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Research Article

Effect of Cornelian Cherry (*Cornus mas* L.) Juice on Selected Quality Properties of Beef Burgers

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Bioactive compounds of plant origin are becoming increasingly popular as food ingredients with a beneficial impact on human health. Therefore, the present study aimed to investigate the possibility of using different doses (0.5 g–1.5 g) of cornelian cherry juice (CCJ) as a functional additive in the production of beef burgers. Results of the experiment showed CCJ addition to cause high acidification of the meat emulsion and to decrease meat production yield was unbeneficial from the economic point of view. In contrast, the CCJ was highly effective in retarding lipid oxidation in beef burgers during storage wherein even a dose of 0.5 g CCJ resulted in beneficial inhibition of oxidative changes and at the same time had no negative effect on the sensory characteristics of beef burgers. CCJ can be applied in the meat industry to develop novel products; however, future research is needed regarding its acidifying properties.

1. Introduction

Food legislation (e.g., Regulation EC no 1129/2011 [1]) regulates the health safety issues of food additives used in food processing. However, many consumers still call for the negative impact of food additives of chemical origin on their health. The social anxiety about the use of synthetic additives in food production has prompted researchers and food manufacturers to explore natural substances with functional properties, for example, chemical compounds of plant origin [2] Fruits are a rich source of phytochemicals, for example, vitamins, minerals, and polyphenols, essential for human health [3]. These bioactive compounds can be used in food processing and thereby affect human health. Recent studies have demonstrated the potential of fruit-derived substances as functional additives to meat products. For example, Tyburcy et al. [4] proved that cranberry fruit juice can be applied in the production of pork burgers as an additive with antioxidant properties. A black currant fruit extract added to pork chops [5] or chokeberry juice used in the production of pork sausages [6] were also reported to inhibit the fat oxidation process. Despite their invaluable impact on human health, fruits are rarely used as additives in meat production, because they may induce changes in the sensory attributes (color and taste) of the finished products [7].

Among many wild fruits, an interesting raw plant material from the viewpoint of chemical composition is fruits of cornelian cherry (*Cornus mas* L.). They are a rich source of biologically-active compounds, such as various essential mineral elements, vitamin C, organic acids, pectin, phenolic acids, flavonoids, iridoids, and triterpenoids [8–15]. These phytochemicals elicit protective effects on atherosclerosis and display antioxidant and anti-inflammatory properties, as well express cardiotonic, antidiabetic, and antiobesity activities [16, 17]. Consumption of fruits is also recommended due to their astringent properties and their potency for recovery and regeneration of damaged epidemic tissues, as well as for alleviating diarrhea and dysentery, sore throat, digestion problems, measles, and chicken pox [18, 19]. The cornelian cherry fruits are very convenient for processing to produce syrups, liqueurs, juices, and jams [12], while their use in the meat industry has not been investigated so far. Therefore, the aim of this study was to determine the effect of cornelian cherry juice on the quality properties of beef burgers. The authors assumed the feasibility of using cornelian cherry juice as a food additive, which could be applied instead of chemical additives to improve the quality of meat products.

2. Materials and Methods

2.1. Ingredients. The postrigor beef cuts (I class) were delivered 48 h postmortem from the meat processing plant "Edward and Grzegorz Dworeccy" (Golejewo, Poland) to the Department of Animal Products Technology and Quality Management, Wrocław University of Environmental and Life Sciences. Raw materials were cleaned, cut into strips, and ground (W-82AN Spomasz, Zary, Poland; 0.5 cm plate diameter). Then, the material was portioned, vacuum packaged, frozen, and stored at −18°C until use.

2.2. Preparation of CCJ. Juice of cornelian cherry (*C. mas* L.) fruits (CJ) was produced as per the following procedure: 1 kg of frozen ripe fruits of cornelian cherry were shredded and heated for 5 min at 95°C (Thermomix, Vorwerk, Wuppertal, Germany), and after heating, the pulp was subsequently cooled down to 40°C and depectinized (0.5 mL/kg of Panzym Be XXL, Begerow GmbH & Co., Darmstadt, Germany) at 50°C for 2 h. Next, the pulp was cleaned of stones and pressed in a laboratory hydraulic press (Zodiak SRSE, Warsaw, Poland). Then, ready juice (CJ) was lyophilized (FreeZone18L, Labconco, USA), vacuum packaged, frozen, and stored at −18°C until use (approx. 1 month). Before application to beef burgers, the juice was reconstituted by dilution in distilled water (1 : 1 w/w). Samples of diluted CJ (CCJ) had an intensive deep red color and bitter-sour taste. The acidity (pH) of CCJ was measured at 2.71 (pH meter inoLab pH 720, WTW, Weilheim, Germany, in accordance with the Polish Standard PN-EN 1132:1999 [20]).

2.3. Identification and Quantification of CJ Active Compounds by HPLC. Contents of iridoids and polyphenols in the samples were determined according to Kucharska et al. [21] by high-performance liquid chromatography HPLC on a Dionex chromatogram (USA). The chromatograph was equipped with an Ultimate 3000 diode detector, an LPG pump-3400A, an EWPS-3000SI autosampler, a TCC-3000SD column thermostat, and Chromeleon v. 6.8 software. The analysis was carried out on a C5–C18 Cadenza Imtakt column (75 × 4.6 mm, 5 μm). The solution of 4.5% v/v aq. formic acid (reagent C) and 100% acetonitrile (reagent D) was used as the eluent at the flow rate of 1 mL/min and split of 20 μL. Separation was carried out using the following gradient: 0-1 min 5% D in C, 20 min 25% D in C, 21 min 100% D, 26 min 100% D, and 27 min 5% D in C. The column was thermostated at 30°C. Anthocyanins were monitored at 520 nm, flavones at 360 nm, and ellagic acid and iridoids at 245 nm. Their contents were expressed as mg/100 mL of CJ.

Table 1: Formulation (g) of beef burgers.

Treatments	Beef	Salt	CCJ
CCJ0	100	1.6	0
CCJ0.5	100	1.6	0.5
CCJ1.0	100	1.6	1.0
CCJ1.5	100	1.6	1.5

CCJ: cornelian cherry juice.

2.4. Preparation of Beef Burgers. All burger batches were manufactured with 100 g of meat and 1.6 g of salt. Four different batters were prepared (Table 1): Treatment CCCJ0: control samples without CCJ addition; treatments CCJ0.5, CCJ1, and CCJ1.5: samples supplemented, respectively, with 0.5 g, 1.0 g, and 1.5 g of CCJ. After thawing, meat was minced through a 0.3 cm plate, mixed with salt or salt and CCJ and formed into discs of 10 cm diameter (weighing approx. 94 g). Next, the burgers were heat-treated (gas and electric oven, Amica 51GE, 180 ± 5°C) until an internal temperature of 72°C has been reached (bayonet thermometer, Amarell TH-101). The finished products were cooled down, vacuum-packed, and stored for 5 months at −15 ± 1°C. The production was replicated in two independent series. All analyses were conducted immediately after the production process (Day 0) in cooled down meat products and in products after 5 months of storage (5 Mths) at −15 ± 1°C.

2.5. pH Measurement of Burger Batters. The pH value was measured directly in burger batters with an inoLab pH 720 pH meter (WTW, Weilheim, Germany) in accordance with the Polish Standard PN-EN PN-ISO 2917:2001 [22] at room temperature.

2.6. Yield of Burger Production Process. The yield of the production process was calculated from the following equation:

$$\%\text{ production yield} = \frac{\text{weight after heat treatment} \times 100}{\text{weight of raw materials}}. \tag{1}$$

2.7. Color Parameters of Beef Burgers. Measurements of color parameters of beef burgers were conducted using a Minolta CR-400 reflectance colorimeter, and results were expressed as L^* = lightness, a^* = redness, and b^* = yellowness parameters in the CIE Lab system. The analysis was carried out at room temperature (22 ± 1°C), directly after the production process and after 5-month storage of burgers.

2.8. Sensory Evaluation. The sensory evaluation of ready-to-eat burgers was performed in accordance with the Polish

Standard PN-ISO 4121:1998 [23]. The evaluation was conducted directly after the production process on 1 cm × 1 cm slices of encoded samples at room temperature (22 ± 1°C) under white light. A professional team of 10 evaluators determined the degree of acceptance of the overall appearance, smell, taste, color, hardness, and juiciness of burgers, using a nine-point hedonic rating scale of acceptance (1, dislike extremely, to 9, like extremely [24]).

2.9. Texture Profile Analysis. The Zwick/Roell Z010 testing machine (Zwick Testing Machines Ltd., Leominster Herefordshire, UK) was used for the texture profile analysis of ready-to-eat burgers. Cylindrical samples of burgers were pressed to 50% of deformation (TPA 50 test, 60 mm/min head speed, 40 s relaxation time). The texture was determined by the following parameters: hardness, gumminess, and chewiness. The measurements were conducted at room temperature (22 ± 1°C), directly after the production process and after 5-month storage of burgers.

2.10. TBA Test. The intensity of oxidative processes in the ready-to-eat beef burgers was evaluated using a spectrophotometric 2-thiobarbituric acid (TBA) filtration method described by Luciano et al. [25] with slight modifications. Briefly, 1 g of a ground sample was homogenized with 10 mL of 10% trichloroacetic acid (Chempur, Piekary Slaskie, Poland) and centrifuged (1000 rpm, 10 min, Sigma 3K30; Sigma Laborzentrifugen GmbH, Osterode am Harz, Germany) at room temperature. Then, homogenates were filtered (Whatman no. 1 filter paper), and the supernatant was collected. Next, 2 mL of clear filtrate was mixed with 2 mL of 0.02 M aqueous thiobarbituric acid (Sigma-Aldrich, St. Louis, MO, USA), and the samples were incubated in a water bath at 100°C for 40 min (Julabo TW12, Julabo Inc., Allentown, USA). The absorbance of the supernatant was measured at 532 nm (spectrophotometer Rayleigh UV-1800, Beijing Rayleigh Analytical Instrument Corp., China). The TBARS values were expressed as equivalents of malondialdehyde (MDA) in mg per kg of sample calculated using 1,1,3,3-tetraethoxypropane (Sigma-Aldrich) as the standard. The determination was conducted immediately after the production process and after 5-month storage of burgers.

2.11. Data Analysis. Data were analyzed using Statistica software v. 13.1. (StatSoft Inc., Poland). Significant differences among groups were identified using Duncan's multiple range test ($P \leq 0.05$). The results were presented as mean values and standard error of the mean (mean ± standard error).

3. Results and Discussion

Results of quantification of CCJ active compounds by HPLC are presented in Table 2. They indicate that 100 mL of CCJ contained 203 mg of iridoids (of which 85% accounted for loganic acid), 8.9 mg of anthocyanins, 2.8 mg of ellagic acid, and 4.1 mg of flavonols. Iridoids are a large group of secondary metabolites; they belong to the group of monoterpenoids in the form of cyclopentanopyran [26, 27]. Iridoids have different pharmacological properties, including antibiotic, anti-inflammatory, or hypotensive ones [28]. Sozański et al. [29] proved protective effects of iridoids extracted from cornelian cherry fruit on diet-induced hypertriglyceridemia and atherosclerosis through enhanced PPARα protein expression and *via* regulating oxidative stress and inflammation. Also the presence of dietary polyphenolic compounds, such as anthocyanins and flavonols, can have a beneficial effect on human health [30]. Anthocyanins with their reactivity have the ability to neutralize free radicals and hence may be used as natural antioxidants [31]. Anthocyanins can replace chemical dyes, but their application in food processing depends on their stability [32].

Table 2: Data of active compounds of cornelian cherry juice, $n = 2$.

Group of compounds	Compound	mg/100 mL
Iridoids	Loganic acid	172.4 ± 8.6
	Cornuside	30.6 ± 1.6
	Total iridoids	**203.00**
Anthocyanins	Cyanidin 3-O-galactoside	1.84 ± 0.3
	Cyanidin 3-O-robinobioside	0.65 ± 0.1
	Pelargonidin 3-O-galactoside	5.44 ± 1.1
	Pelargonidin 3-O-robinobioside	0.90 ± 0.1
	Total anthocyanins	**8.83**
Ellagotanins	Ellagic acid	2.83 ± 0.5
Flavonols	Quercetin 3-glucuronide	2.38 ± 0.5
	Kaempferol galactoside	1.49 ± 0.4
	Kaempferol glucoside	0.29 ± 0.1
	Total flavonols	**4.16**

The addition of cornelian cherry juice to burger batters caused changes in their pH value. The highly acidic CCJ (pH = 2.71) decreased the pH of burger batters along with its growing content (5.87 CCJ0, 5.80 CCJ0.5, 5.78 CCJ1.0, and 5.48 CCJ1.5). The pH values of the batters were close to the isoelectric point (pI) of beef proteins and negatively affected the yield of the production process. The highest ($P \leq 0.05$) yield of the production processes was determined for the samples produced without CCJ addition (72.7%). The highest dose of the plant additive applied (1.5 g) caused the greatest cooking losses and the same caused the lowest production yield (65.3%). The isoelectric point for beef proteins is at 5.1-5.2 and is associated with a decrease in the ability of the protein to bind water [7]. The addition of CCJ to experimental batters caused a reduction in the capacity of meat proteins to retain water during heat treatment and hence in meat production yield. This dependency was also confirmed by Tyburcy et al. [4], who applied cranberry (*Oxycoccus palustris*) and rose (*Rosa rugosa*) juices in pork burgers. Also Zając et al. [33] observed that the addition of 0.05 and 0.1 g/kg of hyaluronic acid to smoked homogenized sausages reduced the stability of meat emulsion and decreased the yield of production process.

Color is one of the most important determinants of the quality of meat products. The color of meat products is

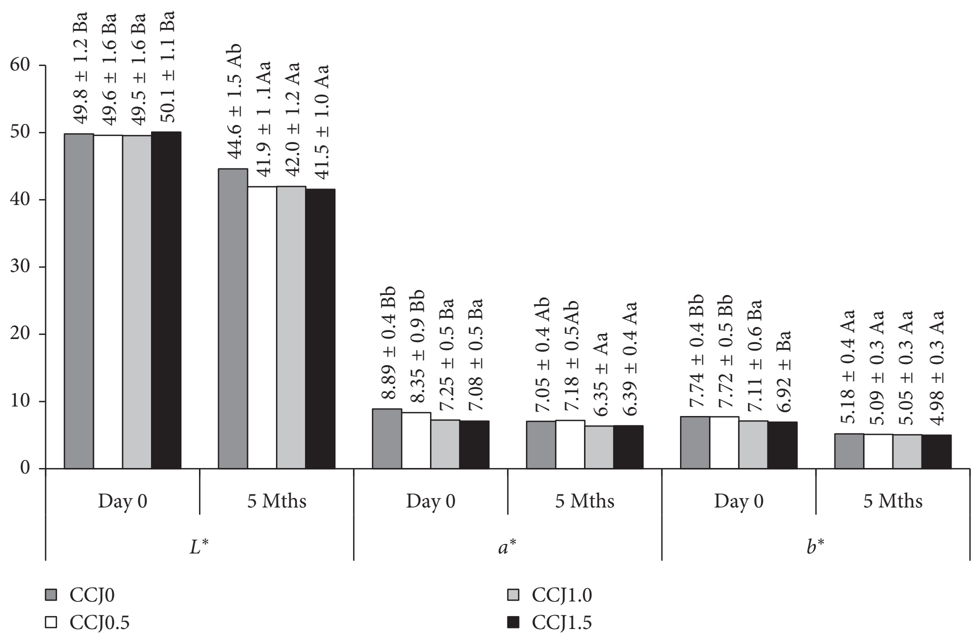

Figure 1: CIE L^*, a^*, and b^* color values of beef burgers, $n = 6$. Means followed by the different lowercase letters between the samples at the same storage time and capital letters between the same samples at different storage times indicate significant differences ($P \leq 0.05$) between values. L^* = color lightness, a^* = redness, and b^* = yellowness.

affected by many factors, including pigmentation of raw meat and fat, functional additives, and technological treatments applied [34]. Raw meat color is significantly affected by the content of myoglobin and the degree of its oxygenation. The content of myoglobin in beef ranges from 6 to 20 mg/kg and is determined by many factors such as age, breed, or kind of animal muscle tissue [35]. The increase in cornelian cherry juice content burger batter caused no change in the values of the L^* parameter (brightness) in burgers (Figure 1). However, all formulations darkened during storage, while the samples of beef burgers manufactured without CCJ were significantly ($P \leq 0.05$) brightest ($L^* = 44.6$). Beef burgers with CCJ added at doses of 1.0 and 1.5 g had lower ($P \leq 0.05$) values of parameter a^* than the samples with 0 g and 0.5 g addition, and these values were much lower after 5-month storage. Immediately after the production process, the highest values of parameter b^* were found in the CCJ0 and CCJ0.5 samples. The use of 1.0 g and 1.5 g of the plant additive resulted in a statistically significant ($P \leq 0.05$) decrease in the values of this parameter. In the own studies, the color of the finished products was mainly attributed to the denaturated form of myoglobin—metmyoglobin, imparting the gray color to meat after the heat treatment [36]. Freeze-storage caused the darkening of beef burgers, which could be due to chemical reactions involving oxygen. The same observation was made by Tril et al. [6] who analyzed meat products with the addition of chokeberry juice. The decrease in the values of parameters a^* and b^* with the growing addition of cornelian cherry juice probably result from the Maillard reaction, which involved reducing sugars present in the CCJ. Kucharska [10] has shown that the content of reducing sugars in fruits of cornelian cherry is 9–14.7%. A similar conclusion was reached by Tyburcy et al. [4] who added cranberry and wild rose juices to pork burgers. Although the CCJ had an intense red color, owing to the presence of anthocyanins (Table 2), this had no direct impact on the color of the experimental beef burgers measured in the CIE $L^*a^*b^*$ scale. The authors attributed this effect to its low level in relation to the raw meat or to the heat treatment which could cause transformation of anthocyanins into colorless chalcones, which as a result of oxidation produce compounds of brown color [37, 38].

Different doses of the cornelian cherry juice added to burger batters influenced results of the sensory evaluation of beef burgers because of its physicochemical properties (Figure 2). The increasing CCJ addition to burger batters resulted in a greater acceptability of the aroma of the finished products; however, the most preferable ones in this respect turned out to be burgers with the highest CCJ addition (5.7 CCJ1.5, 5.4 CCJ1.0, 5.0 CCJ0.5, and 4.4 CCJ0). Better acceptability of this sensory attribute may be associated with a higher content of reducing sugars (ubiquitous in CCJ) in the samples which entered into the Maillard reaction and thereby produced compounds with a desirable, attractive aroma [4, 39]. In assessing the acceptability of the overall appearance of experimental products only, burgers manufactured with the highest, that is, 1.5 g of addition, were rated significantly ($P \leq 0.05$) lower than the others. The taste and the color of experimental beef burgers was rated as high in the case of samples produced with the 0.5 g addition of CCJ and in those produced without the plant additive. Results of the color assessment made by panelists corresponded with those obtained in color measurement in the CIE $L^*a^*b^*$ scale and are probably related to the presence of Maillard reaction products and changes in the stability of

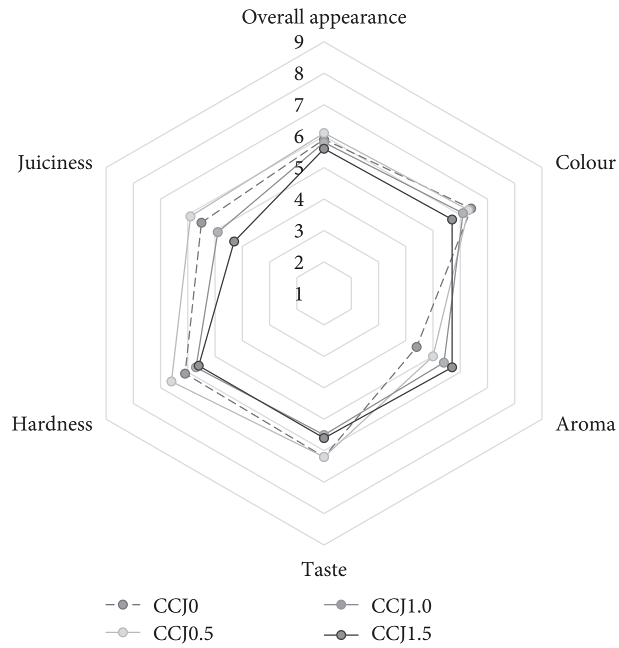

FIGURE 2: Sensory evaluation of beef burgers, $n = 10$.

TABLE 3: TPA (texture profile analysis) test of beef burgers directly after production process (Day 0) and after 5 months (5 Mths) of storage, $n = 5$.

	Time of storage	Hardness (N)	Gumminess (Nm)	Chewiness (N)
CCJ0	Day 0	65.7 ± 2.5 Ba	44.5 ± 6.7 Ba	38.7 ± 5.4 Ba
	5 Mths	36.9 ± 2.5 Aa	26.1 ± 1.7 Aa	24.1 ± 1.5 Aa
CCJ0.5	Day 0	73.3 ± 3.9 Bb	42.8 ± 5.9 Ba	37.3 ± 5.4 Ba
	5 Mths	35.9 ± 3.6 Aa	25.5 ± 2.1 Aa	23.4 ± 2.0 Aa
CCJ1.0	Day 0	73.9 ± 5.2 Bb	43.7 ± 3.8 Ba	38.4 ± 3.7 Ba
	5 Mths	40.7 ± 6.0 Ab	27.2 ± 4.4 Aa	24.9 ± 3.7 Aa
CCJ1.5	Day 0	72.0 ± 5.1 Bb	42.3 ± 3.5 Ba	37.8 ± 1.3 Ba
	5 Mths	39.0 ± 3.2 Ab	28.1 ± 3.4 Aa	25.7 ± 2.9 Aa

anthocyanins. Adverse changes in taste caused by the increasing CCJ content in the model meat products could be attributed to the increase in the salty taste of beef burgers, which was highlighted by the evaluation team. The immediate reason for this was the decrease of production yield, associated with an increase in the acidity of the batters, and hence larger water losses and increased salt content in the finished products [4]. Increased cooking losses with the growing addition of CCJ were also the cause of lesser acceptability of juiciness and hardness of the burgers in the sensory assessment. The burgers with 0.5 g of CCJ received the highest acceptability scores in the assessment of juiciness (5.9) and hardness (6.6), while the lowest scores (5.6) were given to CCJ1.5 samples.

Textural properties of meat products are dependent on the type and amount of used meat and fat and on the addition of water and functional substances [40]. The cornelian cherry juice used in our study had a significant effect on the selected texture parameters of model beef burgers (Table 3). CCJ addition to burger batters increased hardness of the ready-to-eat burgers. The most pronounced effect on burger hardness had CCJ addition of 1.0 g (73.9 N) whereas the smallest changes were recorded using 1.5 g of CCJ (72.9 N) compared to the control sample (65.7 N). In the formulations with CCJ, these changes were not statistically significant. Increase in hardness due to plant additive addition to the recipe was also reported by Tril et al. [6] and Salejda et al. [41] who applied chokeberry juice and tea extract, respectively, in model pork products. In our study, the freeze-storage of beef burgers caused a significant ($P \leq 0.05$) decrease in their hardness, with the highest values measured in CCJ1.0 and CCJ1.5 samples. In the case of such texture parameters such as gumminess and chewiness measured directly after the production process, the highest values (44.5 N and 38.7 Nm, resp.) were determined for the samples manufactured without CCJ. The addition of cornelian cherry juice resulted in the decrease in values of those parameters, but these differences were not statistically significant. In all analyzed formulations, freeze-storage caused a significant ($P \leq 0.05$) decrease in the values of gumminess and chewiness. The observed decrease in values of all measured textural parameters during storage might be associated with water and fat separation from the meat protein matrix and, resultantly, with destabilization of the emulsion [42].

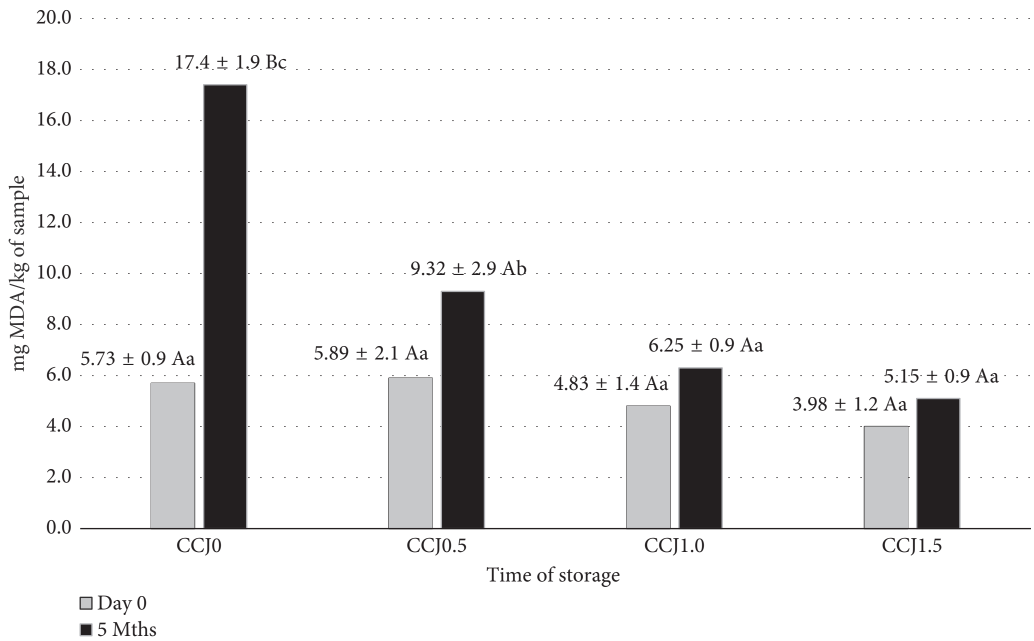

Figure 3: Thiobarbituric acid (TBA) values of beef burgers during storage, $n = 3$. Means followed by the different lowercase letters between the samples at the same storage time and capital letters between the same samples at different storage times indicate significant differences ($P \leq 0.05$) between values.

Results of the present study indicate that lipid oxidation processes occurred in the lipid fraction of experimental beef burgers during 5-month storage in freezing conditions (Figure 3). However, the plant preparation applied effectively limited the intensity of this process. After freeze-storage, the beef burgers with cornelian cherry juice had a lower content of thiobarbituric acid reacting substances (5.15–9.32 mg·MDA/kg) compared with the samples manufactured without the plant additive (17.4 mg·MDA/kg). The highest CCJ dose applied in the study (1.5 g) was the most effective in lipid oxidation inhibition, contrary to the control sample where MDA content increased almost twofold. Inhibition of oxidation processes might be associated with a high content of compounds with antioxidant properties, that is, monoterpenoids (iridoids), phenolic acids, flavonols, and anthocyanins, in the applied cornelian cherry juice. Tang et al. [43] have also demonstrated effective antioxidant action already at the lowest dose of the plant preparation applied. Greater effectiveness in preventing oxidation of lipids with an increasing dose of the plant preparation was also confirmed by Yu et al. [44] and Jia et al. [5], where higher doses of extracts of rosemary and black currant in the recipe were the most effective ones during cold storage (4°C) of meat products.

4. Conclusion

The use of the cornelian cherry juice in the production of beef burgers resulted in a reduction of meat production yield, which suggests the need of introducing functional substances which will neutralize acidifying properties of CCJ to their recipe. Even the lowest dose of the cornelian cherry juice effectively reduced lipid oxidation and allowed maintaining the sensory characteristics of products. This indicates the feasibility of using CCJ to prolong the shelf-life of meat products, and at the same time, of offering novel products enriched with active components of cornelian cherry to consumers.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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