.OTH.D14 (Zwick CmbH & Co.KG. Ulm, Germany) and applying a wide-width Warner-Bratzler (V-blade) with a head speed of 100 mm·min-1 and a 0.2 N pre-cut force. The cutting was carried out on the non-marinated and marinated breast muscle cubes with a cross section of 100 $mm^2$ and a length of 50 mm [35]. A texture profile analysis (TPA) was performed using a Texture Analyser CT3 25 (Brookfield, USA) equipped with a cylindrical probe with a diameter of 38.1 $mm^2$ and a length of 20 mm. A double compressing test of the samples was performed; the samples were compressed to 50 % of their height [4]. The texture was determined on the non-marinated and marinated breast muscle samples in the form of cubes sized 20 mm × 20 mm × 20 mm. The speed of the roller movement during the test was 2 mm/s and the gap between the 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 every sample using a Texture Pro CT [11].

A sensory assessment of the quality of grilled meat samples was performed using a scaling method according to a Baryłko-Pikielna and Matuszewska [2] methodology. The sensory assessment process was conducted in two replications by a 7-member assessment team with the proven sensory sensitivity and trained in accordance with ISO 8587:2006 [13] and ISO 8586:2012 [14] standards. A 5-point evaluation was applied with a defined value limit including the following qualitative indices: odour intensity (from very negative through typical to very strong), flavour intensity (from very

negative through very sour to very desirable), odour desirability (from undesirable to highly desirable), flavour desirability (from undesirable to highly desirable), juiciness (from very dry to very juicy), tenderness (from very hard to very tender) and general desirability (from undesirable to desirable). To conduct the sensory assessment, the thermally treated samples were cooled to 20 ± 2 ºC, cut into 1.5 cm thick slices, perpendicular to the run of meat fibres and then placed in plastic containers. The samples were randomly assessed after they had been encoded. All the evaluations were performed at the sensory laboratory that conformed to all the requirements of the standard PN-EN ISO 8589:2010 [21]. Between every sample test, the assessors took a 30 s break and rinsed their mouths with mineral water.

An ANOVA analysis of variance was applied to statistically analyse the results obtained using a Statistica 13.1 software package [29]. The arithmetic mean ($\bar{x}$) and the standard deviation (SD) were determined. To indicate the significance of differences among the means in the groups, a Tukey's post hoc test with a level of significance ($p < 0.05$) was applied.

## Results and discussion

The percent marinade uptake significantly ($p < 0.05$) differed among the treatment methods utilized (Tab. 1). It was found that marinating with whey (W) added resulted in a higher marinade uptake compared to marinating with lemon juice (LJ) added. The results of the studies [7, 17, 26] show that the pH value of marinated meat depends on the pH of a marinade and the results of the present research study (Tab. 1) are in compliance with those findings. Kumar et al. [18] found that a low pH value of meat after marination had positive effects on the texture and increased the water holding capacity and the moisture content. However, the citric acid can reduce pH to the point where the meat has excessively sour flavours and this might cause the consumers to reject it [16]. The degree of muscle tissue acidification affects the technological and sensory characteristics of meat.

The colour of meat is an important qualitative characteristic that determines the product suitability for culinary purposes. In a marinated product it depends on the meat colour before marination and on the pH and composition of the marinade. In the present research study, it was shown that marinating using both the whey (W) and the lemon juice (LJ) significantly ($p < 0.05$) affected the lightening of the colour of raw breast muscles compared to the non-marinated muscles (Tab. 1). This finding agrees with the results obtained by Serdaroğlu et al. [26] as regards the turkey breast muscles marinated with the lemon juice and grapefruit juice added. The lightening of the marinated breast muscles could result from a lower value of their pH and from a higher amount of extracellular water introduced into the meat during marination [12, 31]. One possible reason for the increased L* values is that muscle proteins swell and the light

reflection alters at a low pH and ionic strength, this resulting in a lighter colour [26]. Vlahova-Vangelova [34] reported that the use of whey when marinating breast muscles of broiler chickens did not affect the colour of surfaces of the raw and grilled breast muscles. The present research studies showed the effect of marinating with whey on the degree of colour saturation of the breast muscles towards red and yellow. Both the raw and the grilled breast muscles marinated using whey were characterized by a significantly reduced ($p < 0.05$) proportion of red (a*) and an increased proportion of yellow (b*) compared to the breast muscles marinated in the lemon juice and to the non-marinated breast muscles.

The nutritional value of poultry meat is an important qualitative component taken into account by the consumer. As a result of marination, the chemical composition of meat may change depending on the ingredients used [1, 6, 25]. The authors' own study showed that the additives added to the marinade (whey and lemon juice) had an effect on reducing the protein content in both the raw breast muscles and those subjected to grilling (Tab. 1). This could be owing to the increased moisture content. The results under this research study are consistent with those by Kumar et al. [18], who marinated breast muscles with the use of lemon juice. Hong et al. [12], in turn, showed that marinating breast muscles of broiler chickens with the lime juice added had no effect on the protein content. In the present research study, it was found that the marination with acidic marinades had a significant effect ($p < 0.05$) on the content of ash in both the raw breast muscles and those after the grilling process. The breast muscles marinated with the use of whey (W) were characterized by a higher content of ash in comparison to those marinated with the lemon juice.

Textural characteristics of meat are important aspects of consumer acceptance. Many instrumental methods have been developed for the purpose of determining food textural properties [11]. In the instrumental assessment of meat texture, the most commonly used parameter, interdependent with tenderness, is the value of the maximum shear force. The analysis of the maximum shear force values measured showed a change in the mechanical properties of meat depending on the marinating additives used both in the raw breast muscles and the grilled muscles (Tab. 2). The marination of breast muscles using whey significantly ($p < 0.05$) decreased the value of shear force compared to marinating with the addition of lemon juice. Ergezer and Gokce [7] showed that the use of lactic acid to marinate turkey breast muscles decreased the value of shear force. Many studies [16, 17, 26, 33] indicated that a low meat pH value after marination had positive effects on the texture. The compression method of texture profile analysis (TPA) mimics the conditions to which the material is subjected throughout the mastication process [5, 6, 30]. The meat texture analysis was performed based on the measurement of strains occurring while the sample underwent compression; under

Table 1. Physicochemical characteristics of non-marinated and marinated breast muscles of broiler chickens
Tabela 1. Cechy fizykochemiczne niemarynowanych i marynowanych mięśni piersiowych kurcząt brojlerów

| Analysed characteristics<br>Badane cechy | | Breast muscles / Mięśnie piersiowe | | | SEM |
|---|---|---|---|---|---|
| | | Non-marinated<br>Niemarynowane | Marinated / Marynowane | | |
| | | Group C<br>Grupa C | Group W<br>Grupa W | Group LJ<br>Grupa LJ | |
| Raw marinated<br>Surowe<br>marynowane | Marinade uptake / Absorbcja marynaty [%] | - | $6,12^{a} \pm 0,52$ | $5,34^{b} \pm 0,36$ | 0,02 |
| | pH value / Wartość pH | $5,90^{a} \pm 0,09$ | $5,77^{b} \pm 0,12$ | $5,80^{b} \pm 0,15$ | 0,03 |
| | Colour / Barwa: L* lightness / jasność | $58,02^{a} \pm 3,98$ | $59,72^{b} \pm 4,05$ | $59,63^{b} \pm 5,12$ | 0,42 |
| | a* redness / czerwona | $1,12^{a} \pm 0,58$ | $0,46^{c} \pm 0,21$ | $0,58^{b} \pm 0,31$ | 0,08 |
| | b* yellowness / żółta | $2,60^{a} \pm 0,93$ | $4,10^{c} \pm 0,60$ | $3,81^{b} \pm 0,77$ | 0,15 |
| | Crude protein content / Zawartość białka [%] | $24,02^{a} \pm 2,01$ | $23,04^{b} \pm 1,22$ | $22,98^{b} \pm 0,40$ | 0,21 |
| | Fat content / Zawartość tłuszczu [%] | $0,82 \pm 0,22$ | $0,78 \pm 0,18$ | $0,76 \pm 0,18$ | 0,06 |
| | Ash content / Zawartość popiołu [%] | $1,18^{c} \pm 0,12$ | $1,32^{a} \pm 0,22$ | $1,28^{b} \pm 0,26$ | 0,03 |
| Marinated and<br>grilled<br>Marynowane<br>i grilowane | pH value / Wartość pH | $6,26^{a} \pm 0,12$ | $6,06^{b} \pm 0,09$ | $6,09^{b} \pm 0,11$ | 0,07 |
| | Colour / Barwa: L* lightness / jasność | $83,87 \pm 1,38$ | $84,00 \pm 2,12$ | $84,18 \pm 1,23$ | 0,32 |
| | a* redness / czerwona | $2,89^{a} \pm 0,48$ | $1,96^{b} \pm 0,46$ | $2,83^{a} \pm 0,50$ | 0,08 |
| | b* yellowness / żółta | $10,40^{c} \pm 0,56$ | $12,79^{a} \pm 1,06$ | $11,69^{b} \pm 0,47$ | 0,22 |
| | Crude protein content / Zawartość białka [%] | $30,21^{a} \pm 1,68$ | $29,54^{b} \pm 1,18$ | $29,46^{b} \pm 1,15$ | 0,24 |
| | Fat content / Zawartość tłuszczu [%] | $1,10 \pm 0,14$ | $0,98 \pm 0,34$ | $0,96 \pm 0,48$ | 0,06 |
| | Ash content / Zawartość popiołu [%] | $1,32^{c} \pm 0,21$ | $1,48^{a} \pm 0,11$ | $1,40^{b} \pm 0,13$ | 0,14 |
| | Weight loss / Straty termiczne [%] | $28,69^{a} \pm 2,36$ | $26,92^{b} \pm 3,10$ | $27,42^{b} \pm 2,84$ | 0,32 |

Explanatory notes / Objaśnienia:
Group C / Grupa C – control group, non-marinated / grupa kontrolna, niemarynowane; Group W / Grupa W – marinade contained acid whey / marynowane z wykorzystaniem serwatki; Group LJ / Grupa LJ – marinade contained lemon juice / marynowane z wykorzystaniem soku z cytryn. Table shows mean values ± standard deviations / W tabeli przedstawiono wartości średnie ± odchylenia standardowe; n = 10; a, b – mean values in rows and denoted by different letters differ statistically significantly ($p < 0.05$) / wartości średnie w wierszach oznaczone różnymi literami różnią się statystycznie istotnie ($p < 0,05$); SEM – standard error of the mean / błąd standardowy średniej.

Table 2. Texture parameters (Warner-Bratzler, texture profile analysis) of non-marinated and marinated breast muscles of broiler chickens
Tabela 2. Parametry tekstury (Warner-Bratzler, texture profile analysis) niemarynowanych i marynowanych mięśni piersiowych kurcząt brojlerów

| Analysed parameters<br>Badane cechy | | Breast muscules / Mięśnie piersiowe | | | SEM |
|---|---|---|---|---|---|
| | | Non-marinated<br>Niemarynowane | Marinated / Marynowane | | |
| | | C group<br>Grupa C | W group<br>Grupa W | LJ group<br>Grupa LJ | |
| Raw marinated<br>Surowe<br>marynowane | Shear force / Siła cięcia [N] | $14,18^{a} \pm 2,46$ | $11,05^{c} \pm 6,10$ | $12,93^{b} \pm 4,22$ | 0,43 |
| | Hardness / Twardość [N] | $26,80^{a} \pm 5,18$ | $18,31^{c} \pm 3,98$ | $22,08^{b} \pm 5,21$ | 0,50 |
| | Springiness / Sprężystość [mm] | $2,06 \pm 0,41$ | $2,59 \pm 0,52$ | $2,33 \pm 0,61$ | 0,02 |
| | Gumminess / Gumowatość [N] | $6,15^{a} \pm 0,98$ | $3,98^{b} \pm 0,76$ | $3,69^{b} \pm 0,76$ | 0,01 |
| | Chewiness / Żujność [mJ] | $12,75^{a} \pm 1,72$ | $10,30^{b} \pm 1,50$ | $8,60^{c} \pm 1,21$ | 0,21 |
| Marinated and<br>grilled<br>Marynowane<br>i grilowane | Shear force / Siła cięcia [N] | $18,78^{a} \pm 3,84$ | $14,53^{c} \pm 3,27$ | $15,73^{b} \pm 2,25$ | 0,32 |
| | Hardness / Twardość [N] | $24,52^{a} \pm 6,12$ | $16,04^{c} \pm 4,62$ | $19,29^{b} \pm 3,60$ | 0,46 |
| | Springiness / Sprężystość [mm] | $3,25 \pm 0,61$ | $2,90 \pm 0,78$ | $3,10 \pm 0,68$ | 0,02 |
| | Gumminess / Gumowatość [N] | $4,20^{a} \pm 0,82$ | $3,58^{b} \pm 1,89$ | $2,95^{c} \pm 1,20$ | 0,02 |
| | Chewiness / Żujność [mJ] | $13,51^{a} \pm 1,21$ | $10,23^{b} \pm 156$ | $9,32^{c} \pm 0,98$ | 0,28 |

Explanatory notes as in Tab. 1. / Objaśnienia jak pod tab. 1.

this analysis the following meat parameters were determined: hardness, springiness, gumminess and chewiness. In the present research study, it was shown that the values of the texture parameters analysed (excluding springiness) were positively reduced as a result of the marination in the acidic marinades. Those results fall in with the findings by Gök and Bor [10], Kumar et al. [18] and Serdaroğlu et al. [26], who used acidic fruit marinades to marinate poultry meat. According to Berge et al. [3] and Kumar et al. [18], the acid breaks the cross-links in the collagen leading to an unstable structure loss of this connective tissue protein. In the present research study, it was shown that marinating using whey had a beneficial ($p < 0.05$) effect on reducing the hardness of both the raw and the grilled breast muscles compared to those marinated using lemon juice. The use of lemon juice caused the chewiness (of the raw product and after heat treatment) and the gumminess (of the grilled product) to significantly ($p < 0.05$) decrease in comparison to whey marinating. The above results match up with those obtained by Serdaroğlu et al. [26] who marinated turkey breast muscles with the citric acid and the grapefruit juice.

Table 3. Sensory characteristics of non-marinated and marinated breast muscles of broiler chickens subjected to grilling [pt]

Tabela 3. Cechy sensoryczne niemarynowanych i marynowanych mięśni piersiowych kurcząt brojlerów poddanych grillowaniu [pkt]

| Analysed characteristics<br>Badane cechy | Group C<br>Grupa C | Group W<br>Grupa W | Group LJ<br>Grupa LJ | SEM |
|---|---|---|---|---|
| Odour intensity<br>Natężenie zapachu | $4,30^{c} \pm 0,52$ | $4,72^{b} \pm 0,37$ | $4,86^{a} \pm 0,44$ | 0,08 |
| Flavour intensity<br>Natężenie smaku | $4,02^{b} \pm 0,76$ | $4,82^{a} \pm 0,51$ | $4,80^{a} \pm 0,60$ | 0,06 |
| Odour desirability<br>Pożądalność zapachu | $4,50^{b} \pm 0,42$ | $4,84^{a} \pm 0,62$ | $4,86^{a} \pm 0,48$ | 0,04 |
| Flavour desirability<br>Pożądalność smaku | $4,05^{b} \pm 0,50$ | $4,84^{a} \pm 0,31$ | $4,88^{a} \pm 0,54$ | 0,05 |
| Juiciness / Soczystość | $4,10^{c} \pm 0,44$ | $4,83^{a} \pm 0,31$ | $4,78^{b} \pm 0,25$ | 0,08 |
| Tenderness / Kruchość | $4,40^{c} \pm 0,49$ | $4,92^{a} \pm 0,31$ | $4,78^{b} \pm 0,41$ | 0,06 |
| Total desirability<br>Ogólna pożądalność | $4,20^{c} \pm 0,50$ | $4,78^{b} \pm 0,42$ | $4,80^{a} \pm 0,35$ | 0,08 |

Explanatory notes as in Tab. 1. / Objaśnienia jak pod tab. 1.

If the determinants of the sensory assessment of the product meet the expectations of the consumer, then the product is accepted. In the present research study, it was found that marinating using both the whey (W) and the lemon juice (LJ) improved the acceptability of sensory characteristics and the general desirability of the breast muscles compared to the non-marinated breast muscles (Tab. 3). Serdaroğlu et al. [26]

indicated that the acidic marinades increased the juiciness and tenderness of turkey breast muscles. In the present research study, it was shown that the breast muscles of broiler chickens marinated using whey (W) were characterized by a significantly ($p < 0.05$) better juiciness and tenderness compared to the muscles marinated using the lemon juice (LJ) and the non-marinated. Also Vlahova-Vangelova et al. [34] showed a beneficial effect of marinating using whey (50 % whey and 50 % water) on the consistency of grilled broiler chicken meat. Kim [17] found that the use of acid whey to marinate beef improved the tenderness and juiciness of the product compared to the control group and it gave the product a more acceptable taste. Wójciak et al. [32] proved that the whey used to marinate maturing beef resulted in a higher intensity of bitter taste while Wójciak et al. [31] got an acidic smell of boiled sausage when using whey and mustard seeds. In the present research study, it was shown that the breast muscles of broiler chickens marinated with the use of whey were characterized by a lower intensity of smell compared to the breast muscles marinated using the lemon juice that did not lower the acceptability of this characteristic compared to the non-marinated breast muscles. The intensity and desirability of the marinated product taste were assessed at a similar level in the marinades tested.

## Conclusions

1. Compared to marinating with the lemon juice, the marination of breast muscles using whey has a positive effect on the tenderness (measured by a shear force), texture (hardness) and ash content of the raw and heat-treated product and also on the reduction in red and the increase in yellow in the general tone of colour.
2. In the sensory assessment, the marination of breast muscles improved the juiciness and tenderness of the grilled product and resulted in achieving the general acceptance.
3. Acid whey can be used as a natural additive to marinate broiler chicken meat.

*Research was funded from Ministry of Science and Higher Education project "Regional Initiative of Excellence" for years 2019-2020 no 026/RID/2018/19.*

## References

[1] Alvarado C., McKee S.: Marination to improve functional properties and safety of poultry meat. J. Appl. Poultry Res., 2007, 16, 1, 113-120.
[2] Baryłko-Pikielna N., Matuszewska I.: Sensoryczne badania żywności. Podstawy. Metody. Zastosowania. Wyd. II. Wyd. Nauk. PTTŻ, Kraków 2014.
[3] Berge P., Ertbjerg P., Larson L.M., Astruc T., Vignon X., Moller A.J.: Tenderization of beef lactic acid injected at different times post mortem. Meat Sci., 2001, 57, 347-357.
[4] Broune M.C.: Texture profile analysis. Food Technol., 1979, 32, 62-66.

[5] Chang H.J., Wang Q., Zhou G.H., Xu X.L., Li C.B.: Influence of weak organic acids and sodium chloride marination on characteristics of connective tissue collagen and textural properties of beef *semitendinosus* muscle. J. Texture Stud., 2010, 41 (3), 279-301.
[6] Choi Y.S., Hwang K.E., Jeong T.J., Kim Y.B., Jeon K.H., Kim E.M., Sung J.M., Kim H.W., Kim C.J.: Comparative study on the effects of boiling, steaming, grilling, microwaving and superheated steaming on quality characteristics of marinated chicken steak. Korean J. Food Sci. An., 2016, 36 (1), 1-7.
[7] Ergezer H., Gokce R.: Comparison of marinating with two different types of marinade on some quality and sensory characteristics of turkey breast meat. J. Anim. Vet. Adv., 2011, 10 (1), 60-67.
[8] Fernández-López J., Fernández-Ginés J.M., Aleson- Carbonell L., Sendra E., Sayas-Barberá E., Pérez-Alvarez J.A.: Application of functional citrus by-products to meat products. Trends Food Sci. Tech., 2004, 15, 176-185.
[9] Ferysiuk K., Wójciak K., Solska E.: Effect of acid whey as starter culture on selected physicochemical properties of fermented pork sausage. World Scientific News, 2018, 93, 23-31.
[10] Gök V., Bor Y.: Effect of marination with fruit and vegetable juice on the some quality characteristics of turkey breast meat. Braz. J. Poultry Sci., 2016, 18 (3), 481-488.
[11] Herrero A.M., Ordóñez J.A., de Avila R., Herranz B., de la Hoz L., Cambero M.I.: Breaking strength of dry fermented sausages and their correlation with texture profile analysis (TPA) and physic-chemical characteristics. Meat Sci., 2007, 77, 331-338.
[12] Hong G.E., Mandal P.K., Kim J.H., Park W.J., Oh J.W., Lim K.W., Lee C.H.: Influence of lime juice on the pink discoloration and quality of sous-vide processed chicken breast during refrigerated storage. J. Food Quality, 2016, 39 (6), 726-731.
[13] ISO 8587:2006. Sensory analysis. Methodology. Ranking.
[14] ISO 8586:2012. Sensory analysis. General guidelines for the selection, training and monitoring of selected assessors and expert sensory assessors.
[15] Karwowska M., Wójciak K.M., Dolatowski Z.J.: The influence of acid whey and mustard seed on lipid oxidation of organic fermented sausage without nitrite. J. Sci. Food Agr., 2015, 95, 628-634.
[16] Ke S., Huang Y., Decker E.A., Hultin P., Purslow P.P.: Impact of citric on the tenderness, microstructure and oxidative stability of beef muscle. Meat Sci., 2009, 82, 113-118.
[17] Kim J.: Effects of acid whey marination on tenderness, sensory and other quality parameters of beef eye of round. Brigham Young University, Provo 2018.
[18] Kumar Y., Singh P., Pandey A., Kumar Tanwar V., Kumor R.R.: Augumentation of meat quality attributes of spent hen breast muscle (*Pectoralis Major*) by marination with lemon juice vis-a-vis ginger extract. J. Anim. Res., 2017, 7 (3), 523-529.
[19] Lytou A.E., Nychas G.J.E., Panagou Z.: Effect of pomegranate based marinades on the microbiological, chemical and sensory quality of chicken meat: A metabolomics approach. Int. J. Food Microbiol., 2018, 267, 42-53.
[20] Murali N., Kumar-Philips N.C., Marcy J., Slavik M.F.: Effect of marinating chicken meat with lemon, green tea and turmeric against foodborne bacterial pathogens. Int. J. Poultry Sci., 2012, 11 (5), 326-332.
[21] PN-EN ISO 8589:2010. Analiza sensoryczna. Ogólne wytyczne dotyczące projektowania pracowni analizy sensorycznej.
[22] PN-ISO 1444:2000. Mięso i przetwory mięsne. Oznaczanie zawartości tłuszczu wolnego.
[23] PN-ISO 936:2000. Mięso i przetwory mięsne. Oznaczanie popiołu całkowitego.
[24] Rozporządzenie Rady (WE) nr 1099/2009 z dnia 24 września 2009 r. w sprawie ochrony zwierząt podczas ich uśmiercania. Dz. U. L 303, ss. 1-30, z 18.11.2009.
[25] Saad Latif S.: Effect of marination on the quality characteristics and microstructure of chicken breast meat cooked by different methods. Lucrări Ştiinţifice, 2010, 53, 753-763.

[26] Serdaroğlu M., Abdraimov K., Önec A.: The effect of marinating with citric acid solutions and grapefruit juice on cooking and eating quality of turkey breast. J. Muscle Foods, 2006, 18, 162-172.
[27] Smithers G.: Whey and whey proteins – from 'gutter-to-gold'. Int. Dairy J. 2008, 18, 695-704.
[28] Stadnik J., Stasiak D.M.: Effect of acid whey on physicochemical characteristics of dry-cured organic pork loins without nitrite. Int. J. Food Sci. Technol., 2016, 51 (4), 970-977.
[29] Statsoft, Inc.: Statistica (data analysis sofware system) Version 13.1, 2018.
[30] U-chupaj J., Malila Y., Petracci M., Benjakul S., Visessanguan W.: Effect of tumbling marination on marinade uptake of chicken carcass and parts quality. Braz. J. Poultry Sci., 2017, 19 (1), 61-68.
[31] Wójciak K.M., Karwowska M., Dolatowski Z.J.: Use of acid whey and mustard seed to replace nitrites during cooked sausage production. Meat Sci., 2014, 96 (2), 750-756.
[32] Wójciak K.M., Krajmas P., Solska E., Dolatowski Z.J.: Application of acid whey and set milk to marinate beef with reference to quality parameters and product safety. Acta Sci. Pol. Technol. Aliment., 2015, 14 (4), 293-302.
[33] Wójciak K.M., Kęska P., Okoń A., Solska E., Libera J., Dolatowski Z.J.: The influence of acid whey on the antioxidant peptides generated to reduce oxidation and improve colour stability in uncured roast beef. J. Sci. Food Agr., 2018, 98, 3728-3734.
[34] Vlahova-Vangelova D.B., Balev D.K., Dragoev S.G., Kirisheva G.D.: Improvement of technological and sensory properties of meat by whey marinating. Scientific Works of University of Food Technologies, 2016, 63 (1), 7-13.
[35] Zhuang H., Savage E.M.: Variation and Pearson correlation coefficients of Warner-Bratzler shear force measurements within broiler breast fillets. Poultry Sci, 2009, 88, 214-220.

## WPŁYW MARYNOWANIA MIĘSA KURCZĄT BROJLERÓW KWAŚNĄ SERWATKĄ NA JAKOŚĆ I AKCEPTACJĘ KONSUMENCKĄ PRODUKTU

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

W badaniach zastosowano kwaśną serwatkę do marynowania mięsa kurcząt brojlerów. Surowiec do badań stanowiły mięśnie piersiowe kurcząt brojlerów (n = 90), które marynowano kwaśną serwatką (n = 30) i porównawczo – marynatą z dodatkiem soku z cytryn (n = 30). Stężenie soku z cytryn dobrano tak, aby odpowiadało pH kwaśnej serwatki (4,54). Mięśnie piersiowe niemarynowane stanowiły grupę kontrolną (n = 30). Oceniano parametry jakościowe produktu surowego i grillowanego (absorpcję marynaty, pH, barwę w systemie CIE L*a*b*), wartość odżywczą (białko, tłuszcz, związki mineralne w postaci popiołu), parametry tekstury (siłę cięcia oraz twardość, sprężystość, gumowatość, żujność) oraz przeprowadzono ocenę sensoryczną [pkt]. W badaniach wykazano, że marynowanie mięśni piersiowych z użyciem serwatki w porównaniu z marynowaniem z wykorzystaniem soku z cytryn zwiększyło pobór marynaty, korzystnie ($p < 0,05$) wpłynęło na kruchość (mierzoną siłą cięcia Warnera-Bratzlera), twardość (ocenianą analizą profilową tekstury TPA), zawartość popiołu w produkcie surowym i poddanym obróbce termicznej, zmniejszenie wysycenia barwy czerwonej (a*), a także zwiększenie wysycenia barwy żółtej (b*) w ogólnym tonie barwy. W ocenie sensorycznej marynowanie z użyciem serwatki korzystnie wpłynęło na soczystość i kruchość grillowanego produktu. Stwierdzono także ogólną akceptację badanych cech. Uzyskane wyniki pozwalają wnioskować, że kwaśną serwatkę można wykorzystać jako naturalną marynatę do mięsa kurcząt brojlerów.

**Słowa kluczowe:** mięso kurcząt brojlerów, marnowanie, serwatka, sok z cytryn, jakość