

## Sensory properties of pork sausage after sea buckthorn extract addition

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**Abstract:** The meat industry is actively trying to replace synthetic antioxidants with natural counterparts. Sea buckthorn is an excellent source of polyphenols and its high antioxidant properties. Various authors tested the antioxidation effect of sea buckthorn on lipids in meat products. The problem of sea buckthorn addition to food is its effect on sensory parameters. Our study incorporated sea buckthorn extract into pork sausage, stored for 21 days, and observed sensory properties and their changes. We mechanically measured the pH, colour, and textural properties of pork sausage samples with minimal variability observed. Also, sensory analysis by informed panellists was conducted on multiple storage days. Sensory evaluation revealed significant deterioration of sensory quality. Sea buckthorn remains an interesting option for the meat industry. However, further multidisciplinary research is still needed.

**Keywords:** meat product; sensory quality; oxidation; natural antioxidant

Oxidation reduces the quality and acceptability of meat products by affecting qualities such as taste, colour, texture, and nutritional content (Soladoye et al. 2015). Antioxidants are extensively used in meat products to prevent oxidation and preserve sensory properties. Commonly used ascorbic acid, butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), nitrites, and nitrates have all been linked to the aetiology of stomach, bowel, and food allergy (Ribeiro et al. 2019). The current public awareness of the potential health consequences of long-term use of synthetic antioxidants (allergic reactions, problems in pregnant women and children, probable carcinogenic action

etc.) (Kumari et al. 2019) has fuelled consumer-driven requests for the usage of natural antioxidants. Although the allowed content of synthetic antioxidants in the lipidic fraction is low (0.02% w/w), and they are thus safe for consumers when used in accordance with the relevant regulations. The meat industry has been motivated to exploit plant-derived additives in meat systems with the goal of replacing synthetic antioxidants (Shah et al. 2014).

Numerous *in vitro* studies have demonstrated the positive effects of natural antioxidants on lipid and protein oxidation, the prolongation of shelf-life, the antioxidant profiles of functionalized meat products,

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and the related potential health benefits. Additionally, the analysis of the antioxidant profiles, the course of action of plant-derived food additives, and the investigation of perspectives for applications in the meat industry have made significant progress (Mannessis et al. 2020).

The genus *Hippophae*, commonly known as sea buckthorn (SB), produces berries that are high in antioxidants such as flavonoids, carotenoids, and 5-hydroxytryptophan (Kang et al. 2009) and has been dubbed the 'king of vitamin C'. These antioxidants in sea buckthorn have been shown to reduce the risk of certain malignancies, atherosclerosis, cardiovascular disease, and aging (Krejcarová et al. 2015; He et al. 2017). Furthermore, various authors have proven strong antioxidative abilities when incorporated into multiple meat products (Püssa et al. 2008; Kozhakhieva et al. 2018; Mäkinen et al. 2020). Nevertheless, in sensory quality terms, SB has a well-defined sour and astringent taste, making the formulation of food products with SB quite challenging (Vilas-Franquesa et al. 2020).

Our study incorporated sea buckthorn extract with confirmed antioxidant properties into pork sausage. As mentioned above, sea buckthorn is well known for its distinctive sour or bitter flavour. We aimed to observe the effect of natural sea buckthorn extract on the sensory parameters of pork sausage measured mechanically and evaluated by sensory panels.

## MATERIAL AND METHODS

Sea buckthorn var. Vitaminnaja berries were obtained from Botanical Garden of Slovak University of Agriculture in Nitra. The extract itself was prepared according to previous study of Jurčaga et al. (2022).

**Pork sausage preparation.** Pork meat, shoulder, and loin, used in sausage preparation, were purchased in a local butcher shop. For the 1 000 g of the final product, the following ingredients were used: pork meat (930 g); water (200 g), salt mixture (20 g), black pepper (2 g), paprika sweet (2 g), paprika spicy (2 g), nutmeg (0.5 g). Antioxidant addition into sausage groups was as follows: Control\_0 – group without added antioxidant; Control\_C – ascorbic acid addition 0.5 g·kg<sup>-1</sup>; Buckthorn\_3 – sea buckthorn extract addition 3 mL·kg<sup>-1</sup>; Buckthorn\_5 – sea buckthorn extract addition 5 mL·kg<sup>-1</sup>.

**pH measurement.** A piercing probe tabletop pH meter (Orion StarTM A211, Beijing, China) was used to determine the pH of the finished products. Calibration solutions (Hamilton AG Bonaduz, Bonaduz,

Switzerland, with pH values of 4, 7, and 10) were used to calibrate the pH measuring machine. Sausage samples were removed from the fridge and allowed to come to room temperature before pH was measured.

**Colour measurement.** The present study used the colorimeter (CR 400, Minolta, Tokyo, Japan) to determine the sample colour. The white plate calibration was performed according to the colorimeter manual. Three colour parameters were measured: lightness ( $L^*$ ), redness ( $a^*$ ), and yellowness ( $b^*$ ). Another two parameters were calculated: chroma [ $C^* = \sqrt{(a^{*2} + b^{*2})}$ ] and hue angle ( $h^\circ = \tan^{-1}(b^*/a^*)$ ). In our measurement, we used option SCI (Specular Component Included) as suggested by Poláková et al. (2023).

**Textural analysis.** To investigate potential textural properties changes in the experimental sausages, a mechanical texture analysis (TA.XTplus Texture Analyser, Godalming, UK) with pre-set parameters selected from the machine library. Using the default settings for the hot-dog analysis, we selected a Warner–Bratzler probe (V-blade) from the analyser library. Before the analysis, all samples were heated and cut into blocks with a 1 × 1 cm base. This step would ensure uniformity of samples to provide relevant and comparable results (Table 1).

**Sensory evaluation.** Sensory evaluation was performed on the 7<sup>th</sup>, 14<sup>th</sup>, and 21<sup>st</sup> day of storage. During the evaluation, a five-point scale was used, and five parameters were observed according to legislation in force: colour, aroma, taste, consistency, and appear-

Table 1. Textural analysis settings

| Product     | Hot dogs                                                   |                              |
|-------------|------------------------------------------------------------|------------------------------|
| Objective   | cutting force of hot dogs using Warner–Bratzler blade      |                              |
| TA settings | option                                                     | measure force in compression |
|             | mode                                                       | return to start              |
|             | pre-test speed                                             | 2.0 mm·s <sup>-1</sup>       |
|             | test speed                                                 | 2.0 mm·s <sup>-1</sup>       |
|             | post-test speed                                            | 10.0 mm·s <sup>-1</sup>      |
|             | distance                                                   | 30 mm                        |
|             | trigger type                                               | auto – 20 g                  |
|             | tare mode                                                  | auto                         |
|             | data acquisition rate                                      | 200 pps                      |
|             | blade set (HDP/BS) (Warner–Bratzler) using 25 kg load cell |                              |
| Accessory   | heavy duty platform (HDP/90)                               |                              |

TA – textural analysis; HDP – heavy duty platform; BS – blade set

ance on a surface (Decree of the Ministry of Agriculture and Rural Development of the Slovak Republic No. 83/2016 Coll. on meat products). The sensory panel consisted of 8 trained evaluators of both genders (4 men and 4 women) with prior experience in evaluating meat products, aged from 25 to 55. All panel members were non-smokers.

**Statistical analysis.** The analysis was conducted using the statistical and data analysis package XLSTAT (Addinsoft, 2021, New York, USA). Results of the various analysis groups were compared using an ANOVA analysis and a Duncan test. For every test, the significance threshold was set at 0.05.

## RESULTS AND DISCUSSION

**pH of meat product.** We observed the pH values of pork sausages for a storage period of 21 days. Measurement was carried out on the 1<sup>st</sup>, 7<sup>th</sup>, 14<sup>th</sup>, and 21<sup>st</sup> day. When compared, we did not observe any significant ( $P \leq 0.05$ ) difference among all sample groups on any measurement day. Regarding pH development in time, we did notice a significant increase in the pH value of the Control\_C group after the first day of storage. After that, the pH values of this group were stable and without significant changes. Also, during storage, we observed fluctuation of pH values of Buckthorn\_5 sausage samples. All results of pH measurement are listed in Table 2. In contrast with our findings, Salejda et al. (2014) observed a pH decrease of pork sausages with sea buckthorn addition. The authors also pointed out that the final product pH decreased with increasing sea buckthorn extract addition. Mesárošová et al. (2024) added chokeberry extract into pork sausages. In their study, the authors observed an increase in pH values in all groups, with the highest values measured in the experimental group without added antioxidants.

**Colour of meat product.** During our experiment, we measured three parameters in the CieLab colour

spectrum – lightness, redness, and yellowness. Furthermore, another two parameters were calculated – chroma and hue angle. Measurement was carried out on the 1<sup>st</sup>, 7<sup>th</sup>, 14<sup>th</sup> and 21<sup>st</sup> day. Among all groups, no significant ( $P \leq 0.05$ ) difference was observed on any day in any parameter. The results of mechanical colour determination are presented in Table 3. Authors Kozhakhieva et al. (2018) reported significant colour changes in horse meat samples treated with sea buckthorn powder extract compared to control without this addition. Authors Bobko et al. (2019) stated that the lightness ( $L^*$ ) parameter in raw cooked meat products was affected by the addition of sea buckthorn. Using the experimental preparation with the addition of 100% bio juice reduced the lightness, but not significantly ( $P > 0.05$ ).

The addition of sea buckthorn extract had a significant effect ( $P \leq 0.05$ ) on the colour parameters of sausages as expressed by parameters in the CieLab system. The 3% addition of extract to the sausage recipe resulted in a significant ( $P \leq 0.05$ ) decrease in lightness ( $L^*$ ) and an increase in redness ( $a^*$ ). This impact was also detected in samples stored in the refrigerator for 28 days (Salejda et al. 2017). Like other authors, we observed a slight darkening of meat products. Nevertheless, in contrast to other studies, the changes observed in our study were insignificant.

**Textural properties of meat product.** Textural parameters observed during the conducted experiment were firmness and toughness. Both parameters showed steady and even results during the whole duration of storage in all analysed sample groups. Likewise, no significant differences among all groups were observed on any measurement day. The results of both textural parameters measurements are listed in Table 4. Salejda et al. (2014) measured various textural parameters of pork sausages with sea buckthorn addition, such as hardness, cohesiveness, springiness, gumminess, and chewiness. Authors reported a decrease in hardness, springiness, and chewiness of experimental pork sausages compared

Table 2. pH values of pork sausage during storage

| Sample      | Day 1                      | Day 7                     | Day 14                    | Day 21                     |
|-------------|----------------------------|---------------------------|---------------------------|----------------------------|
| Control_0   | 6.56 ± 0.04 <sup>aA</sup>  | 6.53 ± 0.06 <sup>aA</sup> | 6.54 ± 0.05 <sup>aA</sup> | 6.49 ± 0.04 <sup>bA</sup>  |
| Control_C   | 6.44 ± 0.03 <sup>aB</sup>  | 6.51 ± 0.03 <sup>aA</sup> | 6.50 ± 0.01 <sup>aA</sup> | 6.49 ± 0.01 <sup>bA</sup>  |
| Buckthorn_3 | 6.57 ± 0.03 <sup>aA</sup>  | 6.59 ± 0.03 <sup>aA</sup> | 6.57 ± 0.01 <sup>aA</sup> | 6.57 ± 0.02 <sup>aA</sup>  |
| Buckthorn_5 | 6.55 ± 0.04 <sup>aAB</sup> | 6.58 ± 0.01 <sup>aA</sup> | 6.52 ± 0.03 <sup>aB</sup> | 6.56 ± 0.01 <sup>aAB</sup> |

<sup>a, b</sup> groups within a column with different superscripts differ significantly at  $P \leq 0.05$ , one-way ANOVA; <sup>A, B</sup> groups within a row with different superscripts differ significantly at  $P \leq 0.05$ , one-way ANOVA; Control\_0 – group without added antioxidant; Control\_C – ascorbic acid addition 0.5 g·kg<sup>-1</sup>; Buckthorn\_3 – sea buckthorn extract addition 3 mL·kg<sup>-1</sup>; Buckthorn\_5 – sea buckthorn extract addition 5 mL·kg<sup>-1</sup>

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Table 3. Results of colour measurement of pork sausage samples during storage

| Sample        | $L^*$ (D65)        | $a^*$ (D65)        | $b^*$ (D65)        | $C^*$              | $h^\circ$          |
|---------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| <b>Day 1</b>  |                    |                    |                    |                    |                    |
| Control_0     | $68.70 \pm 1.05^a$ | $13.18 \pm 0.45^a$ | $20.21 \pm 0.81^a$ | $24.13 \pm 0.87^a$ | $56.86 \pm 0.74^a$ |
| Control_C     | $67.38 \pm 0.44^a$ | $13.41 \pm 0.25^a$ | $19.90 \pm 0.23^a$ | $23.99 \pm 0.33^a$ | $56.03 \pm 0.24^a$ |
| Buckthorn_3   | $67.91 \pm 0.61^a$ | $13.25 \pm 0.48^a$ | $20.40 \pm 0.62^a$ | $24.33 \pm 0.78^a$ | $57.00 \pm 0.17^a$ |
| Buckthorn_5   | $68.50 \pm 0.30^a$ | $12.81 \pm 0.19^a$ | $19.73 \pm 0.42^a$ | $23.53 \pm 0.25^a$ | $57.00 \pm 0.93^a$ |
| <b>Day 7</b>  |                    |                    |                    |                    |                    |
| Control_0     | $67.94 \pm 1.01^a$ | $13.60 \pm 0.89^a$ | $19.73 \pm 1.12^a$ | $23.96 \pm 1.38^a$ | $55.43 \pm 0.89^a$ |
| Control_C     | $67.87 \pm 0.74^a$ | $12.86 \pm 0.46^a$ | $19.01 \pm 0.44^a$ | $22.95 \pm 0.53^a$ | $55.91 \pm 0.87^a$ |
| Buckthorn_3   | $66.59 \pm 0.78^a$ | $13.03 \pm 0.31^a$ | $19.98 \pm 0.49^a$ | $23.85 \pm 0.57^a$ | $56.88 \pm 0.36^a$ |
| Buckthorn_5   | $68.02 \pm 1.54^a$ | $12.65 \pm 0.71^a$ | $19.32 \pm 1.32^a$ | $23.10 \pm 1.48^a$ | $56.80 \pm 0.50^a$ |
| <b>Day 14</b> |                    |                    |                    |                    |                    |
| Control_0     | $67.98 \pm 0.37^a$ | $12.85 \pm 0.63^a$ | $19.92 \pm 0.55^a$ | $23.71 \pm 0.81^a$ | $57.18 \pm 0.55^a$ |
| Control_C     | $67.86 \pm 1.52^a$ | $12.82 \pm 0.33^a$ | $20.18 \pm 0.83^a$ | $23.91 \pm 0.75^a$ | $57.54 \pm 1.17^a$ |
| Buckthorn_3   | $70.39 \pm 3.69^a$ | $12.55 \pm 0.56^a$ | $20.11 \pm 0.51^a$ | $23.72 \pm 0.34^a$ | $58.04 \pm 1.64^a$ |
| Buckthorn_5   | $67.61 \pm 0.20^a$ | $12.56 \pm 0.32^a$ | $19.53 \pm 0.63^a$ | $23.22 \pm 0.69^a$ | $57.26 \pm 0.34^a$ |
| <b>Day 21</b> |                    |                    |                    |                    |                    |
| Control_0     | $68.51 \pm 0.66^a$ | $12.52 \pm 0.18^a$ | $19.47 \pm 0.51^a$ | $23.15 \pm 0.47^a$ | $57.25 \pm 0.63^a$ |
| Control_C     | $68.87 \pm 0.36^a$ | $13.16 \pm 0.13^a$ | $19.36 \pm 0.48^a$ | $23.41 \pm 0.33^a$ | $55.78 \pm 0.92^a$ |
| Buckthorn_3   | $67.71 \pm 1.37^a$ | $12.75 \pm 0.42^a$ | $18.84 \pm 0.11^a$ | $22.75 \pm 1.16^a$ | $55.89 \pm 0.72^a$ |
| Buckthorn_5   | $68.71 \pm 0.60^a$ | $12.36 \pm 0.58^a$ | $19.25 \pm 1.08^a$ | $22.88 \pm 1.08^a$ | $57.29 \pm 0.40^a$ |

<sup>a</sup> groups within a column with different superscripts differ significantly at  $P \leq 0.05$ , one-way ANOVA; Control\_0 – group without added antioxidant; Control\_C – ascorbic acid addition  $0.5 \text{ g}\cdot\text{kg}^{-1}$ ; Buckthorn\_3 – sea buckthorn extract addition  $3 \text{ mL}\cdot\text{kg}^{-1}$ ; Buckthorn\_5 – sea buckthorn extract addition  $5 \text{ mL}\cdot\text{kg}^{-1}$ ; D65 – standard illuminant representing daylight ( $\approx 6500 \text{ K}$ )

Table 4. Results of texture analysis of pork sausage samples during storage

| Sample           | Day 1                       | Day 7                       | Day 14                      | Day 21                      |
|------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| <b>Firmness</b>  |                             |                             |                             |                             |
| Control_0        | $371.77 \pm 80.28^{aA}$     | $396.57 \pm 50.33^{aA}$     | $399.54 \pm 26.69^{aA}$     | $400.60 \pm 33.58^{aA}$     |
| Control_C        | $369.05 \pm 19.67^{aA}$     | $394.52 \pm 30.47^{aA}$     | $392.30 \pm 57.40^{aA}$     | $407.99 \pm 30.30^{aA}$     |
| Buckthorn_3      | $381.08 \pm 51.03^{aA}$     | $396.80 \pm 20.39^{aA}$     | $391.23 \pm 22.75^{aA}$     | $403.17 \pm 38.06^{aA}$     |
| Buckthorn_5      | $380.22 \pm 29.38^{aA}$     | $387.68 \pm 17.39^{aA}$     | $397.75 \pm 10.35^{aA}$     | $398.10 \pm 20.66^{aA}$     |
| <b>Toughness</b> |                             |                             |                             |                             |
| Control_0        | $2\ 354.91 \pm 246.35^{aA}$ | $2\ 248.15 \pm 588.97^{aA}$ | $2\ 336.82 \pm 349.99^{aA}$ | $2\ 441.32 \pm 290.32^{aA}$ |
| Control_C        | $2\ 467.36 \pm 294.95^{aA}$ | $2\ 211.38 \pm 715.46^{aA}$ | $2\ 363.35 \pm 221.42^{aA}$ | $2\ 567.29 \pm 112.78^{aA}$ |
| Buckthorn_3      | $2\ 342.30 \pm 201.19^{aA}$ | $2\ 346.98 \pm 373.26^{aA}$ | $2\ 366.54 \pm 60.62^{aA}$  | $2\ 564.26 \pm 562.97^{aA}$ |
| Buckthorn_5      | $2\ 449.86 \pm 447.07^{aA}$ | $2\ 463.56 \pm 433.84^{aA}$ | $2\ 395.35 \pm 132.16^{aA}$ | $2\ 373.91 \pm 388.50^{aA}$ |

<sup>a</sup> groups within a column with different superscripts differ significantly at  $P \leq 0.05$ , one-way ANOVA; <sup>A</sup> groups within a row with different superscripts differ significantly at  $P \leq 0.05$ , one-way ANOVA; Control\_0 – group without added antioxidant; Control\_C – ascorbic acid addition  $0.5 \text{ g}\cdot\text{kg}^{-1}$ ; Buckthorn\_3 – sea buckthorn extract addition  $3 \text{ mL}\cdot\text{kg}^{-1}$ ; Buckthorn\_5 – sea buckthorn extract addition  $5 \text{ mL}\cdot\text{kg}^{-1}$

to negative control at the end of the 28 day storage period. Kumar et al. (2015) incorporated sea buckthorn extract into pork patties. The authors reported that hardness and cohesiveness increased in treated samples compared to negative control samples. Also, authors Choi et al. (2010) reported increased hardness of pork patties after extract treatment. In our study, we could not confirm significant changes in textural parameters of experimental sausage samples as various abovementioned authors. Different types of meat products can explain opposing results, as same as the different extract preparation methods or various sea buckthorn varieties used.

**Sensory analysis of meat product.** Sensory analysis of pork sausages revealed various problems in accepting experimental samples on all evaluation days. Experimental sausage samples with sea buckthorn addition received a lower average score in all observed parameters. The most notable penalisation of experimental samples was observed in the Taste parameter, mainly compared to the Control\_C group with the addition of ascorbic acid. All evaluators reported a bitter taste and aftertaste of sea buckthorn extract-enriched sausages. Therefore, those samples reached very low acceptance by evaluators. The sensory panel also reported a significant difference between Control\_C and the experimental group colour at the early stage of storage (day 7). This contradicts our mechanical colour measurement, which did not detect significant differences in observed colour parameters. Sensory evaluation of pork sausages with sea buckthorn addition was performed by Salejda et al. (2017). Authors reported that panellists gave the sausages with sea buckthorn extract addition lower ratings

for juiciness, overall look, texture, and flavour than the control samples. However, the samples with the lowest level of plant extract addition scored higher in colour and nearly the same as the control samples in scent assessment. The lower score of experimental sausage in taste or consistency was in line with our findings. However, in our study, we cannot replicate the improvement of aroma or colour reported by the authors. In the study, Püssa et al. (2008) observed that a 2 % supplement of sea buckthorn berry powder did not affect the organoleptic features of chicken and turkey mechanically deboned meat, such as taste, flavour, or texture. The results of sensory analysis vary in individual studies. Different meat products, a variety of sea buckthorn, or simple preferences of evaluators can explain this phenomenon. Visualisation of sensory evaluation results are presented in Figure 1.

## CONCLUSION

In our study, we incorporated sea buckthorn extract into the pork sausages and observed its effect on the sensory parameters of the final product. When compared, we did not observe significant differences among all groups at any measurement day and observed only slight pH fluctuation during storage within individual groups. During the storage period of 21 days, we did not observe a significant difference in mechanically measured colour and texture parameters of firmness and toughness among all groups. Based on our results, we could state that sea buckthorn extract addition has no adverse effect on measured parameters. On the other hand, conducted sensory analysis revealed substantial deterioration

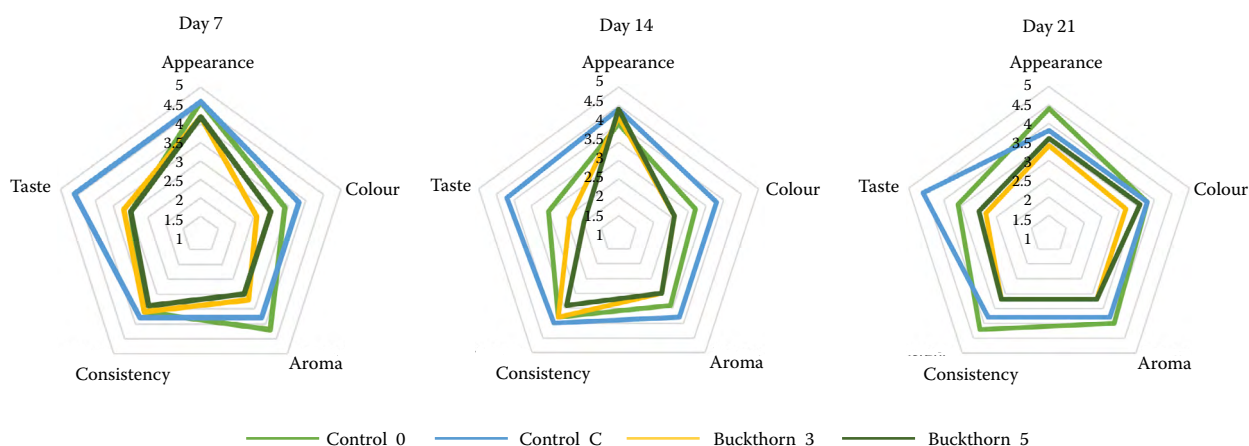


Figure 1. Results of sensory analysis

Control\_C – ascorbic acid addition  $0.5 \text{ g} \cdot \text{kg}^{-1}$ ; Buckthorn\_3 – sea buckthorn extract addition  $3 \text{ mL} \cdot \text{kg}^{-1}$ ; Buckthorn\_5 – sea buckthorn extract addition  $5 \text{ mL} \cdot \text{kg}^{-1}$

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of the sensory quality of experimental pork sausage. Extract addition mainly influenced pork sausage's taste and caused a bitter taste and aftertaste. This negative effect could be eliminated in future experiments by adjusting the dosage, changing the variety used, or combining various extracts of different plants. Sea buckthorn remains an interesting option for the meat industry. However, further multidisciplinary research is still needed.

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