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The effect of the addition of chilli pepper fruits and refrigerated storage time on the quality of pasteurised canned meat

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Abstract: The pork was pasteurised in jars in 4 formulations: control (C), with the addition of chilli peppers (CHP), with the addition of sodium ascorbate (SA), and with the addition of butylated hydroxytoluene (BHT), and stored at 5 °C for 50 days. Although the addition of chilli peppers did not slow down lipid oxidation in pork, this product had lower lightness and higher redness and yellowness than the other products. It was also characterised by the lowest hardness and chewiness values. Sensory evaluation revealed that meat with CHP had a less intense fatty flavour and aroma, and no off-flavour or off-odour. This variant was also evaluated as more juicy and soft, and the taste and aroma of chilli peppers were distinctively perceptible throughout storage. Pork with CHP received significantly higher scores for overall quality.

Keywords: canned meat product; pork; chilli pepper fruits; lipid oxidation; colour; texture analysis; sensory quality

Chilli peppers (*Capsicum annuum* L.) belong to the family *Solanaceae* and encompass a wide range of varieties. This species is one of the most widely cultivated vegetables in the world due to its attractive colour, taste and high nutritional value (Blanco-Ríos et al. 2013). Peppers are abundant in bioactive components, mostly capsaicinoids, carotenoids, ascorbic acid and phenolic compounds (Hervert-Hernandez et al. 2010). However, temperature treatments such as boiling and freezing compromise the content of bioactive compounds in peppers (Loizzo et al. 2015). Hence, there is a need to address the effects of food processing on the healthy compounds much more carefully. This is particularly important considering the latest trend for natural additives with antioxidant potential, which can replace or limit the use of synthetic antioxidants in food (Kumar et al. 2015). So far, the effect of fresh chilli pepper fruits; (*Capsicum annuum* L.) on food quality has been investigated in a limited number of studies. It was revealed for instance that the addition of chilli peppers inhibited lipid oxidation in stored meat products (Sánchez-Escalante et al. 2003; Olorunsanya et al. 2009; Sharaf et al. 2015; Cheng 2016). Similarly, the addition of chilli peppers improved redness of meat, such as pork and beef (Sánchez-Escalante et al. 2003; Cheng 2016), and improved the microbial quality of meat burg-

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ers (Sharaf et al. 2015). Hence, further investigations of this valuable, natural food additive could provide insights into antioxidant loss and opportunities to preserve healthy compounds in processed meat products.

Furthermore, with increasing concerns for food safety, in particular the use of synthetic preservatives, consumer and authorities' demands for natural alternatives to be used in the food sector are also increasing (Nikmaram et al. 2018). Therefore, natural antioxidants have a better chance of being applied over synthetic antioxidants in the meat industry due to consumer acceptability. Most deli meat products including canned meats available on the market contain synthetic antioxidants for the purpose of extending the product shelf-life; hence our intention is to replace these synthetic substances with the raw plant material as a source of natural antioxidants. For projecting a new canned meat product, we have carefully followed the trend in Poland that pork is the most commonly consumed meat in Poland (Statistics Poland 2018). Also, because chilli pepper is characterised by a high content of bioactive components, this fruit can be a valuable additive enriching canned pork. As a result, the aim of this study was to determine the effect of chilli pepper fruit on lipid oxidation, texture parameters, colour and sensory quality of canned pork.

MATERIAL AND METHODS

Material. Pork was obtained from a pig farm in the Warmia and Mazury Region (Poland), from the carcasses of PIC (Pic Improvement Company, www.pic.com) pigs, aged 5–6 months, with body weight of approximately 110 kg, 24 h after slaughter. Natural pure salt (Kujawska) was supplied by CIECH Soda Polska S.A. (Inowrocław, Poland). Chilli pepper fruits (*Capsicum annuum* L.) were imported from Spain (Andalusia) and purchased in a local discount supermarket (Lidl, Olsztyn, Poland). Sodium ascorbate was supplied by STANLAB (Lublin, Poland), and butylated hydroxytoluene (BHT) was supplied by Sigma-Aldrich (Poznań, Poland).

Sample preparation. The experimental material was semi-preserved meat (pork) prepared according to the following composition: ham (40%), hock (32%), bacon (20%), hock skin (8%), salt (1% relative to total meat weight) and water (1% relative to total weight of the meat mass). Four variants of canned pork were prepared: control (C – no additives), with ground chilli peppers (CHP – 3% relative to total weight), with sodium ascorbate (AS – 0.5 g kg^{-1}), and with butylated hydroxytoluene (BHT – 0.2 g kg^{-1}). Details regarding the sample preparation are presented in the supplementary material (see Electronic Supplementary Material – ESM).

Meat samples of 180 g each (net weight) were placed in sterilised glass jars of 235 mL in volume. Jars were then pasteurised in the Rational SCCWE-101 convection oven/steamer (Rational, Landsberg am Lech, Germany) with 100% steam saturation at 100 °C for 90 min. After pasteurisation, jars were immediately cooled in ice water (water + ice cubes) until approx. 20 °C were reached to ensure the microbiological quality of meat products and then visually inspected for tightness (PN-A-82055-4:1997+Az1:2002), and right after stored at 5 °C. Canned meat (16 meat jars per formulation per storage time) was analysed after 24 h (day 0) and after 10, 20, 30, 40 and 50 days of refrigerated storage. The experiment was conducted twice and analyses were performed in replicates.

Chemical composition. The moisture content was determined by drying samples to constant mass, protein content was determined by the Kjeldahl method, and fat content was determined by the Soxhlet method suitable for the determination of fat content in meat products. The analysis was determined in triplicate from each sample in two independent replications.

Lipid oxidation. The TBARS value of meat samples was calculated by the method described elsewhere (Draszanowska et al. 2020). The TBARS value was determined using the formula below and expressed as mg of malondialdehyde (MDA) per kg of the product:

$$\text{TBARS} = A \times K \text{ (mg MDA kg}^{-1}\text{)} \quad (1)$$

where: A – absorbance of the sample; K – conversion factor of 5.5.

TBARS values were determined in triplicate from each sample in two independent replications.

Colour parameters. Two slices (estimated thickness of 10 mm and a diameter of 65 mm) were cut out from the centre of three randomly selected jars of each canning variant. Immediately after removal from jars, the colour parameters of meat slices were measured in the Konica Minolta CR-400 spectrophotometer (Osaka, Japan) with a measurement port of 8 mm in diameter. The standardisation of the apparatus was conducted with the use of a white calibration plate CR-400 with $Y = 89.3$, $x = 0.3159$, $y = 0.3225$. The colour parameters were determined by the CIE (The International Commission on Illumination) L^*, a^* and b^* system (L^* – lightness, a^* – participation of redness, b^* – participation of yellowness) using the D65 illuminant and stan-

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dard observer 2°. The colour saturation (parameter C^*) and also the hue ($h°$ – hue angle) were calculated according to the formula:

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (2)$$

$$h° = artg\left(\frac{b^*}{a^*}\right) \quad (3)$$

where: C^* – coulour saturation; $h°$ – hue angle; a^* – redness; b^* – yellowness.

The measurements were performed at room temperature (20 ± 2 °C) at three randomly selected different points on the surface of each slice in two independent replicates.

Texture profile analysis. Cubes of 10 × 10 × 10 mm in size were cut out from three randomly selected jars of each canning variant for a texture profile analysis (TPA). The analysis was performed at room temperature (20 ± 2 °C) using the Stable Micro System TA.XT.plus texture analyser (Surrey, United Kingdom) with a 50 kg load. Every meat cube was compressed twice. The texture analyser was equipped with the P/100 compression platen and HDP/90 heavy duty platform. Texture analyses were conducted under the following conditions: pre-test speed: 5 mm s^{-1}; test speed: 5 mm s^{-1}; post-test speed: 5 mm s^{-1}; measured distance: 50% strain; time: 5 s. The results were recorded in the Texture Expert 1.22 program. Tests were performed on 14–15 cubes from each sample in two independent replicates.

Sensory evaluation. Jars were removed from the refrigerator 30 min before the sensory evaluation to bring the samples to room temperature. Bite-sized wedges with jelly were cut out from three jars of each canning variant and were randomly encoded with three digit codes. Encoded samples were presented to the panellists on identical white china plates. Water and bread were made available to the panellists during the sensory test as palate cleaners between samples. The sensory evaluation was performed in a specially designed and equipped laboratory at a temperature of around 20 °C with fluorescent lighting. The samples were evaluated by 9 trained panellists with confirmed sensory sensitivity and considerable experience in the sensory testing of meat products. The team of panellists was composed of students and employees of the Department of Human Nutrition who had been trained for three months (36 h in total). The products were rated on a grading scale with equal numeric intervals. Scores were awarded on a scale of 1 to 10 points. The following sensory attributes were evaluated: the intensity of aromas and tastes (1 – undetectable, 10 – very intense); juiciness (1 – dry, 10 – very juicy), softness (1 – hard, 10 – very soft) and overall quality (1 – poor, 10 – very high). Each sample was analysed during two sessions in two independent replicates.

Statistical analysis. The results were processed statistically in the Statistica 12.0 program (StatSoft Inc., USA) by one-way and two-way analysis of variance (ANOVA). The experiment had a completely randomised 4 × 6 × 2 factorial design. The experimental factors were four additives, six storage times and two replicates. Data on the initial characterisation of the tested additives and storage time were subjected to a two-way analysis of variance (ANOVA) after the normality and homogeneity of variance had been confirmed. Since significant interactions were found, each variable (additives and storage time) was processed by independent one-way ANOVA. When significant differences were found in ANOVA, the obtained values were evaluated by Tukey's HSD test (for equal and unequal sample sizes) at a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Proximate composition analysis. The moisture content of control samples was determined at 65.05%, and it was significantly ($P < 0.05$) higher (66.32–67.53%) in the experimental products. The highest water content was noted in canned meat containing 3% of raw chilli peppers. The protein content of the analysed samples ranged from 17.55% to 19.71% and was significantly ($P < 0.05$) lowest in canned meat containing chilli peppers on account of its higher water content. Fat content ranged from 13.30% to 14.48%. This parameter was highest in the control sample, and it was similar in the remaining products.

Lipid oxidation. The ANOVA demonstrated that the MDA content of canned meat was significantly ($P < 0.001$) influenced by the applied additives and storage time (Figure 1). Canned meat with the addition of chilli peppers (CHT) was characterised by significantly ($P < 0.05$) higher MDA content in every stage of the analysis relative to the control and products containing synthetic antioxidants (sodium ascorbate and BHT; Figure 1). A similar study was conducted by Mendiratta et al. (2013), where, in turn, the addition of 10% raw capsicum (*Shimla mirch*) grits did not affect the MDA content of mutton nuggets, which could be attributed to their lower fat content (12.97%). In contrast, Alvarez-Parrilla et al. (2014) observed lower MDA levels in refrigerated (4 °C for 16 days) chopped pork containing dry pasilla peppers than in the control.

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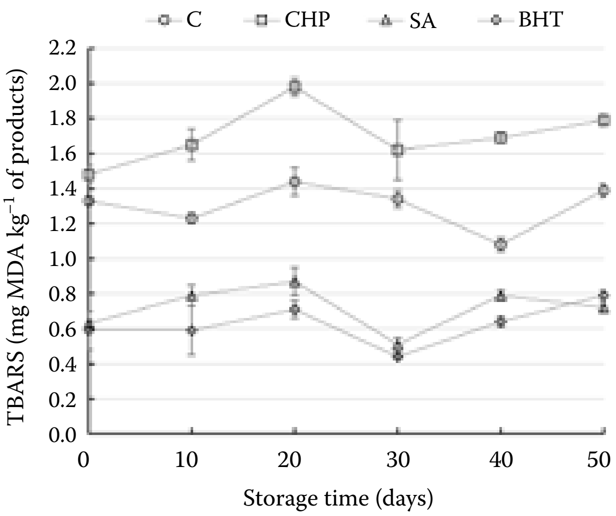

Figure 1. The effect of the interaction of formulation and storage time on lipid oxidation (TBARS) of canned meat

Samples: C – control; CHP – with chilli pepper; SA – with sodium ascorbate; BHT – with butylated hydroxytoluene

In the present study, ground chilli peppers (3%) exerted no antioxidant effects on canned pork, which could be attributed to the applied pasteurisation process. According to Amarowicz (2014) technological processes can alter the antioxidant potential of peppers. Réblová (2012) demonstrated the relationship between a decrease in the antioxidant activity of phenolic acids added to pork lard and increase in a heating temperature at the range of 90 °C to 150 °C.

A significant (P < 0.001) interaction was noted between additives and storage time vs. MDA content (Figure 1). The concentration of MDA increased until storage day 20 in all canned meat variants, but significant differences were not observed in all cases. No clear trends of change in MDA content were observed on successive days of storage in any of the evaluated samples. The decrease in the MDA content of most samples after 30 days of storage could be attributed to the fact that the reaction between MDA and protein proceeded at a faster rate than MDA formation or to the formation of secondary products of lipid oxidation that do not react with thiobarbituric acid (Karpińska-Tymoszczyk 2011). Sánchez Del Pulgar et al. (2012) reported that malondialdehyde readily interacts with other meat compounds, in particular compounds containing primary amine groups such as proteins, phospholipids, DNA and amino acids. These procedures can decrease the content of MDA and other reactive carbonyl compounds that react with TBA and, consequently, decrease TBARS values.

The verge value for lipid oxidation which, when exceeded, makes meat unacceptable for consumers is challenging to define. Zhang et al. (2020) reported that the rancid off-flavours in pork can generally be detectable to a sensory panel when the TBARS value is equal to or higher than 2 mg MDA kg^{-1} meat. Similarly, Almeida et al. (2017) stated that meat products can be considered acceptable as long as values below 3 mg of malonaldehyde kg^{-1} sample are determined. In the present study, MDA content was below 2 mg kg^{-1}, which indicates that all canned meat variants were characterised by high quality throughout the entire period of storage. According to Jayasena et al. (2013), moderate oxidative changes in meat are not entirely undesirable, and, to a certain extent, they are responsible for palatability. Unsaturated fatty acids have several oxidation products, including ketones, aldehydes, alcohols and acids, which can impart a desirable taste to meat products when present at low concentrations. In addition, air access affects lipid oxidation. Of note, less than 1 cm from the lid of the jar was filled with air and the top layer of the meat was covered with about 0.5 cm of jelly, leaving little space for air.

Colour parameters. A statistical analysis of colour parameters at the cross-section of canned meats revealed that the applied additives and storage time significantly (P < 0.001) influenced all colour parameters (L^*, a^* and b^*; Figure 2), and C^* (chroma, Figure 1SA, see ESM) and hue angle (h°, Figure S1B, see ESM). A significant (P < 0.001) interaction was also found between storage time and additives. However, concerning the redness of pork with CHP (Figure 2B), there is a higher error which could be attributed to the preparation of this particular variant where ground chilli peppers and not powder were used, making the non-uniform red colour of this product.

An analysis of lightness values (L^*) measured instrumentally in canned meats revealed lower values of L^* in CHP samples on all days of storage, but the noted differences were not always significant. Canned meat containing CHP was also characterised by a significantly (P < 0.05) higher contribution of redness (a^*) relative to the remaining products throughout the entire experiment. The addition of chilli peppers also contributed to significantly (P < 0.05) higher values of yellowness (b^*; Figure 2) and lower vividness of the colour (C^*, Figure S1A, see ESM) in comparison with the remaining samples. The hue angle significantly increased in samples with chilli peppers resulting in a shift from red to orange (Figure S1B, see ESM). These differences can be explained by the presence of carotenoids such

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as capsanthin, capsorubin and capsanthin-5,6-epoxide in chilli peppers, which are responsible for their red colour (Matsufuji et al. 1998). In a study conducted by Cheng (2016), the addition of powdered cayenne pepper (1%) to pork patties also resulted in significantly higher values of redness (*a**) and yellowness (*b**).

Texture profile analysis. The applied additives and storage time exerted a significant ($P < 0.001$) effect on the hardness ($P < 0.001$) and chewiness ($P < 0.01$) of canned meat. A significant interaction was also found between the experimental factors for hardness ($P < 0.001$; Figure 3). Canned meat with the addition of chilli peppers was characterised by lower hardness

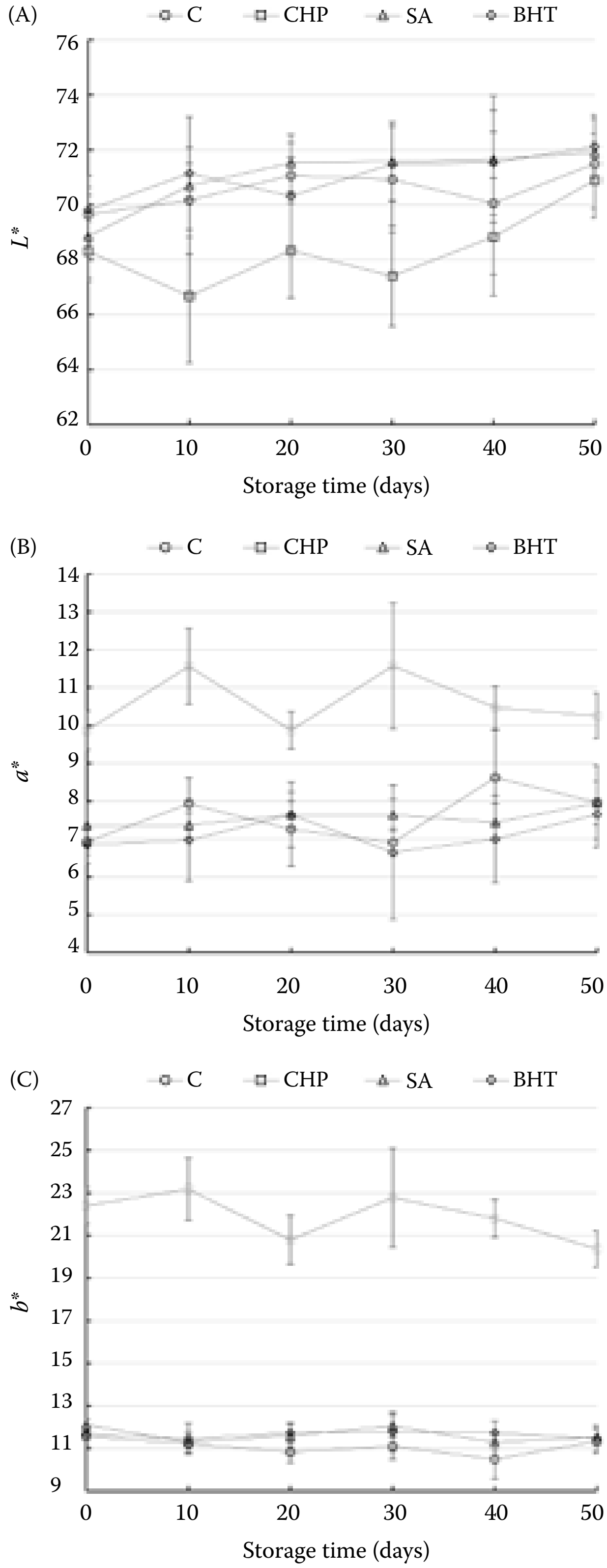

Figure 2. The effect of the formulation and storage time on the colour parameters of canned meat: (A) *L**; (B) *a**; (C) *b**

Samples: C – control; CHP – with chilli pepper; SA – with sodium ascorbate; BHT – with butylated hydroxytoluene

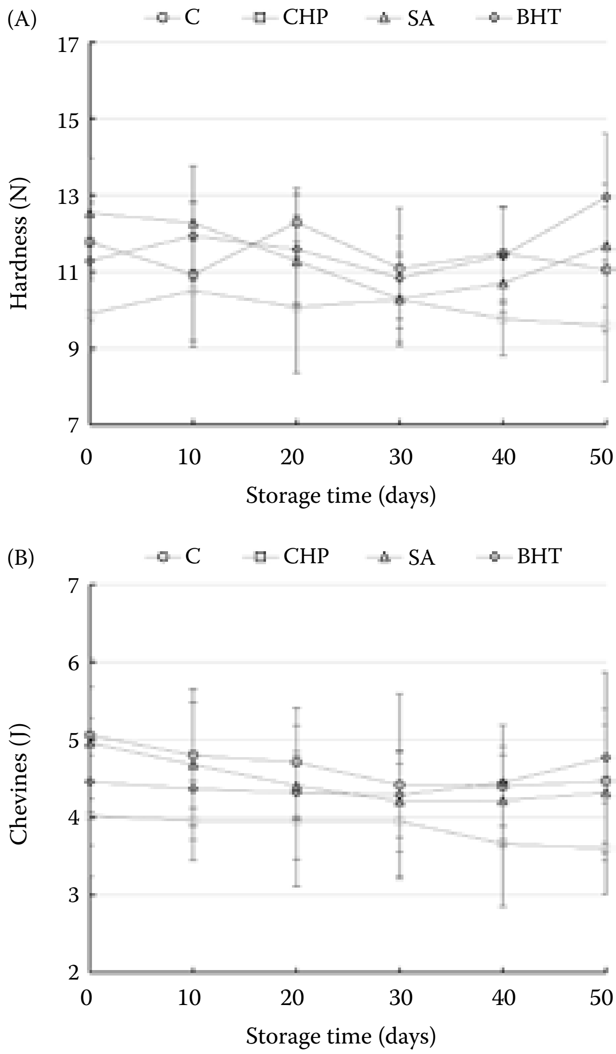

Figure 3. The effect of the formulation and storage time on the texture parameters: (A) hardness; (B) chewiness

Samples: C – control; CHP – with chilli pepper; SA – with sodium ascorbate; BHT – with butylated hydroxytoluene

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and higher chewiness than the remaining products, but the observed differences were not always significant.

No significant changes in hardness were found in control and CHP samples during storage (Figure 3A). In meat preserved with sodium ascorbate, hardness values continued to decrease until day 30, but no further decrease was observed on day 40. The evaluated parameter increased significantly ($P < 0.05$) on storage day 50. Canned meat containing BHT did not undergo any significant changes in hardness until day 40, but a significant ($P < 0.05$) increase in this parameter was noted on day 50.

No significant changes were observed in the chewiness of control, CHP and BHT samples during the experiment. The chewiness of SA samples continued to decrease until day 30 and was stabilised on successive days of storage (Figure 3B).

Sensory evaluation. The results of sensory evaluation are presented in Table S1, see ESM. The fatty aroma of CHP samples was significantly ($P < 0.05$) less intense than in control and SA samples on most analytical dates. Off-odour and off-flavour were not detected in canned meat containing CHP at any point during storage. In the remaining products, the intensity of off-odour and off-flavour was low on days 10 and 20, but it increased during prolonged storage. The intensity of off-odour and off-flavour was the highest in BHT samples.

Canned meat with chilli peppers was regarded as juicier than the remaining samples, but the noted differences were not always significant. The juiciness of CHP and SA samples did not change significantly ($P > 0.05$) during storage, but a significant ($P > 0.05$) decrease in this attribute was noted in BHT samples on day 50. In a study by Mendiratta et al. (2013), the addition of 10% raw capsicum (*Shimla mirch)* grits did not increase the juiciness of mutton nuggets. Meat containing chilli peppers received the highest scores for softness throughout the entire experiment, but the noted differences were not significant. During storage significant ($P < 0.05$) changes were noted only in the BHT sample on day 50.

The addition of chilli peppers reduced the intensity of fatty taste relative to the remaining samples, but the observed differences were not always significant. The intensity of fatty taste remained similar in control and CHP samples throughout the storage period, and it decreased significantly in SA and BHT samples on day 50.

The taste and aroma of chilli peppers were similarly noticeable in canned meat samples containing 3% of that additive throughout the entire storage period. Similar results were reported by Sharaf et al. (2015), where the intensity of chilli pepper aroma in beef burgers did not fluctuate significantly during three months of storage (–18 °C ± 2 °C), regardless of the amount of the additive (1%, 2% and 3%).

Canned meat with chilli peppers received higher scores for overall quality than the remaining products in every stage of the study, and it received significantly ($P < 0.05$) higher scores between days 20 and 50. The quality scores of CHP and SA samples remained stable throughout storage. The overall quality of control and BHT samples continued to decrease during the experiment. Our results correspond to the findings of Mendiratta et al. (2013), where the addition of 10% raw capsicum (*Shimla mirch*) grits improved the overall acceptability of cooked mutton nuggets. According to Sharaf et al. (2015), the overall quality of beef burgers was improved in samples containing 1% and 2% chilli peppers, but it decreased in products enhanced with 3% chilli peppers.

CONCLUSION

Nowadays, consumers prefer meat products containing natural additives because of concerns about the adverse effects of synthetic substances on human health. This study revealed that the addition of 3% fresh ground chilli pepper fruits to canned pork did not slow down lipid oxidation. However, the MDA content of all evaluated products did not exceed 2 mg MDA kg^{-1}, which points to the high overall quality of the tested samples. The pasteurised canned meat with chilli pepper fruits was characterised by similar or better quality than the products with synthetic additives such as BHT and sodium ascorbate. The addition of chilli peppers allowed the product to maintain a favourable red colour during storage as well as texture parameters and sensory quality were improved. Therefore, the use of such additive is a more advantageous alternative to the consumers than synthetic additives.

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