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Chokeberry (*Aronia melanocarpa*) as natural antioxidant for the meat industry

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Abstract: *Aronia melanocarpa* is one of the many fruit types rich in polyphenolic compounds. Therefore, we used this fruit in our research as a possible natural antioxidant, which was added to pork sausages. Four groups were prepared: control group, a group with ascorbic acid, and groups with 3 and 5 mL·kg^{-1} of chokeberry extract. During storage, we monitored changes in pH, colour, texture and oxidative stability of pork sausages and sensory evaluation. We did not observe any negative effects of the extract on the quality of pork sausages during storage. Regarding oxidative stability, the lowest increase in malondialdehyde (MDA) was observed in the group with 5 mL·kg^{-1} of chokeberry extract, which was comparable to the group with ascorbic acid.

Keywords: food additive; lipid oxidation; meat product; plant extract; polyphenols

The demand for meat products has grown dramatically as a result of the world population growth, which has a negative impact on both the environment and human health in addition to directly affecting the production and consumption of meat. New, healthier meat products are in demand as a result of these issues (Barone et al. 2021). Healthier meat products are reformulated either by reducing or replacing unhealthy ingredients (salt, fat) or by incorporating healthy ingredients (plant proteins, vitamins). The meat industry produces a wide range of products, all of which aim to increase the nutritional value and reduce the negative impacts of eating processed meat (Shan et al. 2017).

The production of meat products that are safer is not an easy task. That also requires maintaining the quality of the meat product. Oxidative degradation is a main factor that affects the quality of meat and meat products (Bellucci et al. 2022). Changes in colour, taste and smell are basic indicators of oxidation reactions in products that lead to rejection by consumers. Reduction in nutritional quality (losses of antioxidant vitamins, essential fatty acids, and essential amino acids) and generation of potentially dangerous substances are other significant impacts (Lorenzo et al. 2019).

The main research goal is to find new strategies that can reduce the problems resulting from oxidation

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processes. Synthetic antioxidants such as propyl gallate (PG), tert-butylhydroquinone (TBHQ), butylated hydroxyanisole (BHA), and butylated hydroxytoluene (BHT) have been employed in this context to prevent oxidation reactions (Granato et al. 2017; Lorenzo et al. 2019). However, they can constitute a potential health hazard for consumers. Therefore, one of the most important strategies for regulating and minimising lipid and protein oxidation is the use of natural antioxidants (Nikmaram et al. 2018). Berries (such as bilberries, blackberries, cranberries, and chokeberries) are among the plants that are rich sources of compounds with high antioxidant potential. These compounds contain polyphenols, which prevent the oxidation of proteins and lipids (Lorenzo et al. 2018). It has been demonstrated that adding the extracts of these fruits to meat products enhances their sensory characteristics while also raising their nutritional content and safety (Ganhão et al. 2013).

Some well-known berries, such as chokeberry – *Aronia melanocarpa*, correlated with high phenolic content, were also shown to have strong antioxidant activity. In comparison with the lingonberry, blueberry, and cranberry crops, the chokeberry exhibits notably greater anthocyanin and phenol content, and antioxidant activity (Oszmiański and Wojdylo 2005).

As known, chokeberry fruits stand out for their antioxidant potential and rich amounts of polyphenolic compounds. Therefore, the aim of the present study was to assess the possibility of adding chokeberry extract at different concentrations (3 and 5 mL·kg^{-1}) as a natural antioxidant to improve the physicochemical and sensory properties of raw-cooked meat products that were stored under vacuum at 4 °C for 21 days.

MATERIAL AND METHODS

The entire experiment was carried out in three replications. Each run of the experiment and each measurement were carried out in six replications (n). All the results are the average values from each experiment. The size of each experimental group (negative control – Con; second group – Con-C; third group – AM1; fourth group – AM2) consisted of two kilograms of meat products.

Extract preparation. The Botanic Garden of the Slovak University of Agriculture in Nitra provided the plant material – *A. melanocarpa*. It was extracted according to Shirahigue et al. (2010).

After being dried and homogenised, 20 g of Aronia fruits were put in a shaker with 100 mL of 80% ethanol, and the mixture was allowed to rest for 24 h in the dark and at room temperature. The filtrate received an addition of ethanol up to a 100 mL maximum volume. The liquid part was then evaporated at 65 °C until dry in a vacuum rotary evaporator. The weighed dry residue was dissolved in 50 mL of water. The finished extract was stored at 4 °C in the dark.

Determination of total antioxidant capacity (TAC). To determine the antioxidant capacity of the extracts, we used the free 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method according to Brand-Williams et al. (1995), which was modified by Demianová et al. (2021). Total antioxidant capacity was measured in 3.9 mL DPPH solution.

Determination of total polyphenol content (TPC). The Folin-Ciocalteu assay was used to determine the total polyphenol content according to Singleton et al. (1999), which was modified by Bobková et al. (2021). The final concentration is expressed in grams of gallic acid equivalents per kilogram of dry matter (g GAE·kg^{-1}; GAE – gallic acid equivalent).

Polyphenol quantification by high-performance liquid chromatography with a diode array detector (HPLC-DAD). The determination and quantification of polyphenols in the chokeberry extract used in our experiment were conducted according to the methodology described by Gabriele et al. (2018) using HPLC-DAD.

Frankfurter preparation. The meat product was made using the following ingredients: water, pork meat, nutmeg, black pepper, sweet and sour paprika, and a salting mixture containing 0.3% sodium nitrite. The loin and shoulder for the production of meat products were purchased from a local butcher. The composition of the frankfurters is listed in Table 1. After all of the ingredients were combined, the antioxidants were added. No antioxidant ingredient was used in the preparation of the group Con. Ascorbic acid (0.5 g.kg^{-1}) was present in the group Con-C. The amount of the *A. melanocarpa* extract was 3 mL·kg^{-1} in the group AM1 and 5 mL·kg^{-1} in the group AM2. The finished pork frankfurters were vacuum-sealed, packaged, and stored at 4 °C for 21 days after being heat-cured by wet smoking to reach a core temperature of 70 °C for 10 min at least.

pH measurement. The pH value was measured using the Orion StarTM A211 Benchtop pH meter (Thermo Fisher Scientific, USA). Using a triple-calibration solution (pH 4, 7, and 10; Hamilton AG Bonaduz, Switzerland) at 20 °C, we calibrated the pH electrode. Frankfurters were taken out of refrigerated storage and allowed to thaw to a temperature of up to 20 °C in order to measure the pH of the product, as this was the calibration temperature. The pH was measured on days 1, 7, 14, and 21.

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Table 1. Ingredients used to prepare 1 kg of meat products

Ingredients	Con	Con-C	AM1	AM2
Water (mL)	200	200	200	200
Pork meat (kg)	1	1	1	1
Black pepper (g)	2	2	2	2
Sweet paprika (g)	2	2	2	2
Sour paprika (g)	2	2	2	2
Nutmeg (g)	0.5	0.5	0.5	0.5
Salting mixture (g)	20	20	20	20
Antioxidants				
Ascorbic acid (g)	–	0.5	–	–
Aronia melanocarpa (mL)	–	–	3	–
	–	–	–	5

Con – negative control (without antioxidant); Con-C – 0.5 g·kg^{-1} (ascorbic acid); AM1 – 3 mL·kg^{-1} chokeberry extract addition; AM2 – 5 mL·kg^{-1} chokeberry extract addition; '–' – the absence of an individual ingredient

Textural analysis. The textural properties were determined using the TA.XTplus Texture Analyser (Godalming, United Kingdom) as the texture analyser instrument. Before analysis, the frankfurters were cooked to a core temperature of 70 °C. Before analysis, the materials were cut into pieces of 1 × 1 cm in size. Using the default settings for the hot-dog analysis, we selected a Warner-Bratzler probe (V-blade; Godalming, United Kingdom) from the analyser library. The toughness and firmness measurements were performed. The texture analysis was measured on days 1, 7, 14, and 21.

Colour determination. After each sample was homogenised, the colour was measured with a spectrophotometer (CM-2600d; Konica Minolta, Japan) set to the Specular Component Included (SCI; Konica Minolta, Japan). We used a D65 light source and an 8 mm-diameter port on a 10° observer. The white plate calibration was carried out at 23 °C, according to the instructions in the manual. The experiment results are shown as values in the CIELab colour interface, with L^* indicating lightness, a^* indicating redness-greenness, and b^* indicating yellowness-blueness. The colour measurements were done on days 1, 7, 14, and 21.

Determination of oxidative stability. Measurements of the malondialdehyde (MDA) content by a thiobarbiturate test using a 2-thiobarbituric acid (TBA) solution served as the basis for the oxidative stability of the raw-cooked product. In a 250 mL volumetric flask, we used 2.1623 g of TBA and 125 mL of distilled water to make this solution. The volumetric flask was placed in a water bath. The solution was heated to 90 °C until the TBA was dissolved. After cooling the solution, 15 mL of 1 mol·L^{-1} sodium hydroxide (NaOH) and 3 mL of 1 mol·L^{-1} hydrochloric acid (HCl) were added, and the mixture was then topped up with 250 mL of distilled water. We used 1.5 g of the material for the analysis. Five mL of 0.8% BHT and precisely one millilitre of ethylenediaminetetraacetic acid (EDTA) were carefully mixed into the sample. After using 8 mL of 5% trichloroacetic acid (TCA) solution, samples were homogenised for 30 s at 10 000 revolutions per minute (rpm) (IKA T 18 digital ULTRA-TURRAX®; Turrax, Germany). Then we let the samples stand for 10 min and after that the sample was centrifuged for 5 min at 3 500 g and 4 °C (Hettich Universal 320; Hettich, Germany). The highest hexane layer of the sample was removed and discarded. The remaining material was filtered into a 10 mL volumetric bank, and 5% TCA solution was added to make up the volume. The sample absorbance was then measured using a spectrometer (T80 UV/VIS; PG Instruments, United Kingdom) at a wavelength of 532 nm. The results were obtained using a calibration curve.

Sensory evaluation. After preparation, a panel of experts performed the sensory evaluation on day 7, 14, and 21. Each sample was heated before the evaluation. Five sensory parameters were evaluated: colour, consistency, odour, taste, and overall appearance. Each parameter was assigned a number between 1 and 5. The parameter with the highest score is represented by number 5, and the parameter with the lowest score is represented by number 1. The sensory panel consisted of 10 trained assessors, both males and females, ranging in age from 25 to 50 years. All assessors came from the Institute of Food Science, and all of them had experience with rating the quality of meat products.

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Statistical analysis. The results of the various analysis groups were compared using the analysis of variance (ANOVA) and Duncan's test. For each test, the significance threshold was set at 0.05. The analysis was conducted using the statistical and data analysis package XLSTAT (version 2021). All the results are the average values from each experiment.

RESULTS AND DISCUSSION

Determination of total antioxidant capacity and total polyphenol content. Two characteristics were observed to examine the properties of chokeberry extract. The TAC and TPC were measured on day 1 after the preparation. TAC results of chokeberry extract were determined as 82.1 ± 0.32% of DPPH radical inhibition. The total polyphenol content of the selected extract was 590.01 ± 1.17 g GAE·kg^{-1}.

Polyphenol quantification by high-performance liquid chromatography with a diode array detector. HPLC-DAD analysis was performed on the extract used to enhance the quality of sausages. Polyphenols, primarily proanthocyanins, anthocyanins, phenolic acids, and flavonoids, are found in black chokeberries. Table 2 shows a list of several polyphenolic compounds which were quantified.

In their study Gajic et al. (2020) detected various anthocyanin or quercetin derivatives by HPLC analysis of chokeberry extract. Gerasimov et al. (2023) conducted a study focused on polyphenolic compound detection in black chokeberry. The authors listed numerous flavonols from which we could confirm only the presence of rutin. Regarding organic acids, in our study we could not confirm the presence of any acid from the above-mentioned study, but we identified caffeic and ferulic acid. Different results obtained in our study and by the above-mentioned authors could be explained by different extraction methods.

pH measurement. All groups contain similar pH values throughout the storage period, as seen in Table 3. Additionally, no significant differences ($\alpha = 0.05$) were observed in any of the groups during the storage period; all showed only small changes. The highest pH values were shown all the time by the group Con without the addition of antioxidants. After day 1 of storage, the biggest differences between individual samples were observed. As storage progressed, the differences between individual samples decreased. A slight increase in pH in meat products after the addition of chokeberry extract had no significant effect on sensory evaluation. This manifestation can also be caused by a small addition of the extract to the products. Berry extract was used in meat products in experiments by several authors. Jurčaga et al. (2022b) added blackcurrant and Kamchatka honeysuckle extracts to raw-cooked meat products (frankfurters). Similarly in our study, the lowest values were measured in experimental groups with a higher addition of extracts. However, in their study,

Table 2. A list of phenolic compounds with retention time (min), wavelength (nm), and concentration (mg·L^{-1} ± standard deviation)

Phenolic compound	Retention time	Wavelength	Concentration
Chlorogenic acid	6.303	320	4 351.97 ± 10.44
Neochlorogenic acid	4.073	320	5 545.22 ± 11.43
Cryptochlorogenic acid	6.850	320	7 38.64 ± 3.28
Caffeic acid	7.750	320	22.32 ± 0.60
Ferulic acid	12.493	320	49.23 ± 0.23
Rutin	12.493	372	281.20 ± 0.70

Table 3. pH values of meat products measured during storage

Group	1st day	7th day	14th day	21st day
Con	6.31 ± 0.012^{a}	6.43 ± 0.021^{a}	6.53 ± 0.062^{a}	6.54 ± 0.060^{a}
Con-C	6.23 ± 0.060^{b}	6.35 ± 0.044^{b}	6.44 ± 0.021^{b}	6.41 ± 0.015^{b}
AM1	6.24 ± 0.032^{b}	6.37 ± 0.012^{b}	6.46 ± 0.015^{b}	6.39 ± 0.010^{b}
AM2	6.17 ± 0.010^{c}	6.33 ± 0.012^{b}	6.43 ± 0.031^{b}	6.40 ± 0.010^{b}

$^{a–c}$ Means followed by different letters represent statistically significant differences between samples in the column; Con – negative control (without antioxidant); Con-C – 0.5 g·kg^{-1} (ascorbic acid); AM1 – 3 mL·kg^{-1} chokeberry extract addition; AM2 – 5 mL·kg^{-1} chokeberry extract addition

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the lowest values were measured in the control group with the addition of ascorbic acid. Belluci et al. (2022) used açaí extract in pork patties. Compared to our results, pork patties with the addition of açaí extract showed significantly lower values.

Textural analysis. Before measurement, all samples were cut into pieces of 1 × 1 cm in size. There is no accepted scientific meaning for the descriptive word 'firmness'. Statistically significant differences in the firmness parameter were observed only after the 1st day of storage. The addition of chokeberry extract did not affect the observed firmness in any way. The force required to cut through a sample piece in its whole over time is referred to as toughness. According to the statistical analysis, no significant differences were observed between the samples, but Table 4 shows visible changes after 14 days of storage between the control group and the experimental groups and after 21 days of storage between the control group and the AM1 group.

Colour analysis. In all groups, we recorded relatively stable results during the entire storage period. We can most likely thank the vacuum packaging for preserving this parameter. The pigments did not come into contact with oxygen in the air, and therefore, they did not deteriorate. Our research demonstrated that the *A. melanocarpa* extract did not negatively affect the product's colour as seen in Table 5. As we mentioned earlier in the text, this phenomenon can also be caused by vacuum packaging or by the selected amount of extract. Similar conclusions were drawn by Jurčaga et al. (2022a), who added the Amelanchier extract to pork sausages. During the entire storage period, they observed only minimum deviations in all components of the colour. The same conclusion was drawn by Bellucci et al. (2022), who did not observe any significant colour changes after adding acai extract. Kowalczyk et al. (2023) added chokeberry leaf extract into raw burgers. The addition changed the raw burger colour in general, with significant changes observed in the a^* and b^* values. The hamburgers with the lowest amount of extract (0.01%) had the highest a^* and b^* values, which were statistically significant ($P < 0.05$). These values were more than 25% higher than the control burgers.

Determination of oxidative stability. Lipid oxidation is the reaction that progresses with oxidative stress depending on the amount of unsaturated fatty acids. These reactions are responsible for off-flavour, discolouration, loss of nutritional value, and decreased shelf life of meat products (Cao et al. 2020; Xiong et al. 2020). The results are expressed as mg of MDA per kilogram of the finished product. After a week of storage, we recorded the highest MDA value in the control group and the lowest in the experimental group AM2. No statistically significant differences were observed between individual samples. After 14 days of storage, the control group observed the highest increase. A statistically significant difference was noted between the control group and the other experimental groups, which showed significantly lower values than the control group. After 21 days of storage, as expected, the highest value was measured in the control group without the addition of antioxidants. We also measured an increased value in the experimental group AM1 (with a lower addition of extract) compared to the control with the addition of ascorbic acid and in the experimental group AM2, where the lowest value of MDA was meas-

Table 4. Values of firmness (g ± standard deviation) and toughness (g·s^{-1} ± standard deviation)

Sample	1st day	7th day	14th day	21st day
Firmness				
Con	393.18 ± 14.83^{b}	356.1 ± 36.05^{a}	479.04 ± 117.10^{a}	524.28 ± 55.12^{a}
Con-C	347.35 ± 38.35^{c}	410.03 ± 76.24^{a}	381.59± 45.50^{a}	439.89 ± 91.88^{a}
AM1	341.35 ± 16.47^{bc}	324.05 ± 55.28^{a}	506.87 ± 70.73^{a}	464.67 ± 109.52^{a}
AM2	453.53 ± 28.98^{a}	389.71 ± 26.59^{a}	549,53 ± 14.76^{a}	512.41 ± 68.451^{a}
Toughness				
Con	2 671.41 ± 168.88^{a}	2 144.03 ± 116.26^{a}	3 326.26 ± 266.00^{a}	3 500.2 ± 122.96^{a}
Con-C	2 308.35 ± 105.25^{a}	2 831.80 ± 676.70^{a}	2 690.89 ± 587.43^{a}	3 084.84 ± 247.13^{a}
AM1	2345.48 ± 75.69^{a}	2 145.34 ± 393.94^{a}	2811.83 ± 72.50^{a}	2 709.31 ± 529.96^{a}
AM2	2 888.49 ± 100.68^{a}	2 661.57 ± 166.25^{a}	2 814.21 ± 81.2^{a}	3 531.82 ± 243.16^{a}

$^{a–c}$ Means followed by different letters represent statistically significant differences between samples in the column; Con – negative control (without antioxidant); Con-C – 0.5 g·kg^{-1} (ascorbic acid); AM1 – 3 mL·kg^{-1} chokeberry extract addition; AM2 – 5 mL·kg^{-1} chokeberry extract addition

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Table 5. Determination of meat product colour

Storage day	Parameters	Group				*P*-value
		Con	Con-C	AM1	AM2	
1st day	*L** (D65)	65.96 ± 1.224^{b}	67.85 ± 0.907^{a}	65.86 ± 0.900^{b}	66.93 ± 1.381^{b}	0.001
	*a** (D65)	12.44 ± 0.706^{a}	12.99 ± 0.367^{a}	12.94 ± 0.793^{a}	12.90 ± 0.813^{a}	0.331
	*b** (D65)	19.38 ± 0.896^{a}	19.49 ± 0.325^{a}	19.25 ± 0.838^{a}	19.44 ± 0.690^{a}	0.747
7th day	*L** (D65)	66.73 ± 0.562^{a}	67.44 ± 0.701^{a}	66.57 ± 1.619^{a}	67.02 ± 1.229^{a}	0.278
	*a** (D65)	12.62 ± 0.481^{b}	13.29 ± 0.496^{a}	12.90 ± 0.488^{b}	13.15 ± 0.609^{a}	< 0.0001
	*b** (D65)	19.72 ± 0.504^{c}	19.83 ± 0.756^{bc}	20.39 ± 0.700^{ab}	20.30 ± 0.582^{a}	0.022
14th day	*L** (D65)	65.93 ± 2.848^{a}	66.68 ± 0.935^{a}	66.77 ± 1.104^{a}	67.08 ± 1.351^{a}	0.735
	*a** (D65)	12.95 ± 0.698^{a}	12.89 ± 0.570^{a}	12.11 ± 0.762^{b}	13.04 ± 0.566^{a}	< 0.0001
	*b** (D65)	18.98 ± 0.762^{a}	19.19 ± 0.441^{a}	18.94 ± 0.914^{a}	19.16 ± 1.277^{a}	0.734
21st day	*L** (D65)	66.14 ± 1.378^{a}	66.44 ± 0.923^{a}	66.93 ± 1.062^{a}	66.78 ± 0.867^{a}	0.001
	*a** (D65)	11.89 ± 0.320^{b}	12.75 ± 0.651^{a}	11.68 ± 0.664^{b}	12.20 ± 0.564^{b}	< 0.0001
	*b** (D65)	18.82 ± 0.512^{b}	19.21 ± 0.677^{ab}	19.23 ± 0.694^{ab}	19.87 ± 0.576^{a}	0.000

$^{a–c}$ Means followed by different letters represent statistically significant differences between samples in the column; Con – negative control (without antioxidant); Con-C – 0.5 g·kg^{-1} (ascorbic acid); AM1 – 3 mL·kg^{-1} chokeberry extract addition; AM2 – 5 mL·kg^{-1} chokeberry extract addition; *L** – lightness; *a** – redness-greenness; *b** – yellowness-blueness

ured. The highest percentage increase by up to 65% in the concentration of malondialdehyde was recorded in the negative control (group Con). Of the experimental groups, the highest increase of 44% was recorded in the group with 3 mL of chokeberry extract (AM1). The group with ascorbic acid (Con-C) and the experimental group with 5 mL·kg^{-1} of chokeberry addition (AM2) achieved a comparable increase of 40% and 38%, respectively. All results are shown in Table 6. Kowalczyk et al. (2023) reported in their study that the chokeberry leaf extract at concentrations of 0.05% and 0.1% could inhibit lipid oxidation by approximately 11% and 27%, respectively. Tamkuté et al. (2021) also confirmed that the addition of chokeberry extract effectively inhibited the production of malondialdehyde in pork meat products. Similar outcomes were observed by Turgut et al. (2017) for meatballs that were preserved with pomegranate extract. According to Hazra et al. (2012), adding *Moringa oleifera* extract decreased the lipid oxidation of cooked buffalo meat by more than 30%.

Sensory evaluation. The sensory quality of the product is definitely the most significant factor in determining customer satisfaction. Quality markers such as taste and odour cannot be affected by any experimental addition. Our goal was to monitor changes in the selected parameters during storage time. After seven days, we did not observe any statistically significant difference between the groups (α = 0.05). However, in the colour parameter, the control group achieved the lowest score of 3.6 ± 1.34 points on average. On the other hand, an experimental group AM1 achieved the best scores in the colour parameter. This experimental group AM1, achieved the overall best score, and the control group

Table 6. Values of malondialdehyde in meat products

Sample	1st day	7th day	14th day	21st day
Con	0.163 ± 0.006^{a}	0.199 ± 0.016^{a}	0.240 ± 0.009^{a}	0.269 ± 0.013^{a}
Con-C	0.161 ± 0.009^{a}	0.181 ± 0.005^{a}	0.203 ± 0.012^{b}	0.225 ± 0.022^{ab}
AM1	0.161 ± 0.010^{a}	0.184 ± 0.014^{a}	0.208 ± 0.011^{b}	0.232 ± 0.019^{b}
AM2	0.157 ± 0.005^{a}	0.183 ± 0.011^{a}	0.197 ± 0.010^{b}	0.217 ± 0.011^{b}
P-value	0.873	0.469	0.016	0.057

$^{a, b}$ Means followed by different letters represent statistically significant differences between samples in the column; Con – negative control (without antioxidant); Con-C – 0.5 g·kg^{-1} (ascorbic acid) AM1; – 3 mL·kg^{-1} chokeberry extract addition; AM2 – 5 mL·kg^{-1} chokeberry extract addition

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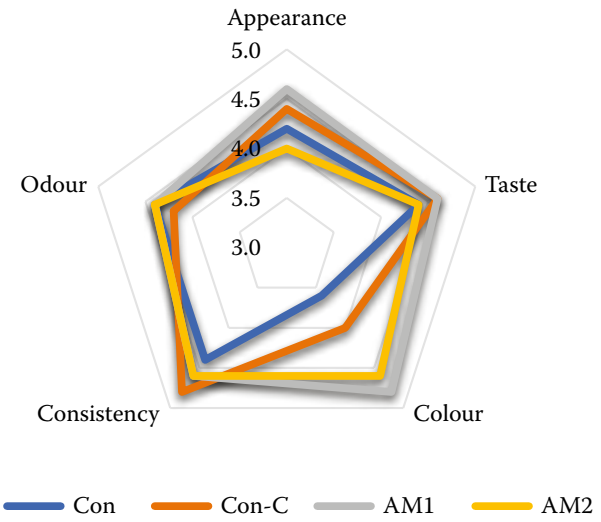

Figure 1. Visualisation of sensory evaluation after day 7

Con – negative control (without antioxidant); Con-C – 0.5 g·kg^{-1} (ascorbic acid); AM1 – 3 mL·kg^{-1} chokeberry extract addition; AM2 – 5 mL·kg^{-1} chokeberry extract addition

achieved the overall worst score (Figure 1). After fourteen days, we observed a decrease in the control group score in all the parameters (overall worst score). The control group, with the addition of ascorbic acid, achieved the overall best score. At the end of the storage period, the best evaluated sample was from the experimental group with a higher addition of chokeberry extract (AM2). A graphical representation can be seen in Figure 2. According to Sayas-Barberá et al. (2020),

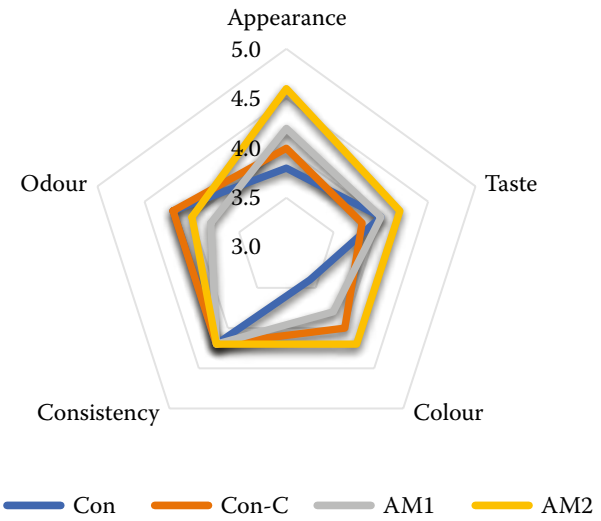

Figure 2. Visualisation of sensory evaluation after day 21

Con – negative control (without antioxidant); Con-C – 0.5 g·kg^{-1} (ascorbic acid); AM1 – 3 mL·kg^{-1} chokeberry extract addition; AM2 – 5 mL·kg^{-1} chokeberry extract addition

adding powdered date pits stabilised the colour of beef burgers and decreased the amount of off-odours. The results of Hazra et al. (2012) showed a comparable effect when *M. oleifera* leaf extract was added to cooked buffalo meat at concentrations of 1, 1.5, and 2%. The meat was given significantly higher evaluations for colour, flavour, softness, and overall quality. It has also been demonstrated that adding mulberry (*Morus alba*) polyphenols at concentrations of 2% and 4% improves the sensory qualities and general acceptability of dry minced pork slices (Xu et al. 2018).

CONCLUSION

Our experiment proved that the chokeberry extract has comparable positive effects on pork sausages if compared with the addition of ascorbic acid. We did not observe any negative effects in any measured parameter during storage. In terms of oxidative stability, we observed the best results in the experimental group by adding 5 mL·kg^{-1} of extract (AM2); similar results were also recorded in the sensory evaluation. From our findings, we can say that chokeberry extract has great potential for future use as a natural antioxidant in the meat industry. However, further experiments are still needed.

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