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Development and Characterization of a Walnut-Enriched Pork Salami

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Abstract

The paper aims to develop an innovative homemade salami enriched with walnuts and to conduct a sensory and physicochemical analysis of the final product. Salami is one of the most popular and widely consumed foods, appreciated for its rich flavor, whether enjoyed on its own or paired with other ingredients. The core objective of this study was to create a natural product with nutritional benefits, leveraging the wholesome properties of its key ingredients – pork and walnuts.

To ensure a high protein content, only one type of meat – pork – was used as the raw material. The final product was free from additives and preservatives, making it a healthier option without potential long-term adverse effects.

The salami was prepared using a custom recipe, refined through multiple trials and taste tests. Sensory evaluation was conducted by a panel of 10 tasters, who completed sensory sheets based on an organoleptic examination of the product. Additionally, physicochemical analyses were performed to determine moisture and total dry weight content, salt content (using the Mohr method), titratable acidity and ash. The results showed that all values obtained comply with the current national standards.

Keywords: salami, walnut, proximate composition of salami, nutritional profile

1. Introduction

Salami is a traditional cured meat product widely appreciated for its distinctive flavor, texture, and versatility in culinary applications. In recent years, consumer demand has increasingly shifted toward healthier meat products with improved nutritional profiles and reduced levels of artificial additives and preservatives [1,2]. This trend has stimulated interest in developing functional meat products enriched with bioactive ingredients of plant origin, such as nuts, seeds, and dietary fibers, which can enhance both the sensory characteristics and the nutritional value of traditional formulations [3,4]. The incorporation of natural ingredients aligns with the growing consumer preference for clean-label, additive-free foods that support health without compromising taste or texture.

Recent studies have explored the inclusion of non-meat functional ingredients in processed meats to improve their health profile. Kausar et al. (2019) emphasized that the addition of plant-derived proteins, fibers, and nut components can address traditional limitations of processed meats, such as high saturated fat content, low dietary fiber, and lack of bioactive compounds. The integration of these natural ingredients can enhance nutritional value, oxidative stability, and consumer-perceived healthfulness while maintaining acceptable technological and sensory attributes [5]. This approach provides a valuable framework for reformulating traditional meat products like salami

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to deliver both health benefits and high sensory appeal.

Among potential plant-based enrichments, walnuts (*Juglans regia* L.) are particularly promising due to their rich content of polyunsaturated fatty acids – especially alpha-linolenic acid (ALA) – as well as antioxidants, vitamins, and minerals [6,7]. Their inclusion in meat systems has demonstrated improvements in the fatty acid profile, lipid oxidation resistance, and overall nutritional quality [8,9]. Moreover, walnuts have been shown to exert beneficial effects on oxidative stability and sensory performance in various meat matrices, including restructured beef steaks and emulsified sausages [10]. However, formulation challenges remain, particularly concerning texture, moisture retention, and flavor balance, which must be optimized for consumer acceptance.

Beyond product-specific benefits, the nutritional implications of walnut incorporation extend to public health. Spence et al. (2023) demonstrated that substituting part of the dietary meat intake with walnuts significantly improved overall nutrient quality, increasing omega-3 fatty acid, magnesium, and fiber intake while reducing cholesterol and saturated fat. Such findings support the concept that integrating walnuts into popular meat products can contribute to healthier dietary patterns without requiring radical changes in consumption habits [11]. The novelty of this study lies in the development of a traditional, homemade-style salami reformulated through a 50% replacement of pork backfat with roasted walnut kernels, while maintaining a fully additive-free and preservative-free formulation. This approach aligns with Romanian artisanal meat-processing traditions, where natural ingredients are preferred but fat-reduction strategies are rarely applied. Compared with existing reformulation studies, our work combines a homemade technological process with a clean-label concept, representing a niche yet highly relevant direction in functional meat product development. The research focuses on evaluating the sensory attributes and physicochemical characteristics – specifically moisture, dry matter, salt content, titratable acidity, and ash – of the final product, ensuring compliance with national standards. Ultimately, this study explores the potential of a culturally relevant, homemade-type product to integrate health-oriented modifications without compromising sensory quality.

2. Materials and method

2.1. Materials

Fresh post rigor pork meat and pork backfat from a local slaughterhouse were used for salami preparation. Other ingredients used were fresh garlic, walnuts (purchased from a local producer) and spices like pepper, salt, sweet paprika powder and chili paprika powder (Fuchs Condimente RO SRL, Romania).

All reagents used for the chemical analyses were purchased from Chimreactiv (Bucharest, Romania) and were of analytical purity.

2.2. Salami production

The control salami (CS) was prepared according to the following recipe: pork meat (5 kg), lard (1.5 kg), salt (0.15 kg), pepper (0.06 kg), fresh garlic (0,06 kg), sweet paprika powder (0.03 kg) and chili paprika powder (0.03 kg). The reformulated salami (RS) was obtained based on the same recipe as the control, except that 50% of the pork fat was replaced with walnut kernels. Walnuts were roasted at 145°C for 15 minutes to enhance flavor and reduce moisture. After cooling, walnut kernels were chopped to an approximate particle size of 3–5 mm.

Table 1. The recipe used to obtain the two types of salami

Ingredients	CS	RS
Pork meat (g)	5000	5000
Lard (g)	1500	750
Walnut kernel (g)	-	750
Salt (g)	150	150
Pepper (g)	60	60
Garlic (g)	60	60
Sweet paprika powder (g)	30	30
Chili paprika powder (g)	30	30

The technology for obtaining the salami consisted of: chilled pork meat and lard were cut into long strips, ground through a 6 mm diameter cutting plate and mixed with the other ingredients for 5 minutes to obtain a homogenous meat batter. The final temperature of the mixture must be below 12°C. The

obtained mixture was stuffed into collagen membranes with a diameter of 50 mm and a length of 40 cm, manually tied, hung and cooked in a smoking chamber. Smoking was performed using hardwood sawdust, following a temperature profile of 40–50°C for drying (30 min), followed by hot smoking at 78°C until the core temperature reached 72°C. Relative humidity was maintained at 65–75% throughout the process. After smoking, salamis were vacuum-packed and stored at 2-4°C for 48 hours before analysis.

2.3. Proximate analysis

The two types of salami (CS and RS) were analyzed for moisture, total dry weight, sodium chloride, ash and titratable acidity (% lactic acid) contents. Each analysis was performed in triplicates. A Kern thermobalance DAB 100-3 was used for the determination of the moisture content and a Nabertherm GmbH LE 4/11/R6 oven for the ash content. The amount of total dry weight was calculated by difference. The sodium chloride content was determined by the Mohr method and the titratable acidity was determined by the titration method with 0.1 N NaOH and expressed as a percentage of lactic acid.

2.4. Sensory analysis

A panel of untrained judges consisted of 10 members from the students of Faculty of Food Engineering from Timișoara was used to evaluate the salami samples in terms of appearance, taste, odor, color, consistency and overall acceptability. A 5-point hedonic scale ranging from 1 denoting „dislike extremely" to 5 denoting „like extremely" was used. Following their removal from cold storage, the samples were presented to the panelists in a randomized order, in natural light. Also, samples were coded with three-digit random numbers and served at 18–20°C. Panelists cleansed their palate with water and unsalted crackers between samples. Sensory data were analyzed using one-way ANOVA ($p < 0.05$).

2.5. PCA analysis

The Principal Component Analysis (PCA) was applied to highlight the relationships between the physicochemical parameters and the sensory characteristics of the two types of salami analyzed: the traditional homemade salami and the homemade salami with walnut addition.

2.6. Statistical analysis

Physicochemical measurements were analyzed using Student's t-test ($p < 0.05$) to determine significant differences between CS and RS samples. Sensory scores were analyzed using one-way ANOVA followed by Tukey's test ($p < 0.05$). PCA was performed using Past 4.03 (Øyvind Hammer, 2020) and conducted on the correlation matrix. All variables were standardized (z-score normalization) prior to computation in order to remove the influence of different measurement units.

3. Results and Discussion

3.1. Proximate composition

The proximate composition of the control and reformulated salami (with walnuts) is shown in Table 2.

Table 2. Proximate composition of control and reformulated salami samples

	CS	RS
Moisture (%)	24.8 ± 0.264	24.3 ± 0.173
Total dry weight (%)	75.2 ± 0.264	75.7 ± 0.173
Sodium chloride (%)	1.315 ± 0.015	1.287 ± 0.019
Ash (%)	3.97 ± 0.055	4.61 ± 0.127
Titratable acidity (% lactic acid)	0.37 ± 0.017	0.35 ± 0.01

Moisture in pork salami is crucial for its texture and shelf life, and it decreases significantly during the fermentation and ripening process. The replacement of traditional ingredients with walnuts led to slight modifications in the chemical composition of the product. The reformulated pork salami showed a moderate decrease in the moisture content (from 24.8% to 24.3%) and a corresponding increase in total dry weight (from 75.2% to 75.7%). This small reduction in moisture indicates that the inclusion of walnuts may have slightly enhanced the solid fraction and reduced water retention in the matrix, possibly due to the higher fat and fiber content of walnuts. Similar trends were reported by Franco et al. (2019), who observed small reductions in moisture in reformulated sausages when animal fat

was replaced with vegetable-based ingredients, and by Jiménez-Colmenero et al. (2010), who noted that reformulated meat products containing oil-in-water emulsions or oleogels showed reduced water content compared to controls [12,13]. Also, in the literature it is specified that the desired final moisture content is typically between 35% and 45%, with dried type salamis having moisture levels of 35% or lower, while semi-dried types have 45–50% [14].

Sodium chloride content decreased minimally from 1.315% in the control to 1.287% in the reformulated sample. This minor reduction could be attributed to the walnut addition diluting the overall salt concentration in the mixture, or to interactions between salt and the nut's lipid-protein matrix that affect salt distribution. Comparable decreases in NaCl content were found by Pérez-Álvarez et al. (2020), who reported no significant differences ($p > 0.05$) in salt content between control and reformulated sausages when using plant-based fat replacers [15].

The ash content in pork salami is generally between 1% and 4.3%, as it's the inorganic residue from burning the food and represents the mineral content [16,17]. In our study the ash content increased from 3.97% in CS to 4.61% in RS. This rise reflects the higher mineral contribution of walnuts, which are rich in magnesium, phosphorus, and potassium. Similar increments have been observed in meat products reformulated with oilseeds or nuts, as reported by Barbut et al. (2016), who found elevated ash levels when adding plant-derived ingredients with higher mineral content than animal fat [18].

Titratable acidity in salami type products is typically expressed as a percentage of lactic acid and is a measure of the total acid concentration, which is crucial for flavor, preservation, and safety. Titratable acidity showed only a minor, non-significant change (from 0.37% lactic acid to 0.35% lactic acid), indicating that the reformulation did not markedly affect fermentation or acid production. This stability aligns with findings from Domínguez et al. (2017), who reported that replacing animal fats with vegetable oils or nuts did not significantly modify the pH or acidity of fermented meat products [19]. Also, Capita et al. (2006) observed a low acidity (like 0.30%±0.01% lactic acid) in pork sausages like chorizo [20].

Given that pork backfat typically contains 30–35% SFA and minimal n-3 fatty acids, while walnuts contain approximately 60–70% PUFA and are rich in α-linolenic acid (ALA), replacing 50% of the backfat is expected to substantially improve the fatty acid profile of the finished product. Although fatty acid composition was not analyzed in this study, literature indicates that even partial incorporation of walnuts increases PUFA/SFA ratio, enhances antioxidant intake, and reduces cholesterol contribution of meat products. Therefore, the reformulated salami can be considered nutritionally advantageous, particularly in terms of lipid quality.

3.2. Sensory analysis

Although consumers' interest in functional meat products is growing, many are unwilling to give up flavor in favor of healthier reformulated products [21]. Since pork backfat is crucial to the juiciness, tenderness, and flavor intensity of the salami, substituting it in meat products represent a sensory challenge [12]. The scores for several sensory qualities as well as the general acceptance of the control and reformulated salamis are presented in Figure 1.

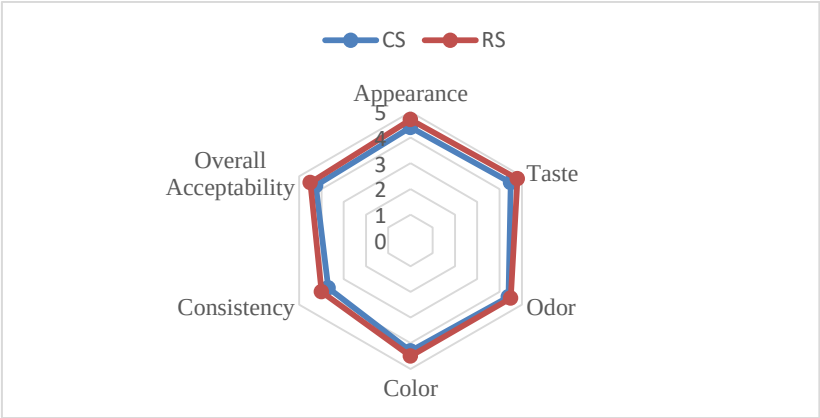

Figure 1. Sensory analysis of the salami samples

The sensory evaluation results indicate that the homemade salami with walnuts (reformulated salami – RS) obtained slightly higher scores for all evaluated parameters compared with the control homemade salami (CS). The reformulated product was rated better in terms of appearance (4.7 vs. 4.4), taste (4.8 vs. 4.5), odor (4.5 vs. 4.4), color (4.5 vs. 4.3), and consistency (4.0 vs. 3.7). These improvements may be attributed to the pleasant flavor and aroma imparted by the walnut components, as well as to their influence on the product's visual characteristics. The slightly higher consistency score suggests a minor improvement in texture, possibly due to the contribution of the walnut matrix to the overall structure of the product. Consequently, the overall acceptability of the walnut-enriched salami (4.5) was higher than that of the control sample (4.26), indicating that the addition of walnuts enhanced consumer perception and acceptance. These findings are in good agreement with previous studies on reformulated meat products, where the inclusion of plant-based ingredients or oils improved flavor attributes without negatively affecting color, texture, or overall acceptability [22].

3.3. PCA analysis

Due to the structure of the dataset – only two samples were included (homemade salami and homemade salami with walnuts) – the PCA extracted a single principal component (PC1). Mathematically, when the number of observations is n = 2, the maximum number of components is n − 1, thus only one component can be generated.

The extracted component had an eigenvalue of 0.615392, and PC1 accounted for 100% of the total variance, indicating that this axis alone was sufficient to describe the differences between the samples and the correlations among the analyzed variables (Figure 2). This outcome accurately reflects the dimensionality of the dataset and does not indicate overfitting or computational error.

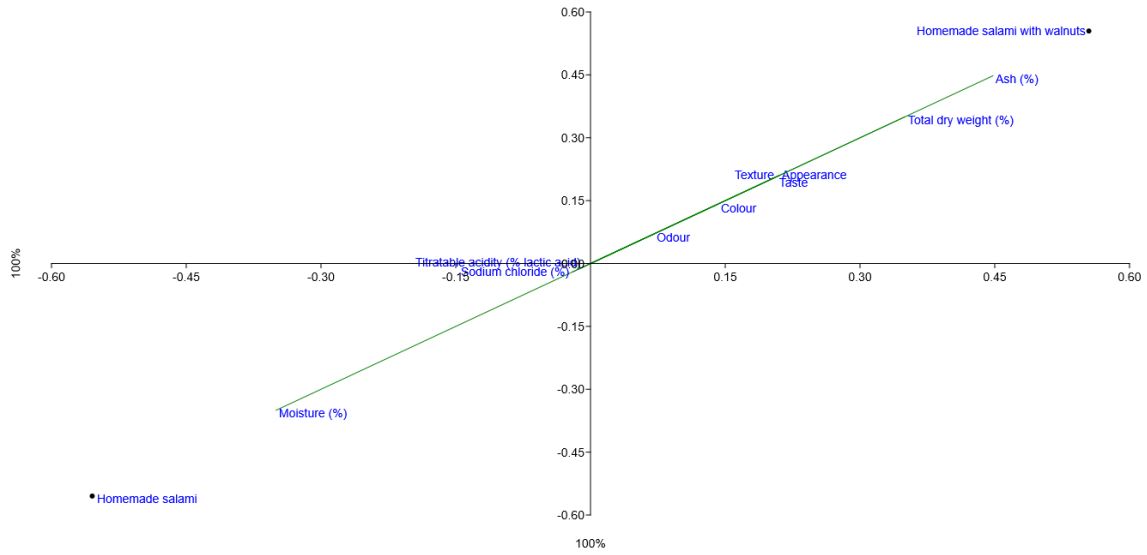

Figure 2. PCA analysis of the salami samples

The PCA projection revealed a clear separation between the two salami formulations along PC1.

The "homemade salami with walnuts" sample was positioned on the positive side of the PC1 axis and was strongly associated higher ash content, higher total dry matter, and superior sensory attributes (appearance, taste, texture, colour, odour).

This distribution indicates that the addition of walnuts led to an improvement in the nutritional composition, by increasing the mineral and dry matter content, together with a higher sensory appreciation from the evaluators.

Conversely, the "homemade salami" sample (control, without walnuts) was located on the negative side of the PC1 axis and was linked with higher moisture, sodium chloride content, and titratable acidity.

These correlations suggest that the control product had a higher water content and a slight tendency toward increased acidity and salinity, aspects that

can be associated with the absence of fat- and mineral-rich ingredients such as walnuts.
The PCA results confirm that the walnut addition exerts a significant influence on the overall product profile, leading to an increase in nutritional value and an improvement in sensory properties.
Therefore, the incorporation of walnuts into the homemade salami formulation can be considered an effective technological strategy for obtaining a meat product with enhanced functional value and improved organoleptic characteristics.

4. Conclusion

Walnut kernels are an excellent and accessible source of bioactive compounds, including polyunsaturated fatty acids, phenolic compounds, tocopherols, and antioxidants, making them an ideal functional ingredient for food products. Walnut kernel, owing to its high nutritional value and strong bioactive potential, represents a valuable non-conventional material for improving the functional and health-promoting quality of foods. The reformulation of pork salami with walnuts resulted in a slight decrease in moisture and sodium chloride content, a small but meaningful increase in ash, stable acidity, and slightly higher total solids. These modifications suggest that walnut addition improves the mineral content of the salami, but also its physicochemical characteristics. The observed changes confirm that partial replacement of animal fat with plant-based ingredients can improve nutritional quality without compromising product integrity.

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