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Technological feasibility, sensory acceptance and microbiological quality of Mutton-Based Sausages

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ABSTRACT :
Small-ruminant farming plays a crucial role in local livelihoods across Madagascar, yet the sector remains dominated by the sale of fresh meat with limited processing. This study aims to enhance food security by transforming small-ruminant products and by-products into value-added foods. Three sausage formulations: mutton, beef, and a mixed beef–mutton blend, were produced using household-scale equipment. Consumer acceptability was assessed through a hedonic test involving 61 untrained participants, while microbiological quality was evaluated using standard laboratory methods. The mixed sausage formulation achieved significantly higher acceptability scores (4.4/5; $p < 0.05$) than the pure formulations. Beef and mutton sausages were equally appreciated by consumers. All microbiological counts were within acceptable limits, confirming product safety. These findings demonstrate the feasibility of processing mutton into high-quality sausages and highlight opportunities for diversifying small-ruminant products to improve food security in Madagascar. Further studies should explore a broader range of value-added products.

Keywords : Small ruminants, value addition, mutton, beef, sausages, food security, Madagascar.

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I. INTRODUCTION

Madagascar hosts approximately 2.3 million sheep and goats, with meat demand rising, particularly in regions influenced by Islam. Large areas unsuitable for cattle farming are available for small ruminants, which offer shorter production cycles and higher reproductive rates **[1]**. Small ruminant farming is accessible to women and children, and its products are increasingly sought after in regional and international markets **[2]**.

Currently, most production is sold fresh. Processing these products, however, could drive sector development and enhance regional food security, particularly through the effective use of by-products **[3]**. This study aims to valorize small ruminant products and by-products to contribute to food security. It combines literature review, experimental sausage production, sensory evaluation (hedonic and descriptive tests), and microbiological analysis. Two hypotheses were tested: (1) small ruminant products and by-products can be valorized, and (2) processed products are appreciated by consumers. The study is organized into introduction, materials and methods, results and discussion, and conclusion.

II. MATERIALS AND METHODS

II.1. Materials and formulation

Beef and sheep meat, along with beef casings (50–65 mm) and sheep casings (16–18 mm), were obtained from local markets. Spices included table salt, sugar, garlic (*Allium sativum*), ginger (*Zingiber officinale*), green pepper (*Piper nigrum*), coriander (*Coriandrum sativum*), and a "four-spice" blend consisting of black pepper (*Piper nigrum*), nutmeg (*Myristica fragrans*), clove (*Syzygium aromaticum*), and cinnamon (*Cinnamomum verum*). Sunflower oil (*Helianthus annuus*), wine (*Vitis vinifera*), and ice water were also used. All ingredients were locally sourced.

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Other materials included information sheets, three sausage samples, disposable cups, toothpicks, a towel, a bottle of water, and bread.

Sausage production equipment consisted of an electric meat grinder (220 V, 1 kg/min), a 5-kg precision scale (1 g), glass containers, stainless-steel knives and spoons, a 3 L pot, a 1500 W gas stove, kitchen thermometer, and funnel. Ice water was added during mixing to regulate temperature and ensure proper protein binding. No additional flavor enhancers or fat were included beyond the natural content of the meats.

Three sausage formulations were prepared: beef-only (F1), sheep-only (F2), and mixed beef–sheep (F3).

Table 1. Composition of the three formulations

Ingredient	F1 (Beef)	F2 (Sheep)	F3 (Mixed Beef & Sheep
Meat	85% Beef	85% Sheep	42.5% beef + 42.5% sheep
Casings	2m	2m	2m
Salt	2%	2%	2%
Sugar	0,2%	0,2%	0,2%
Ice water	10%	10%	10%
Garlic	0,2%	0,2%	0,2%
Ginger	0,2%	0,2%	0,2%
Green pepper	0,2%	0,2%	0,2%
Coriander	0,3 %	0,3 %	0,3 %
Four-spice blend	0,5%	0,5%	0,5%
Oil	1,2%	1,2%	1,2%
Wine	0,2%	0,2%	0,2%

II.2. Methods

II.2.1. Literature and Web Review

The literature review involved collecting, analyzing, and synthesizing relevant information from various sources.

II.2.2. Sausage Production

Three sausage formulations were prepared following a production flowchart developed based on the literature review. Figure 1 illustrates the sausage production diagram.

II.2.3. Sensory Analysis

To obtain a comprehensive understanding of the perceived quality of the product, two types of sensory analyses were conducted: descriptive analysis and hedonic evaluation. The objective was to determine the organoleptic properties of the product based on sensory perceptions.

The hedonic and descriptive tests assessed the degree of pleasure provided by the product using a 5-point rating scale (Table 2 and Table 3).

Table 2. Rating scale for hedonic test

Score	Meaning
1	Very unpleasant
2	Unpleasant
3	Neither pleasant nor unpleasant
4	Pleasant
5	Very pleasant

Table 3. Rating scale for descriptive test

Score	Meaning
1	Not pronounced
2	Less pronounced
3	Medium
4	Pronounced
5	Very Pronounced

For the descriptive test, each sensory descriptor was measured on an intensity scale from 1 to 5 across all samples. The descriptors included appearance, odor, texture, taste, and flavor. The 5-point intensity scale is presented in Table 3.

II.2.3.1. Sample Coding

To conduct the tests anonymously and randomly, codes were assigned to each sample. For the hedonic test, codes were: 798 for mixed beef–sheep sausages, 843 for beef-only sausages, and 961 for sheep-only sausages. For the descriptive test, codes were: 372 for mixed beef–sheep sausages, 238 for beef-only, and 115 for sheep-only.

II.2.3.2. Organoleptic Evaluation

Photo 2 shows organoleptic evaluation of the three sausages.

Photo 2: Subjects tasting the samples

Each judge evaluated the three sausage samples based on their sensory perceptions and fulfilled their valuation sheet test.

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II.2.3.3. Filling of Evaluation Sheets

Photo 3 show evaluation sheets for each sample.

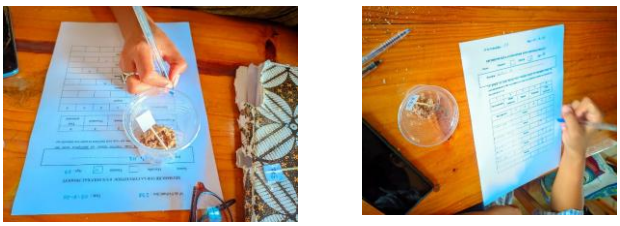

Photo 3: Filling of evaluation sheets

II.2.4. Microbiological Analysis

Microbiological quality was assessed at the ACSQDA laboratory. The targeted microorganisms included coagulase-positive *Staphylococcus*, total coliforms, *Escherichia coli*, and *Bacillus cereus*.

II.2.5. Statistical Analysis of Sensory Data

The completed evaluation sheets were processed using XLStat18 software. Analyses included descriptive statistics and analysis of variance (ANOVA) to detect statistically significant differences in product acceptability.

III. RESULTATS

III.1. Sausage Formulation Technology

The key steps of sausage production are illustrated in the flowchart below (Fig 1).

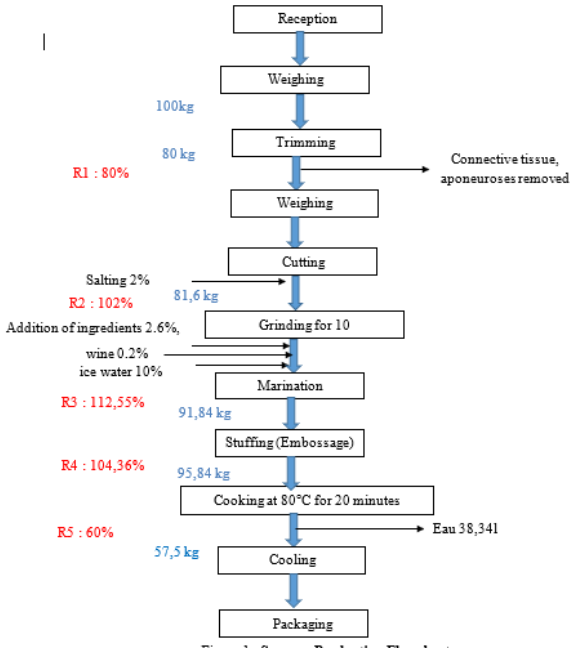

Figure 1 : Sausage Production Flowchart

Notes: R1–R5: mass variation (% each step) Quantities in kg (product weight at that stage).

III.2. Sensory Qualities of Sausages

The results of the hedonic and descriptive evaluations are presented below.

III.2.1. Hedonic Analysis

III.2.1. 1. Average acceptability

The product acceptability results are shown in Table 4.

Table 4. Acceptability results

Panelists	Sample	Mean / 5	Mean / 20	Taste Desciptor
61	798: Mixed	4,4	17,6	Pleasant
	843: 100% beef	3,5	14	Neither pleasant nor unpleasant
	961: 100% sheep	3,5	14	Neither pleasant nor unpleasant

According to Table 4, the mean scores ranged from 4.4 to 3.5, falling within the categories "pleasant" and "neither pleasant nor unpleasant."

III.2.1. 1. 2. Comparison of sample means

Table 5 presents the p-values from the Friedman test comparing the samples.

Table 5. p-values of hedonic comparison of the three sausages

Sample	798: Mixed	843: 100% beef	961: 100%
798: Mixed	1		
843: 100% beef	**< 0,0001**	1	
961: 100%	**0,001**	0,609	1

The Friedman analysis ($P < 0.05$) revealed a statistically significant difference between samples 798 and 843, as well as 798 and 961, indicating distinct preferences. Mixed sausages (798) were the most appreciated, while 100% beef

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(843) and 100% sheep (961) were moderately appreciated. No significant difference was observed between samples 843 and 961 ($p > 0.05$).

III.2.1. 1. 3. Acceptability by age

Figure 3 illustrates average acceptability of samples by age group.

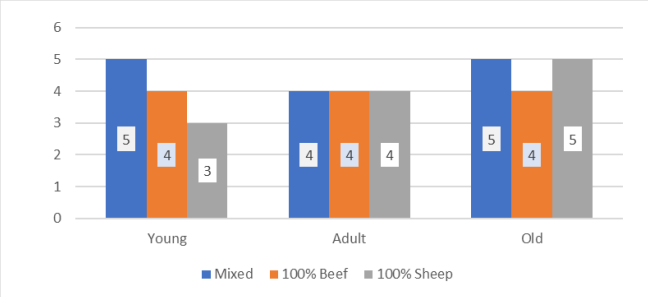

Figure 2: Average acceptability by age

Young consumers preferred the mixed sausage (798), followed by pure beef (843) and pure sheep (961). Adults showed no strong preference among the three products. Older consumers favored the mixed (798) and 100% sheep (961) sausages, and to a lesser extent, pure beef (843).

Acceptability by gender

Figure 4 shows average acceptability of samples by gender.

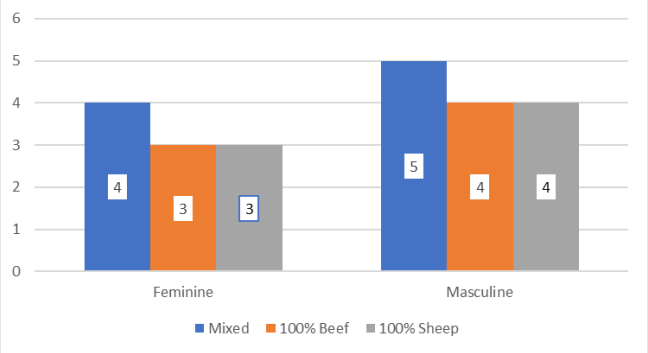

Figure 3: Average acceptability by gender

Both women and men showed higher preference for sample 798 (mixed sausage) compared to the other two samples.

III.3.2. Descriptive Analysis

Figure 4 illustrates the sensory profile of the mixed beef–sheep sausage.

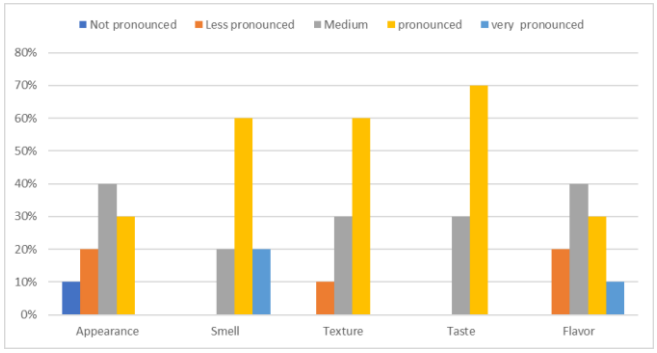

Figure 4: Sensory profile of mixed sausage

The figure shows that the product's sensory characteristics were predominantly perceived as "pronounced," especially flavor and texture. "Medium" intensity was the secondary perception, while low ("not pronounced," "less pronounced") and maximum ("very pronounced") intensities represented only a small part of the overall perception.

III.4. Microbiological Quality

The microbiological quality results of the mixed sausages are presented in Table 6.

Table 6. Microbiological results of mixed sausages

Microorganisms	**Criteria (CFU/g)**	**Results**	**Evaluation**
Total coliforms	$1{,}10.10^2$	<1	Satisfying
Coagulase-positive Staphylococcus	<1	<1	Satisfying
Escherichia coli	10	<1	Satisfying
Bacillus cereus	$1{,}0.\ 10^3$	<1	Satisfying
Conclusion			**Satisfying**

The microbiological analysis confirms that the product fully complies with current reference standards. The absence of pathogenic or harmful microorganisms indicates strict hygiene control throughout the production process. Therefore, the consumer health risk is considered low, demonstrating adherence to Good Manufacturing Practices (GMP).

IV. DISCUSSION

Sausage making is an ancient method for valorizing and preserving meat **[4]** and contributes to diversifying meat products available to consumers. The range of sheep meat products remains limited **[5]**, and promoting consumption, especially among younger generations requires the development of innovative, convenient-to-cook products. This study developed sausages using sheep meat,

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incorporating locally available spices and ingredients, which avoids reliance on imported additives a major constraint in some countries **[6]**.

For fresh sausages, the lean-to-fat ratio is crucial for juiciness, flavor, and texture. Fat content between 20–30% is generally recommended **[7]**. In this study, sausages were made from lean meat only, with salt (2 g/100 g) as the sole flavor enhancer. Salt also contributes to preservation and protein extraction, essential for sausage binding **[8].** In France, this salt content is considered low **[9].**

The production process, including grinding, mixing with ice water to control temperature and ensure binding, stuffing, and marinationwas feasible in a semi-artisanal setting **[10, 11]**. Packaging ensured product transport and traceability.

Consumer testing involved predominantly adult respondents, 64% of whom were women. Adults were targeted for their higher purchasing power and openness to exploring diverse flavors **[12]**, while women are known to consume more charcuterie **[13]**.

Hedonic evaluation (Table 3) showed that mixed beef–sheep sausages were rated between 4 and 5, indicating "pleasant" to "very pleasant." Friedman analysis ($P < 0.05$) confirmed that mixed sausages were preferred over single-meat variants. Beef provides a firm texture and pronounced flavor, while sheep meat offers richer, sometimes subtler aromas and a more tender texture **[14]**. Combining the two results in a balanced flavor profile and controlled juiciness, avoiding excessive dryness (lean beef) or fatness (sheep alone) **[7]**. Sheep-only and beef-only sausages were moderately appreciated, scoring 3.4, with no significant difference, indicating that both can be marketed successfully. Age-wise, younger consumers preferred mixed sausages, older consumers favored mixed or sheep-only, and adults showed no specific preference. These results align with cultural and dietary influences on meat acceptability **[5, 15]**.

The sensory profile of the sausages was characterized as "pronounced," reflecting strong, easily identifiable flavor and texture attributes. Modern consumers also consider animal diet, environmental impact, and welfare in their purchasing decisions **[5, 16]**.

Overall, the study demonstrates that semi-artisanal production of mixed sheep–beef sausages is technically feasible and well accepted by consumers, offering an opportunity to diversify meat products and increase sheep meat consumption.

V. CONCLUSION

In Madagascar, small-ruminant production is primarily oriented toward the sale of fresh meat. However, processing and value addition could become a key driver of development for this sector, particularly because it makes use of by-products that are neither fully consumed nor properly exploited. Two hypotheses were therefore formulated: (1) small-ruminant products and by-products can be valorized, and (2) the transformed products and by-products are acceptable to consumers. The objective of this study is to contribute to food security by enhancing the value of small-ruminant products and by-products.

The methodology included a bibliographic and webographic review, sausage production trials, sensory and microbiological analyses, and finally statistical analysis of the data using XLStat18. The results demonstrate the technical feasibility of producing sausages from mutton in the Boeny Region and confirm their good sensory acceptance, particularly the mixed beef–mutton sausages. Moreover, mutton sausages were found to be as acceptable as beef sausages. The marketing of these mixed sausages could capture a significant market share. The products also displayed satisfactory microbiological quality in compliance with standards.

These findings confirm that mutton can be efficiently transformed into sausages that are acceptable to local consumers. However, although relevant, the hedonic test provides only an overall measure of acceptability. Further research should explore additional value-added products beyond sausages.

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