INFLUENCE OF STARTER CULTURES AND SWISS CHARD POWDER ON THE TEXTURAL PROPERTIES OF SMOKED PORK LOIN

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Abstract: The aim of the study was to examine the effect of Swiss chard powder and starter cultures on the textural properties of smoked pork loin. The production was organized into five experimental groups: Group I - cooking salt and dextrose (negative control); Group II - nitrite salt and dextrose (positive control); Group III - nitrite salt, starter culture BactoFerm Rosa, and dextrose; Group IV - cooking salt, Swiss chard powder (producer 1), and starter culture BactoFerm Rosa; and Group V - cooking salt, Swiss chard powder (producer 2), and starter culture BactoFerm Rosa. Textural parameters (hardness, springiness, adhesiveness, cohesiveness, and gumminess) were instrumentally measured after completion of the production process, at mid-storage (30 days), and at the end of the shelf life (60 days). The obtained results for the five groups of smoked pork loin revealed statistically significant differences ($p \leq 0.05$) both immediately after thermal processing and during storage. The highest hardness and gumminess values were recorded in Group I, while the remaining groups showed significantly lower values. According to the results, the addition of starter cultures had a significant effect on the textural properties - contributing to increased springiness, reduced hardness and gumminess, and altered adhesiveness - which resulted in an improved structure and desirable sensory characteristics of the final product.

Keywords: hardness, springiness, adhesiveness, cohesiveness, gumminess

1. INTRODUCTION

Meat processing represents an inevitable part of the overall production process of meat intended for human consumption (Khalid et al., 2023). In the meat industry, nitrites are the most widely used additives (Silovska Nikolova et al., 2022; Silovska Nikolova & Belichovska, 2020). They are incorporated to achieve the desirable reddish-pink color, to prevent the growth and proliferation of pathogenic microorganisms, and to inhibit lipid oxidation, thereby enhancing the aroma and flavor of the product (Lavado et al., 2021). However, despite their technological advantages, numerous studies have also indicated potential negative effects on human health (Pearson & Dutson, 1987; Hui, 1992; Bošnir et al., 2003).

Silovska Nikolova & Belichovska. (2023a) emphasized that in the past few decades, considerable research has been dedicated to identifying suitable alternatives to nitrites; nevertheless, no fully appropriate substitute has been established to date. The scientific literature reports extensive investigations into the application of natural plant-derived sources of nitrates in combination with starter cultures containing nitrate-reducing bacteria, which enable the conversion of nitrate into nitrite during meat product manufacturing (Silovska Nikolova et al., 2023b; Silovska Nikolova et al., 2022; Kim et al., 2019a; Kim et al., 2019b; Hwang et al., 2018; Choi et al., 2017). Starter cultures are microbiological preparations containing specific bacterial strains capable of fermentation, contributing to the development of the desired flavor, aroma, and texture, while simultaneously optimizing the safety and sensory properties of the final product.

According to Guerrero et al. (1999), texture, alongside color, is one of the most critical factors influencing consumer food choice. In meat products, tenderness and juiciness represent some of the most significant textural parameters determining product acceptability among consumers (Szczesniak, 1990). Chrystall (1994) further highlighted that sensory attributes - particularly tenderness and juiciness - together with other features such as color, flavor, and aroma, rank among the most important characteristics of meat and meat products.

The aim of this study was to examine the influence of Swiss chard powder and starter cultures on instrumentally measured textural parameters, with the objective of obtaining products with improved sensory and technological properties.

2. MATERIALS AND METHODS

The research was conducted in the meat industry *"Fi-Sa Komerc"*, where their technological procedure for the production of smoked pork loin was taken as a basis. Five groups of smoked pork loin were produced in three independent iterations, as follows:

- Group I – negative control (2.5% table salt and 0.5% dextrose);
- Group II – control group (2.5% nitrite curing salt and 0.5% dextrose); Group III – 2.5% nitrite curing salt, 0.025% starter culture *BactoFerm Rosa*, and 0.5% dextrose;

- Group IV – 2.5% table salt, 0.5% dextrose 0.25%, Swiss chard powder (manufacturer 1), and 0.025% starter culture *BactoFerm Rosa*; and
- Group V - 2.5% table salt, 0.5% dextrose 0.25%, Swiss chard powder (manufacturer 2), and 0.025% starter culture *BactoFerm Rosa*.

The smoked pork loin was produced from frozen pork loin (*m. longissimus dorsi*) with bones, fat, and connective tissue removed. The raw material was dry-defrosted and selected based on optimal pH values (5.7–6.2) to avoid pale, soft, and exudative meat. After shaping and removal of residual blood, a pre-measured dry curing mixture was applied, and the pieces were stored for 14 days at 0–4 °C and 85–90% relative humidity. The technological process consisted of the following steps: heating (45 °C for 15 min), drying (68 °C chamber temperature, 45 °C internal, for 2.5 h), smoking (70 °C for 1 h), roasting (80 °C chamber temperature, 70 °C internal, for 1.5 h), curing (85 °C chamber temperature, 74 °C internal, for 30 min), and cooling. The smoked loins were vacuum-packed in polyethylene bags and stored at 4 °C for a duration of 60 days.

For instrumental texture analysis, a TA.XTplus Texture Analyzer (Stable Micro Systems Ltd., Surrey, UK) was used. Analyses were carried out at room temperature (20 °C) with a maximum temperature deviation of ±2 °C. The texture profile analysis (TPA) was performed:

- immediately after thermal processing (final products)
- at mid-shelf life (30 days) and
- at the end of shelf life (60 days).

The test samples were prepared with dimensions of 1.5 mm × 65 mm × 45 mm (height × length × width). For TPA, a cylindrical aluminum probe in the form of a plunger with a diameter of 25 mm (P/25) was mounted on the instrument. Each sample was compressed twice to 50% of its height with a load of 50 kgf (500 N). The interval between the two compressions was 3 s, with a crosshead speed of 1 mm/s. The software recorded the force–time curves representing the compression profile of each sample.

Experimental data were processed and organized using Microsoft Excel XP. Normality of distribution was checked by testing the homogeneity of variances. Following confirmation of homogeneity, the data were analyzed using the multivariate general linear model (GLM) and ANOVA (for comparison of three or more groups), while associations between parameters were further evaluated through multivariate linear descriptive analysis (LDA) (IBM SPSS Statistics 23, release 23.0.0.0). The experimental design for texture assessment was set up as a 5 × 10 × 3 factorial experiment (5 experimental groups, 10 samples collected from each stage of processing and storage time, and 3 production replications). Whenever the interaction between group and sample was statistically significant ($p < 0.05$), it was included in the statistical model; when nonsignificant, it was excluded.

3. RESULTS AND DISCUSSION

This section presents and analyzes the results of the instrumental texture analysis of smoked pork loin, with a focus on the parameters hardness, springiness, adhesiveness, cohesiveness, and gumminess, measured immediately after production and during storage. The results are discussed in relation to the different experimental groups and storage intervals.

Table 1. Hardness - maximum force (N) during the first compression of smoked pork loin, measured immediately after production and during storage (Duncan's test, α = 0.05)

Time from production to the end of shelf life	**Smoked pork loin groups**				
	I	**II**	**III**	**IV**	**V**
	x̄ ± SD				
End of production (after thermal processing)	17.52 ± 1.63^{aA}	14.67 ± 2.39^{bA}	15.69 ± 3.17^{bA}	15.76 ± 2.75^{bA}	14.77 ± 2.06^{bA}
Mid-shelf life (30 days post-production)	15.07 ± 1.49^{aB}	11.66 ± 2.46^{cB}	13,15 ± 2.50^{bB}	13.05 ± 2.48^{bB}	14.02 ± 3.22^{baA}
End of shelf life (60 days post-production)	14.02 ± 3.22^{aB}	10.01 ± 3.10^{cC}	12.37 ± 2.51^{bB}	11.83 ± 2.84^{bB}	13.93 ± 1.49^{aA}

x̄ - mean value; SD - standard deviation; mean values followed by different letters (a–d) within the same row are significantly different ($p \le 0.05$); mean values followed by different letters (A–C) within the same column are significantly different ($p \le 0.05$).

Source: Author's own research

Hardness, defined as the maximum force recorded during the first compression of the smoked pork loin, both after thermal processing and throughout storage, is presented in Table 1. Immediately after thermal treatment, the highest hardness value was observed in Group I (17.52 N), while the lowest was recorded in Group II (14.67 N). During storage, a reduction in hardness was observed across all samples, expressed as a decrease in the maximum force required during the first compression. At the end of the storage period, hardness values ranged from 10.01 N (Group II) to 14.02 N (Group I). Differences in hardness among the groups, as well as within groups during storage, were statistically significant ($p \leq 0.05$).

At the end of the production process, the highest springiness (0.86 mm) was observed in Group III, whereas the lowest (0.72 mm) was recorded in Group I. The difference between Group I and all other groups was statistically significant ($p \leq 0.05$) (Table 2). During storage, no major differences in springiness were detected. At the end of the shelf life (60 days post-production), springiness values ranged from 0.70 mm (Group I) to 0.92 mm (Group IV). The differences between Group I and all other groups were statistically significant ($p \leq 0.05$).

Table 2. Springiness (mm) of smoked pork loin after production and during storage (Duncan's test, α = 0.05)

Time from production to the end of shelf life	**Smoked pork loin groups**				
	I	**II**	**III**	**IV**	**V**
	x̄ ± SD				
End of production (after thermal processing)	0.72 ± 0.21^{bA}	0.83 ± 0.05^{aA}	0.86 ± 0.06^{aA}	0.84 ± 0.05^{aA}	0.73 ± 0.06^{aA}
Mid-shelf life (30 days post-production)	0.71 ± 0.21^{bA}	0.82 ± 0.04^{aA}	0.84 ± 0.06^{aB}	0.92 ± 0.06^{aA}	0.82 ± 0.05^{aA}
End of shelf life (60 days post-production)	0.70 ± 0.20^{bA}	0.80 ± 0.05^{aB}	0.83 ± 0.06^{aBA}	0.92 ± 0.06^{aA}	0.81 ± 0.04^{aA}

x̄ - mean value; SD - standard deviation; mean values followed by different letters (a–d) within the same row are significantly different ($p \leq 0.05$); mean values followed by different letters (A–C) within the same column are significantly different ($p \leq 0.05$).

Source: Author's own research

At the end of the production process, adhesiveness ranged from –3.47 N·mm (Group III) to –5.46 N·mm (Group I). The difference between Group I and all other groups was statistically significant ($p \leq 0.05$). During storage, a slight decrease in adhesiveness was observed across all five groups. However, the within-group differences in adhesiveness during storage were not statistically significant. At the end of the shelf life, adhesiveness values ranged from –3.17 N·mm (Group III) to –5.17 N·mm (Group I). The difference in adhesiveness between Group I and all other groups was statistically significant ($p \leq 0.05$) (Table 3).

Table 3. Adhesiveness (N·mm) of smoked pork loin after production and during storage (Duncan's test, α = 0.05)

Time from production to the end of shelf life	**Smoked pork loin groups**				
	I	**II**	**III**	**IV**	**V**
	x̄ ± SD				
End of production (after thermal processing)	-5.46 ± 2.10^{bA}	-3.67 ± 1.28^{aA}	-3.47 ± 1.31^{aA}	-4.18 ± 1.05^{aA}	-3.80 ± 1.13^{aA}
Mid-shelf life (30 days post-production)	-5.22 ± 2.04^{bA}	-3.56 ± 1.23^{aA}	-3.28 ± 1.27^{aA}	-4.00 ± 1.04^{aA}	-3.60 ± 1.08^{aA}
End of shelf life (60 days post-production)	-5.17 ± 2.04^{bA}	-3.56 ± 1.23^{aA}	-3.17 ± 1.27^{aA}	-3.90 ± 1.06^{aA}	-3.43 ± 1.08^{aA}

x̄ - mean value; SD - standard deviation; mean values followed by different letters (a–d) within the same row are significantly different ($p \leq 0.05$); mean values followed by different letters (A–C) within the same column are significantly different ($p \leq 0.05$).

Source: Author's own research

At the end of the production process, the highest cohesiveness (0.76) was recorded in Group II, while the lowest cohesiveness (0.73) was observed in Group III. Although the differences among groups were relatively small, they were statistically significant ($p \leq 0.05$). These differences resulted from variations in piece size as well as water content. Several studies have demonstrated that the hardness of meat products is inversely related to their water content (Serra et al., 2007; Monin et al., 1997).At the end of the shelf life (60 days post-production), cohesiveness values ranged from 0.71 (Group I and Group II) to 0.73 (Groups III and IV). While the within-group differences during storage were minor, they were nevertheless statistically significant ($p \leq 0.05$).

Table 4. Cohesiveness of smoked pork loin after production and during storage (Duncan's test, α = 0.05)

Time from production to the end of shelf life	**Smoked pork loin groups**				
	I	**II**	**III**	**IV**	**V**
	$\bar{x} \pm SD$				
End of production (after thermal processing)	0.74 ± 0.02^{bA}	0.76 ± 0.02^{aA}	0.73 ± 0.06^{bA}	0.75 ± 0.03^{baA}	0.75 ± 0.05^{baA}
Mid-shelf life (30 days post-production)	0.72 ± 0.02^{bBA}	0.72 ± 0.02^{bB}	0.74 ± 0.02^{aA}	0.74 ± 0.03^{baA}	0.73 ± 0.05^{baA}
End of shelf life (60 days post-production)	0.71 ± 0.06^{cB}	0.71 ± 0.02^{cbC}	0.73 ± 0.02^{aA}	0.73 ± 0.05^{baA}	0.72 ± 0.03^{cbaA}

$\bar{x}$ - mean value; SD - standard deviation; mean values followed by different letters (a–d) within the same row are significantly different ($p \leq 0.05$); mean values followed by different letters (A–C) within the same column are significantly different ($p \leq 0.05$).

Source: Author's own research

At the end of the production process, the highest gumminess (26.64 N), representing the greatest amount of energy required for sample disintegration (breakdown) prior to swallowing, was observed in Group I, while the lowest gumminess (22.23 N) was recorded in Group IV (Table 5). The differences between Group I and all other groups were statistically significant ($p \leq 0.05$). During storage, a consistent decrease in gumminess was observed. At the end of the shelf life, gumminess values ranged from 20.80 N (Group IV) to 25.06 N (Group I). The differences between Group I and all other groups were statistically significant ($p \leq 0.05$).

Table 5. Gumminess (N) of smoked pork loin after production and during storage (Duncan's test, α=0.05)

Time from production to the end of shelf life	**Smoked pork loin groups**				
	I	**II**	**III**	**IV**	**V**
	$\bar{x} \pm SD$				
End of production (after thermal processing)	26.64 ± 2.06^{aA}	23.43 ± 3.68^{bA}	23.76 ± 2.71^{bA}	22.23 ± 2,78^{bB}	23.06 ± 4.03^{bA}
Mid-shelf life (30 days post-production)	25.79 ± 2.05^{bBA}	22.74 ± 3.62^{bA}	22.90 ± 2.70^{bBA}	21.08 ± 3.53^{aA}	22.31 ± 3.96^{bA}
End of shelf life (60 days post-production)	25.06 ± 2.02^{aB}	22.31 ± 3.96^{bA}	22.20 ± 2.65^{bB}	20.80 ± 2.74^{bA}	22.07 ± 3.56^{bA}

$\bar{x}$ - mean value; SD - standard deviation; mean values followed by different letters (a–d) within the same row are significantly different ($p \leq 0.05$); mean values followed by different letters (A–C) within the same column are significantly different ($p \leq 0.05$).

Source: Author's own research

4. CONCLUSION

The results of this study confirmed that the improved texture of smoked pork loin was mainly attributed to the addition of starter cultures, whose proteolytic activity contributed to increased springiness and cohesiveness, as well as reduced hardness and gumminess. The addition of the starter culture, as well as its combination with Swiss chard powder, resulted in a softer and more elastic structure compared to the conventionally nitrite-cured product. These findings indicate an improved structure and optimized sensory characteristics, making the product more readily acceptable to consumers.

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