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PHYSICOCHEMICAL PROPERTIES OF PORK LOIN MARINATED IN KEFIR, YOGHURT OR BUTTERMILK AND COOKED SOUS VIDE

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ABSTRACT

Background. The most important qualities of meat and meat products include tenderness, juiciness and color. Sour meat marinating is a commonly used technique. In the available literature, there are no reports on the use of fermented dairy products (FDP) for meat marinating. The acids contained in FDP can improves the tenderness, taste, flavor, juiciness and color of meat products. The use of lower heat treatment temperature for a long time for cooking meat also positively affects its sensory properties and texture. The aim of the study was to determine the influence of marinating meat in kefir, yoghurt or buttermilk and cooking it sous vide (SV) on its physicochemical properties.

Material and methods. Muscle cut into slices (*m. longissimus dorsi thoracis*) was placed in plastic bags, FDP were added to the meat, and the bags were then vacuum-sealed and refrigerated (4°C/48 h). After this time, one of the samples of each variant was analyzed, and the second was cooked SV (63°C/3 h). In the raw and cooked samples, the following were determined: chemical composition, acidity, redox potential, fat oxidation degree and physical parameters, such as texture (TPA test) and color (CIE Lab).

Results. Marinating meat did not affect weight loss during meat storage and heat treatment, nor the moisture and protein content. Meat marinating decreased the pH, but had no effect on the content of fat oxidation products and the reduction potential in raw meat. Marinating meat in buttermilk and yogurt and cooking SV resulted in lowering the fat content and limiting oxidation, increasing the reduction potential, reducing hardness and chewiness and increasing the redness of the samples.

Conclusion. Marinating meat, especially in buttermilk or yogurt and cooking SV, improves its texture and color and limits oxidation processes. There was no positive effect of marinating meat in kefir on the parameters tested.

Keywords: fermented dairy products, marinating, sous vide, physicochemical properties, meat

INTRODUCTION

The most important qualities of meat and meat products include tenderness, juiciness and color (Ergezer and Gokce, 2011). Researchers and manufacturers have long studied the conditions of tenderness and juiciness, especially during muscle maturation (Koohmaraie et al., 2002), as well as treatments or preparations that

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can improve the culinary properties of meat e.g., salt, polyphosphates, lactate (Ergezer and Gokce, 2011; Sharedeh et al., 2015). Some of them try to use natural food ingredients such as lemon juice, kefir, lemon, and pineapple marinades, potato tuber juice, soy sauce and wine sugar and organic acids, tamarind, lemon, lime, and calamansi, red wine (Feng et al., 2016; Jinap et al., 2018; Kargiotou et al., 2011; Mozuriene et al., 2016; Żochowska-Kujawska et al., 2012). Meat marinating is a commonly used technique (Alvarado and McKee, 2007; Mozuriene et al., 2016; Żochowska-Kujawska et al., 2012). Acid pickling improves tenderness, taste, flavor and juiciness (Goli et al., 2011), as well as extending the shelf life of the product by limiting the growth of bacteria (Alvarado and McKee, 2007).

Fermented dairy products (FDP), such as buttermilk, kefir and yoghurt, are natural products that have a beneficial effect on human health. They contain live bacterial cultures (Table 1) that produce natural lactic acid through lactic fermentation and other organic acids to a lesser extent. Lactic acid is one of the most widely used preservatives. The antimicrobial effect of lactic acid results both from lowering the pH of the environment below the growth range of microorganisms, as well as inhibiting their metabolism by undissociated acid molecules (Alvarado and McKee, 2007; Goli et al., 2012). In the available literature, there are no reports on the use of FDP for meat marinating.

The use of lower heat treatment temperatures over a long time for cooking meat positively affects its sensory properties and texture. The sous vide (SV) method consists in cooking the raw material closed in a vacuum in thermostable bags under controlled temperature and time conditions (Ruiz et al., 2013). This method prevents losses of volatile substances and reduces the level of losses during cooking (Vaudagna et al., 2002); it inhibits unpleasant odors from the oxidation of both fats and proteins (Roldan et al., 2014); it also increases the food durability by reducing the growth of aerobic bacteria (Garcia-Linares et al., 2004) and eliminates the risk of re-infection during storage. The sous vide – SV cooking conditions differ significantly from those used in traditional cooking methods. In gastronomy, for preparation of dishes it is recommended to cook meat at a low temperature (58–63°C) for a long time (10–48 h), while in the meat industry, the temperature is usually 75–80°C (García--Segovia et al., 2007; Roldan et al., 2014; Ruiz et al., 2013). However, a temperature of 63°C to ensure optimal tenderness and juiciness of meat may be insufficient to ensure the safety of a meat product stored in the refrigerator for a long time. We suggest marinating

Table 1. Microflora and chemical composition of fermented dairy products FAO/WHO (2003)

	Kefir	Yoghurt	Buttermilk
	live bacterial cultures		
Chemical composition	LAB (*Acetobacter*, *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Streptococcus* ssp.) yeasts (*Saccharomyces omnisporus*, *Saccharomyces cerevisae*, *Saccharoniyces exigus*, *Kluyveromyces marxianus*)	*Lb. delbrueckii* ssp. *bulgaricus*, *Streptococcus thermophilus*	*Lc. lactis* ssp. *lactis*, *Lactococcus lactis* ssp. *cremoris*, *Lactococcus lactis* ssp. *lactis biovar diacetylactis*, *Leuconostoc mesenteroides* ssp. *cremoris*
Fat, %	3	1.5	0.5
Carbodydrates, %	5.2	4.6	4.0
Protein, %	3.4	4.3	3.3
Calcium, mg/100 g	120	170	116

meat in FDP as an element of food preservation using hurdle technology. The sous vide – SV has been extensively studied in meat and meat products (Botinestean et al., 2016; García-Segovia et al., 2007; Roldan et al., 2014; Sánchez del Pulgar et al., 2012). Nevertheless, there is a lack of knowledge about the use of this marinated pork cooking system in FDP.

The aim of the research was to investigate the impact of 48-hour meat marinating in kefir, yogurt or buttermilk on chemical composition, acidity, redox potential, fat oxidation degree, and physical parameters such as the texture and color of raw and cooking pork loin SV at 63°C.

MATERIALS AND METHODS

Raw material preparation

Loins with a homogeneous histological structure (*m. longissimus dorsi thoracis*), from Great White Poland pigs were obtained from a slaughterhouse 24 h after slaughter (pH 5.6–5.8). Muscles were cut into eight slices 4 cm thick and weighing about 170 grams, perpendicular to the direction of the muscle fibers. The slices were placed in separate plastic bags (cooking bags 80GR vaccum cooking, Orved S.p.A, Italy). Fermented dairy products (Dairy Cooperative Mlekovita, Poland) were added to the meat: kefir (K) to two, buttermilk (B) to two and yoghurt (Y) to two slices in a 10% (m/m) proportion. The control group (C) consisted of two pieces of meat without any addition. All bags were then vacuum-sealed (VAC-20 DT, Edesa, Spain) and refrigerated for 48 h at 4°C. After this time, one of the samples of each variant was analyzed, while the second was cooked in a water bath at 63°C for 3 h. After cooking, the samples were cooled in water at 2°C for 1 h and stored overnight at 4°C. Samples without cooking were marked KR, BR, YR and CR, while cooked samples were marked KC, BC, YC and CC.

Processing loss and proximate composition analysis

Marinating loss was calculated by measuring the differences in weight before and after marinating. while processing loss was calculated by measuring the differences in weight before and after cooking. Moisture was determined according to ISO 1442:1997. Total nitrogen content was evaluated by the Kjeldahl method using a Kjeltec™ 8100 (Foss Tecator, Höganäs, Sweden). Protein was calculated using the factor 6.25. Total fat was assayed by means of the Soxhlet method, in accordance with ISO 1444:2000.

Chemical analysis

The pH was measured using a homogenate prepared with 10 g of the sample and distilled water (100 mL) and a digital pH meter CPC-501 (Elmetron, Poland) equipped with the pH electrode (ERH-111, Elmetron, Poland), in accordance with ISO 2917:1999. Redox potential (ORP) was measured using a homogenate prepared with 10 g with 30 ml of deionized water using a digital ORP-meter CPC-501 (Elmetron, Poland) set to the millivolt scale and equipped with a redox electrode (ERPt-13, Elmetron, Poland). Lipid oxidation was assessed using the thiobarbituric acid reactive substances' (TBARS) method (Raharjo et al., 1992). The absorbance was determined at 532 nm (Nicole Evolution 300, Thermo Electron Corporation, USA). The thiobarbituric acid reactive substances' – TBARS were calculated and expressed as mg malonaldehyde (MDA) per 1 kg of meat.

Physical analysis

Hunter color lightness (L^*), redness (a^*) and yellowness (b^*) values were measured on freshly cross cut surfaces of each sample using a 8200 Series reflection spectrocolorimeter (X-Rite Inc., USA), using a illuminant D65 and 10° observer angle and a 12 mm port/viewing area. The spectrocolorimeter was calibrated against white and black standard tiles. Ten measurements for each sample were taken at random locations on the surface of each of the meat samples.

Texture profile analysis (TPA) was performed using a texture analyzer (TA-XT2i, Stable Micro Systems Ltd., UK). Six cylindrical cores (25 mm length × 20 mm diameter) per treatment were cut from the central portion of steak. Prior to analysis, samples were allowed to equilibrate to room temperature. Core samples were compressed twice between two parallel plates to 50% of their original height with a time interval of 5 s between the two compression cycles, at a crosshead speed of 2 mm/s. A TA-25 with a 2-inch diameter stainless probe was used. The calculation of TPA values was obtained using force and time plots. Values for hardness, cohesiveness, springiness and chewiness were determined as described by Bourne (1978).

Statistical analysis

The experiment was repeated three times. Chemical analyses were performed for nine replicates in each experiment. The fix effect of the treatments and the random effect of replications were included in the model. Analysis of variance (ANOVA) was performed on all variables using the General Linear Model process of SAS statistical software. The differences in the mean values were compared by Tukey's multiple comparison method, and mean values and standard error of the means (SEM) were reported ($p < 0.05$).

RESULTS AND DISCUSSION

Processing loss and proximate composition analysis

In this study, the effect of 48-hour meat marinating in FDP (kefir, yogurt or buttermilk) on the technological characteristics, chemical characteristics and physical parameters of raw pork loin (*m. longissimus dorsi thoracis*) and that cooked SV at 63°C was analyzed. Table 2 shows the results obtained on the processing loss and the chemical composition of raw and SV-cooked pork loin. Marinating the meat for 48 h in a FDP vacuum resulted in low weight loss at 1.5%. Generally, the storage of meat with disturbed tissue structure, e.g. by cutting, causes a loss of its mass. Leakage of meat juices takes place under the influence of gravity. In addition, vacuum sealing of raw meat may cause slightly larger water losses resulting from the physical increase of pressure on the meat during vacuum packaging and from the partial exudation of surface water due to the vacuum (García-Segovia et al., 2007). Some authors have recorded the positive effect of sour marinades on water retention capability (Mozuriene et al., 2016). These properties are often correlated with swelling and/or increased extractiveness of myofibrillar proteins associated with an increase in ionic strength and a decrease in pH (Goli et al., 2011, 2012; Sharedeh et al., 2015). However, they did not use complex systems such as FDP for meat marinating nor vacuum conditions. The SV-cooked samples at 63°C showed mass losses of 15%. Loss of mass during meat cooking results mainly from changes in proteins. These changes start at a temperature of 40°C when myofibrillar proteins shrink and deepen as the temperature increases. Protein coagulation strengthens the structures of the muscle fiber, thus reducing its volume and ability to retain water. Moreover, the spaces between the myofibrilles are tightened, as a result of which a part of

Table 2. Effect of meat marinating in kefir (K), yogurt (Y) or buttermilk (B) on the processing loss and the chemical composition of raw pork loin and pork loin cooked SV

Samples		Processing loss, %		Chemical composition, %		
		marinating loss	cooking loss	moisture	proteins	fat
Raw	CR	1.60 ±0.19[a]	–	70.16 ±1.50[a]	20.26 ±1.08[a]	5.32 ±0.51[a]
	KR	1.47 ±0.14[a]	–	71.74 ±2.36[a]	21.24 ±0.64[a]	6.72 ±0.95[a]
	BR	2.52 ±0.32[b]	–	71.81 ±1.20[a]	20.44 ±0.75[a]	5.60 ±1.40[a]
	YR	1.30 ±0.11[a]	–	72.43 ±1.24[a]	21.90 ±1.12[a]	5.49 ±0.59[a]
Cooked	CC	–	14.75 ±0.20[a]	64.57 ±0.92[b]	28.54 ±0.58[c]	6.07 ±0.98[b]
	KC	–	14.75 ±0.49[a]	65.04 ±0.86[b]	29.32 ±0.49[c]	4.72 ±0.48[bc]
	BC	–	16.05 ±1.09[a]	64.98 ±0.54[b]	29.98 ±0.18[c]	3.50 ±0.42[c]
	YC	–	14.96 ±0.75[a]	65.28 ±0.81[b]	30.01 ±1.06[c]	3.44 ±0.47[c]

Means within a column with different small letters differ significantly ($p < 0.05$).

the capillary water is lost during cooking. There was no effect of meat marinating on moisture and protein content ($p < 0.05$). Of course, the heat treatment reduced the meat's moisture content by an average of 6 percentage points relative to the moisture content of the raw meat, thus increasing the content of other ingredients, especially protein by about 10 pp. According to Sánchez del Pulgar et al. (2012), the way of meat cooking does not affect its juiciness. Water losses are the result of the temperature used. Likewise, vacuum cooking does not cause a greater retention of juice in meat. However, under certain conditions, it may cause slightly larger losses of water resulting from the physical increase of pressure exerted on the meat during vacuum packaging and from partial exudation of surface water caused by the vacuum (García-Segovia et al., 2007). Nevertheless, water is not the only ingredient lost during cooking. Along with water, other water-soluble components are lost. Using the SV method, the losses of these components are limited, and if the cooking temperature exceeds the collagen solubility temperature, after cooling, they are bound in a gelatinous structure (Sánchez del Pulgar et al., 2012). It seems surprising that the fat content decreases in marinated samples, especially in buttermilk and yogurt, and cooked SV. Perhaps this is due to the fact that yogurt contains twice and buttermilk six times less fat than kefir (Table 1).

Chemical analysis

The chemical characteristics are shown in Table 3. As expected, the pH of raw meat marinated in the FDP as well as meat marinated and cooked SV was lower ($p < 0.05$) than that of the control samples. However, the type of marinade did not affect ($p < 0.05$) the pH of the samples. Decreasing the pH of the marinated samples results from the low pH of the marinade used. The yoghurt pH is 4.4 due to the fact that *Str. thermophilus* and *Lc. bulgaricus* strains are able to convert lactose to lactic acid. Likewise, the pH of kefir is about 4.2, which stems from the presence of organic acids, ethanol, carbon dioxide and other volatile compounds (Zajšek and Goršek, 2010). Buttermilk is a by-product of whipping sweet cream into butter, produced with the participation of *Lc. Lactis* subsp. *cremoris*, *Lc. lactis* subsp. *lactis*, *Leuc. mesenteroides* subsp. *cremoris* and *Lc. lactis* subsp. *Diacetilactis*, characterized by a pH of about 4.5.

Meat marinating for 48 h in FDP had no effect on the content of fat oxidation products in raw meat, and the results did not exceed 1 mg of malondialdehyde (MDA) in 1 kg (Table 3). Thermal treatment caused a four-fold increase in the content of these products in the control (non-marinated) sample, considerably above 3 mg of MDA. Sánchez del Pulgar et al. (2012) also obtained high TBARS values, from 2.4 mg to 4.0 mg MDA per kilogram of SV-cooked pork cheeks.

Table 3. Effect of meat marinating in kefir (K), yogurt (Y) or buttermilk (B) on the pH, TBARS and OPR values of raw pork loin and pork loin cooked SV

Samples		Acidity, pH	TBARS, mg MDA/kg	ORP, mV
Raw	CR	5.76 ±0.04^{a}	0.91±0.10^{a}	272.71 ±12.56^{a}
	KR	5.46 ±0.09^{b}	0.75 ±0.22^{a}	295.21 ±24.84^{a}
	BR	5.41 ±0.11^{b}	0.83 ±0.19^{a}	283.77 ±10.55^{a}
	YR	5.44 ±0.12^{b}	0.79 ±0.29^{a}	288.78 ±18.13^{a}
Cooked	CC	5.85 ±0.13^{a}	3.69 ±0.18^{b}	265.52 ±14.81^{a}
	KC	5.61 ±0.20^{b}	2.32 ±0.33^{d}	315.87 ±19.05^{b}
	BC	5.56 ±0.15^{b}	1.51 ±0.41^{c}	312.00 ±14.01^{b}
	YC	5.57 ±0.16^{b}	1.23 ±0.52^{c}	310.23 ±22.01^{b}

Means within a column with different small letters differ significantly ($p < 0.05$).

They found that this was the result of a long-term thermal treatment (6 or 12 h) causing an increase in lipid oxidation. However, the authors did not use any marinade. Meat marinating in FDP, especially in buttermilk or yogurt, caused a significant reduction in fat oxidation in SV-cooked samples. Some LABs have been shown to have antioxidant activity and are able to reduce the risk of reactive oxygen species accumulating. LABs can degrade peroxide anion and hydrogen peroxide (Kullisaar et al., 2003). In the FDP, peptides with antioxidant activity have been identified (Kudoh et al., 2001), including casein calcium peptides (Sakanaka et al., 2005). Diaz and Decker (2004) report that cooking increases the catalytic activity of iron in meat, while milk proteins have a strong chelating activity, which can effectively reduce the oxidation.

The reduction-oxidation potential (ORP) expresses the degree of progression of biochemical reactions that cause oxidation processes in meat. The ORP value depends on the amount of oxidants and reducers contained in the meat. The more oxidants, the higher the ORP value. Factors that affect the ORP include pH, water activity, oxygen, type of biochemical processes and concentration of reagents. Meat marinating did not affect the ORP value (Table 3). However, marinating the meat and then cooking it by means of SV increased the ORP value. The type of marinade did not have any significant impact ($p < 0.05$) on the parameter being analyzed in this case.

Physical analysis

Texture is one of the most important qualitative features of meat and its products. It affects the acceptance of meat among consumers. Parameters describing the texture in the TPA test are: hardness, elasticity, cohesion and chewiness. Sánchez del Pulgar et al. (2012) showed no significant effect of SV-cooked pork cheeks on texture parameters. However, many authors observe the beneficial effect of marinating on the texture of meat. Our use of these two techniques resulted in changes in meat hardness (Table 4). Marinating meat, especially in buttermilk or yogurt, only caused a slight increase ($p < 0.05$) in hardness, but it did not affect the remaining texture parameters. In contrast, SV cooking of meat marinated in buttermilk or yogurt significantly reduced ($p < 0.05$) its hardness and chewiness as compared to the control. Similarly, Żochowska-Kujawska et al. (2012) found the influence of marinating in wine, lemon juice, kefir or pineapple juice on the reduction of hardness in venison. Marinating the meat, especially in an acid solution, causes a lowering of pH, which significantly increases protein hydration (Goli et al., 2011) and tenderness. These properties are often correlated with swelling and/or increased extractiveness of

Table 4. Effect of meat marinating in kefir (K), yogurt (Y) or buttermilk (B) on the texture parameters of pork loin of raw and SV-cooked pork loin

Samples		Texture profile analysis (TPA)			
		hardness, N	cohesiveness	springiness	chewiness, N
Raw	CR	14.73 ±2.19[a]	0.73 ±0.16[a]	0.71 ±0.20[a]	6.82 ±1.62[a]
	KR	15.28 ±1.90[a]	0.44 ±0.09[b]	0.56 ±0.21[a]	5.07 ±1.02[a]
	BR	19.49 ±1.14[b]	0.55 ±0.14[ab]	0.74 ±0.23[a]	7.67 ±1.49[a]
	YR	18.47 ±1.59[ab]	0.52 ±0.13[ab]	0.71 ±0.27[a]	5.37 ±1.22[a]
Cooked	CC	89.28 ±10.28[c]	0.55 ±0.03[b]	0.49 ±0.03[a]	43.49 ±11.57[b]
	KC	75.46 ±9.04[c]	0.57 ±0.08[ab]	0.52 ±0.08[a]	22.63 ±6.19[c]
	BC	59.47 ±8.09[d]	0.57 ±0.03[ab]	0.48 ±0.03[a]	16.49 ±2.73[c]
	YC	68.39 ±6.21[cd]	0.62 ±0.03[ab]	0.48 ±0.02[a]	19.81 ±4.86[c]

Means within a column with different small letters differ significantly ($p < 0.05$).

myofibrillar proteins. These changes can be explained by physico-chemical mechanisms, mainly related to the decrease in pH and the increase in ionic strength. In an acidic environment, the hardness of connective tissue is reduced by weakening electrostatic interactions between myofibrillar protein chains or by enzymatic mechanisms (Hwang et al., 2000). Lactic acid, which is naturally formed during meat maturation and naturally occurring FDP, may have a significant impact on changes. Likewise, lowering the pH by placing meat in a marinade can significantly increase the activity of cathepsins, for which the optimal pH is in the range from 3.5–5.0, which can be observed in the studies by Żochowska-Kujawska et al. (2012), as well as in our study. It has been shown that the addition of calcium-containing ingredients (such as kefir or calcium lactate) increases the proteolysis caused by calpains. In addition, as a result of acidification, the temperature of thermal denaturation of muscle proteins decreases.

Color, like texture, is a very important parameter of meat quality. Meat marinating in FDP did not affect the value of parameter L^* (lightness) in both raw and SV-cooked samples (Table 5). The sous vide – SV thermal treatment caused an increase in the L^* value, i.e. lightening the color. The most important parameter of the color of meat and meat products is redness (a^*). The intensity of redness in cooked meat is inversely proportional to the degree of myoglobin denaturation. Changes in redness indicate processes that occur in meat during processing and marinating. Lower a^* values were found in raw meat marinated in FDP than in the control. This was probably due to the protective antioxidant action of bioactive peptides in the hydrolysis of milk proteins (Brandelli et al., 2015). Heat treatment of meat causes degradation of myoglobin and then changes in the a^* value. The higher the temperature, the greater the degradation of myoglobin (García-Segovia et al., 2007; Sánchez del Pulgar et al., 2012). Vaudagna et al. (2002) found that using the SV technique can reduce degradation of myoglobin, which we observe in our studies in the form of an increase in redness ($p < 0.05$). Similarly, Sánchez del Pulgar et al. (2012) found an increase in redness of SV-cooked pig cheeks as compared to those cooked in air-filled packages. The authors explained this as being due to the higher thermostability of deoxymyoglobin compared to oxy- and metmyoglobin (Mancini, 2009), assuming that vacuum packaging increases the contribution of myoglobin redox form in meat. The use of FDP and SV can limit the oxidation of myoglobin and increase its thermal stability, minimizing changes in a^* and limiting the reduction in its redness. An important factor impacting on the color of meat is oxidation-reduction potential, which determines the

Table 5. Effect of meat marinating in kefir (K), yogurt (Y) or buttermilk (B) on the color parameters of pork loin of raw and SV-cooked pork loin

Samples		Color		
		L^* value	a^* value	b^* value
Raw	CR	55.54 ±1.23^{a}	3.46 ±0.31^{a}	11.13 ±0.78^{a}
	KR	56.03 ±1.65^{a}	1.81 ±0.42^{bc}	9.80 ±1.22^{b}
	BR	56.56 ±2.95^{a}	1.97 ±0.40^{b}	9.64 ±1.33^{b}
	YR	56.08 ±1.75^{a}	1.34 ±0.15^{c}	9.74 ±1.29^{b}
Cooked	CC	73.26 ±1.89^{b}	2.71 ±0.36^{d}	13.56 ±1.24^{a}
	KC	76.42 ±1.40^{b}	2.22 ±0.34^{bd}	12.64 ±0.70^{a}
	BC	76.34 ±1.91^{b}	2.23 ±0.35^{b}	12.61 ±0.48^{a}
	YC	77.08 ±2.36^{b}	2.01 ±0.29^{b}	12.60 ±0.50^{a}

Means within a column with different small letters differ significantly ($p < 0.05$).

iron redox status placed centrally in the porphyrin ring of the myoglobin molecule. The low ORP value found in our studies also helps to keep the heme pigments in a reduced form. Strzyżewski et al. (2008) showed that while the change in the active acidity of meat can cause changes in color parameters such as lightness (L^*), yellowness (b^*) and saturation (C^*), it does not affect redness (a^*). The yellowness (b^*) of meat marinated in FDP was smaller ($p < 0.05$) than that of the control sample. The sous vide – SV cooking increased the b^* value by an average of 2 units, regardless of the marinade type. Higher b^* values of SV-cooked meat compared to raw meat may be due to the formation of a brown form of myoglobin, i.e. metmyoglobin, in the final product.

CONCLUSIONS

No significant effect of meat marinating for 48 h in kefir, yoghurt or buttermilk under vacuum and *sous vide* cooking at 63°C on weight loss, moisture content and protein was recorded. In contrast, the fat content of marinated samples, especially those marinated in buttermilk and yogurt, as well as SV-cooked ones, was lower than in the remaining ones. The acidity of meat marinated in FDP and SV-cooked was lower than that of the control. Marinating the meat in FDP, especially in buttermilk or yogurt, followed by SV cooking resulted in a significant reduction in fat oxidation, an increase in the ORP value, and a reduction in hardness and chewiness compared to samples marinated in kefir and the control. The use of FDP and SV may limit the oxidation of myoglobin, increase the thermal stability of myoglobin, minimize changes in redness and decrease the reduction of redness. Further research should focus on the optimization of meat marinating in buttermilk and yogurt and the selection of sous vide cooking parameters.

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