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Analytical and Comparative Study Applied to Different Types of Cheese-Filled Sausages

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Abstract
This study aims to perform and highlight both an analytical and comparative evaluation of different types of sausages stuffed with cheese, with emphasis on their physicochemical properties and sensory characteristics. Moisture content, salt concentration, ash content, color, texture, and flavor were determined using specific analytical methods. These characteristics were compared across several samples; thus, the study seeks to identify variations in terms of quality, consistency, and, not least, consumer acceptability. Three sausage samples were prepared, each with different cheese concentrations (5%, 10%, and 20%), then subjected to a smoking process and analyzed in comparison with non-smoked samples. Differences in cheese content significantly influenced both texture and flavor; higher cheese levels were associated with increased product juiciness, while smoked samples exhibited superior aroma and color characteristics compared to non-smoked variants. The results of this study highlight the importance of optimizing these factors to improve product quality and increase consumer acceptance.
Keywords*: smoked sausages; non-smoked sausages; cheese proportion; sausages with cheese addition; sensory quality.*

1. Introduction

The meat processing industry represents a dynamic sector of the global food industry. It is driven by the need to ensure food security for a growing population and for various demands of modern consumers. Among all categories of processed meat products, sausages hold a distinct position in the dietary traditions of many European countries, where pork-based preparations have been central to food culture for centuries [1,2].

According to current global statistics, the average annual consumption of meat is approximately 37kg, with a mean annual production growth rate of 2.5%, the largest contributors being the USA, China, Australia, Germany, Russia, Argentina, France, and Brazil. Nutritionists recommend a daily intake of approximately 150g of meat or processed meat

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products and 25g of animal fats as part of a balanced diet [1]. Processed meat products such as sausages are recognized as important sources of complete proteins, B-group vitamins, and essential minerals including iron and zinc, all of which play key roles in human metabolic function [1,2,3]. Excessive consumption of processed meat has been associated with an increased risk of colorectal cancer, type 2 diabetes, and coronary heart disease, prompting the food industry to seek healthier formulations while maintaining consumer acceptability [4,5,6].

The development of innovative complex meat products that combine traditional raw materials with premium complementary ingredients represents a strategically significant trend. Consumers are increasingly attracted to products that offer enhanced flavor, improved nutritional value, and a pleasant textural surprise, while remaining free of chemical additives and preservatives [5,6].

Cheese-filled sausages combine the familiarity of a traditional product with the added sensory value of melted cheese, offering juiciness and a distinctive flavor profile.

The origins of the modern cheese-filled sausage concept can be traced to Austria, where around 1970 the *Käsekrainer* was created - a smoked, semi-cooked sausage containing embedded cubes of Emmental cheese that melt during thermal processing.

The name comes from the German words *Käse* (cheese) and *Krainer*, referring to the Kranjska region of Slovenia. The recognized inventors of this product are Herbert Schuh and Franz Thalhammer from the Austrian region of Buchkirchen. The *Käsekrainer* rapidly became an iconic urban street food, typically served grilled. Its success subsequently spread across Central and Eastern Europe, where local producers, including those in Romania, adopted and adapted the recipe, integrating semi-hard stretched-curd cheeses such as *caşcaval* into the traditional sausage formulation [7,8].

Caşcaval is a semi-hard stretched-curd cheese with characteristic elasticity and a favorable melting behavior. Its dry matter content (55–60%) and fat-in-dry-matter content (45%) allow it to maintain structural integrity during moderate thermal processing. Unlike fresh cheeses, *caşcaval* does not dissolve excessively during smoking or cooking, retaining visible cubes in the cross-section of the sausage [7].

Smoking is an important complementary technology in the production of sausages. As a traditional preservation method used for centuries, smoking contributes to extending shelf life and to the development of characteristic color, aroma, and texture in the final product [9,11,12]. Smoked meat products from the Balkan region are typically produced in small smokehouses using open fire or smoldering hardwood, a practice that imparts complex phenolic and carbonyl compounds responsible for the distinctive sensory profile of smoked sausages [9,10,13].

The dehydrating effect of smoking also contributes to microbiological stability by reducing surface water activity and delivering antimicrobial compounds from wood combustion [11,14].

Despite the growing commercial popularity of cheese-filled sausages, scientific literature specifically addressing their physico-chemical and sensory characterization remains limited. Comparative studies evaluating the effect of different cheese concentration levels, combined with and without smoking treatment, on product quality parameters are uncommon [7,8].

Understanding how *caşcaval* concentrations of 5%, 10%, and 20% interact with the pork meat matrix, and how smoking modulates the resulting quality profile, is therefore of direct relevance to both research and industrial practice.

The present study aims to develop and characterize three experimental formulations of cheese-filled sausages incorporating *caşcaval* at concentrations of 5%, 10%, and 20% of the total meat mass, each evaluated in smoked and unsmoked variants, yielding six sample groups for comparative analysis.

All results were interpreted in relation to applicable Romanian and European food safety regulations. The main purpose is to identify the optimal cheese concentration and processing condition that maximizes product quality and commercial viability.

2. Materials and methods

2.1. Materials

Experimental batches of cheese-filled sausages were produced with varying cheese concentrations of 5% (S1), 10% (S2), and 20% (S3). Each batch was then split into two processing groups: smoked (Sm) and non-smoked (USm). The study was designed as a comparative experiment involving six sample groups, obtained by combining three cheese concentration levels, with two processing treatments mentioned above.

All six sample groups were produced from the same base formulation, developed for a total meat mass of

5 kg, followed the same standardized technological process.

Cheese-filled sausages (Figure 1) were prepared using pork meat, pork backfat, spices, and semi-hard cheese purchased from the local market. Smoked samples were subjected to a traditional wood smoking process in a smokehouse, while non-smoked samples were air-dried. All products were analyzed after a 7-day ripening period.

Figure 1. Different preparation stages of cheese-filled sausages

2.2. Method

Samples were removed from refrigeration and brought to an evaluation temperature of 16–18°C before assessment.

A trained sensory panel consisting of 5 assessors aged between 22 and 36 years, with experience in meat product evaluation, assessed the following sensory attributes: external and cross-sectional appearance, texture/consistency, color, odor/aroma, and taste/flavor. A 5-point hedonic scale was applied, where 5 represented "excellent" and 1 represented "unsatisfactory". Each attribute was described using standard descriptive terminology. Evaluations were performed under controlled conditions (neutral lighting, absence of interfering odors, individual tasting booths).

Three physico-chemical parameters were determined for all sample groups, using analytical methods.

Moisture content was determined gravimetrically. Samples of approximately 5g were weighed into pre-dried and pre-weighed melting pot, then dried in a convection oven at 103 ± 2°C to constant mass.

Ash content was determined by incineration. Samples of approximately 3g were placed in pre-weighed porcelain melting pot, charred over a direct flame until cessation of smoke, then transferred to a muffle furnace at 550 ± 25°C until a white, carbon-free ash residue of constant mass was obtained.

Salt (NaCl) content was determined by volumetric titration (Mohr method). A 2g sample was homogenized with 30 ml hot distilled water, allowed to rest for 10–15 minutes with occasional stirring, then filtered into a conical flask. The filtrate was titrated with 0.1N $AgNO_3$ solution in the presence of K_2CrO_4 (10%) as indicator, until a permanent brick-red (brick-orange) color endpoint was observed.

The results of all determinations were expressed as the arithmetic mean (X) ± standard deviation (sX). Comparisons among batches were performed using descriptive analysis.

3. Results and Discussion

3.1. Sensory analysis of cheese-filled sausage samples

Sensory evaluation was performed on all six sample groups (S1-USm, S2-USm, S3-USm, S1-Sm, S2-Sm, S3-Sm). Results are presented in Table 1.

Table 1. Centralized Sensory Evaluation Results for Unsmoked and Smoked Cheese-filled sausages

Sensory Attribute	**S1 (5% cheese)**		**S2 (10% cheese)**		**S3 (20% cheese)**	
	USm	**Sm**	**USm**	**Sm**	**USm**	**Sm**
External Appearance	3.40	4.20	4.00	4.60	3.80	4.40
Cross-section Appearance	3.40	3.60	3.80	4.20	3.60	3.80
Texture/ Consistency	3.40	3.80	4.00	4.40	3.80	4.20
Color	3.20	3.40	4.00	4.20	3.60	4.00
Odor/ Aroma	3.40	4.00	4.00	4.40	3.60	4.20
Taste/ Flavor	3.60	3.80	4.20	4.60	3.80	4.00
Average score	**3.40**	**3.80**	**4.00**	**4.40**	**3.70**	**4.10**

External Appearance: smoking significantly improved scores across all concentrations. S2-Sm achieved the highest score (4.60), with uniform reddish-brown surface and intact casing. S3 samples showed slightly irregular surface due to increased cheese volume pressure on the casing wall.

Cross-section Appearance: S2-Sm obtained the best score (4.20), with well-defined cheese cubes uniformly distributed in a compact mosaic paste. S3 samples showed partial cheese cube merging and a less defined mosaic pattern due to thermal melting at 20% concentration. S1 samples showed sparse cheese distribution.

Texture/ Consistency: progressive improvement from S1 to S2 in both treatments. S2-Sm (4.40) achieved optimal balance. S3 samples, while juicy, showed reduced structural firmness and slight fat exudation tendency.

Color: color showed the lowest scores for S1-USm (3.20) and the highest for S2-Sm (4.20). Smoking consistently enhanced surface color through Maillard reactions and smoke compound deposition. S2 samples showed the best internal color contrast between pink-red meat and golden-yellow cheese cubes.

Odor/ Aroma: smoking produced the greatest positive impact on aroma scores (+0.60 for S1; +0.40 for S2 and S3). S2-Sm (4.40) was described as the most harmonious, complex notes of smoked wood, spices, and warm melted cheese. S3 samples presented a dominant cheese aroma that partially masked the spice profile. S1 unsmoked showed the mildest, least characteristic aroma.

Taste/ Flavor: taste/ flavor showed the widest range across samples (3.60–4.60). S2-Sm achieved the highest score of all attributes (4.60). S3-Sm (4.00) was pleasant but dominated by cheese flavor. S1 samples delivered insufficient flavor differentiation from a standard plain sausage.

Smoking consistently improved average scores by +0.40 across all concentrations. S2-Sm achieved the highest overall average (4.40), confirming the 10% smoked formulation as optimal. S1 samples (USm: 3.40; Sm: 3.80) showed acceptable but with the lowest overall quality. S3 samples (USm: 3.70; Sm: 4.10) performed well but were ranked below S2 due to structural and flavor balance concerns.

3.2. Physicochemical evaluation of cheese-filled sausage samples

Physico-chemical characteristics were determined for all six sample groups, using the methods mentioned in the previous paragraph. The mean values are presented in Table 2, followed by a comparative analysis.

Table 2. Physico-chemical average characteristics score of unsmoked and smoked cheese-filled sausage samples

Sausage assortment	Moisture (%)	Ash (%)	NaCl (%)
USm	40.38±0.90	2.03±0.18	1.93±0.21
Sm	40.50±1.63	2.19±0.18	2.11±0.23

Moisture content values ranged from 38.89% to 42.15% across all sample groups, with an overall mean of 40.44 ± 1.32%. The mean moisture of unsmoked samples (40.38 ± 0.90%) was slightly lower than that of smoked samples (40.50 ± 1.63%), a result that reflects the higher variability within the smoked group, the elevated value recorded for S2-Sm (42.15%), which may be attributable to localized cheese moisture redistribution during thermal processing.

Ash content values ranged from 1.82% to 2.32% across all samples, with an overall mean of 2.11 ± 0.21%. Smoked samples showed consistently higher mean ash values (2.19 ± 0.18%) compared to unsmoked samples (2.03 ± 0.18%), a difference attributable to the concentration effect of moisture loss during the smoking process. Within each processing group, ash content increased progressively with cheese concentration — from 1.82% (S1-USm) to 2.11% (S3-USm) in unsmoked samples, and from 1.99% (S1-Sm) to 2.32% (S2-Sm) in smoked samples - reflecting the mineral contribution of *caşcaval* cheese, its calcium and phosphorus content, to the total mineral load of the product.

NaCl concentrations ranged from 1.69% to 2.37% across all samples, with an overall mean of 2.02 ± 0.24%. Smoked samples showed a slightly higher mean NaCl value (2.11 ± 0.23%) compared to unsmoked samples (1.93 ± 0.21%), consistent with the concentrating effect of moisture loss during smoking. Among smoked samples, S1-Sm (5% cheese) recorded the highest NaCl value (2.37%), while S2-Sm (10%) and S3-Sm (20%) were lower (1.95% and 2.01% respectively), suggesting that at higher cheese concentrations the inherent moisture and fat content of the *caşcaval* partially dilutes the salt concentration in the overall batter. Among unsmoked samples, S1-USm showed the lowest NaCl value (1.69%), increasing progressively with cheese concentration to 2.04% (S3-USm), reflecting the intrinsic salt content of the *caşcaval* itself (typically 1.5–2.5% NaCl).

4. Conclusion

The present study conducted a comprehensive analytical and comparative assessment of cheese-filled sausages produced with three different *caşcaval* concentrations (5%, 10%, and 20%) in both smoked and unsmoked variants, evaluating sensory and physicochemical quality parameters across six experimental sample groups. The following

conclusions were drawn:

Among all sample groups, S2-Sm (10% smoked) received the highest overall flavor scores, described by evaluators as well-balanced: moderately salty, with a harmonious integration of smoky, spicy, and cheesy notes in which no single element dominated. At 20% concentration (S3-Sm), the cheese flavor, while pleasant in isolation, tended to overshadow the traditional sausage spice profile, reducing the overall balance of the product. At 5% (S1 samples, both smoked and unsmoked), the cheese contribution to flavor was perceptible but insufficient to meaningfully differentiate the product from a standard plain sausage. No off-flavors, rancid notes, or foreign aromas were detected in any sample group, confirming the microbiological and oxidative stability of all formulations within the 7-day evaluation window.

Cheese-filled sausages incorporating *caşcaval* represent a viable and commercially promising product category, combining the authenticity of Romanian pork sausage tradition with the premium sensory characteristics of a high-quality dairy ingredient. The 10% smoked formulation (S2-Sm) represents the recommended candidate for commercial development, offering the best compromise between sensory excellence, technological reliability, microbiological safety, nutritional value, and cost efficiency.

Future research perspectives should focus on:

(i) microbiological shelf life assessment of smoked and unsmoked variants under standardized refrigerated storage conditions;

(ii) exploration of alternative semi-hard cheese varieties and different hardwood species for smoking, with the aim of further optimizing the sensory and nutritional profile of this innovative product category.

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