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Development of sheep-based *jerky beef* analog

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Abstract

Jerky beef is a dehydrated meat product that represents a convenient alternative for animal protein consumption. In response to the growing demand for ready-to-eat foods with high biological value, this study aimed to develop formulations of a sheep-based *jerky beef* analog by evaluating different slice thicknesses and drying temperatures. Samples were prepared at four thicknesses (3, 4, 5, and 6 mm) and subjected to two drying temperatures (60 °C and 70 °C). The products were analyzed for physicochemical composition, color, texture, water activity, drying time, and yield. Both thickness and temperature significantly influenced parameters such as drying time, yield, pH, proximate composition, and color. Among the tested conditions, drying at 70 °C provided superior economic feasibility, particularly in terms of yield, indicating its potential as a promising alternative for the development of sheep-based *jerky beef* analogs.

Keywords: *jerky beef*; sheep meat; protein; dehydration.

Practical Application: Development of innovative sheep-based jerky with optimized drying parameters.

1 INTRODUCTION

The rising demand for functional, ready-to-eat foods rich in high-quality protein and low in fat has driven significant innovation in meat-based snack products (Zdanowska-Sąsiadek et al., 2018). *Jerky*, a dried meat snack typically made from beef, offers convenience, extended shelf life, and nutritional benefits, making it increasingly appealing to health-conscious and on-the-go consumers (He et al., 2023). Dehydrated meat products exhibit reduced water activity and, when processed under appropriate conditions, present a lower microbiological risk. Moreover, they are valued for their distinctive flavor, which enhances their appeal to consumers (Bayinbate et al., 2025; Khan et al., 2015; Lim et al., 2012).

Market reports indicate that the global protein snacks sector is experiencing consistent growth, with projections of significant expansion by 2030, reinforcing the positive trend of this segment (Mordor Intelligence, 2024). Although beef protein has traditionally been the basis for jerky, different studies have explored variations using chicken (Alamuoye et al., 2024), turkey (Aşkın et al., 2022), fish (Kim et al., 2014), and even plant-based alternatives (Kim et al., 2022), highlighting the diversification potential of this category. In this context, the search for new protein sources that combine distinctive nutritional value with technological innovation becomes strategic to meet emerging consumer demands.

Sheep meat offers a compelling alternative raw material due to its favorable fatty acid composition, particularly its content of stearic, oleic, and linoleic acids, which may offer health advantages over more saturated profiles (Junkuszew et al., 2020; Mykolaichuk et al., 2024). Oleic acid has been associated with the reduction of low-density lipoprotein (LDL) cholesterol levels (Pedersen et al., 2025), while linoleic acid has been linked to a lower risk of atherosclerosis and other diseases (Das, 2021; Mercola et al., 2023). Additionally, stearic acid does not affect high-density lipoprotein (HDL) cholesterol (Briggs et al., 2017; Hunter et al., 2010).

In addition to its lipid profile, sheep meat is a relevant source of proteins, vitamins (Zhang et al., 2025), and minerals such as iron (Cabrera & Saadoun, 2014), which reinforces its potential as a functional and nutritious food. Previous studies (Mykolaichuk et al., 2024) have shown that crossbred sheep exhibit higher levels of unsaturated fatty acids and improved omega-6 to omega-3 ratios, thereby enhancing meat quality and nutritional appeal. Such characteristics expand the possibilities for innovation in sheep-based products, particularly in the development of value-added foods that meet the demands of consumers seeking convenience, healthiness, and a diverse range of market options.

According to D'Arrigo et al. (2025), in the coming years, sheep meat consumption is expected to expand in certain countries, becoming more present in the population's diet, while in other regions it will remain restricted to specific consumer groups (OECD & FAO, 2022). In Brazil, however, sheep meat consumption remains quite low, around 0.5 kg per capita/year, a figure well below the global average of 1.78 kg, which highlights that it is

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still a protein consumed in a limited way in the country (Centro de Estudos Avançados em Economia Aplicada [CEPEA], 2023). This discrepancy not only reveals the low domestic consumption habit but also reinforces the need for incentives aimed at diversification and the development of higher-value-added products. Consequently, opportunities for innovations such as jerky analogs and other processed products adapted to the Brazilian consumer profile could increase the sector's competitiveness, enhance the production chain, and meet the growing demand for differentiated, nutritious, and health-oriented foods.

Within this context, the objective of this study was to develop a sheep-based jerky analog and to investigate the impact of slice thickness and drying temperature on its physicochemical properties, yield, and process efficiency. Attributes such as water retention, pH, texture (shear force), color, and yield are known to be affected by processing conditions, including slice thickness and drying temperature (Mishra et al., 2017). Understanding these effects is essential not only to ensure the sensory quality of the final product but also to optimize technological steps, reduce processing losses, and meet the expectations of consumers seeking differentiated, nutritious, and higher value-added meat products. Therefore, the proposed investigation aims to contribute to the development of innovative alternatives in the sheep meat industry, fostering portfolio diversification and enhancing the sector's competitiveness.

1.1 Relevance of the work

The development of sheep-based *jerky beef* analog contributes to diversifying animal protein consumption, adding value to sheep farming, and enhancing the commercial worth of cuts with lower consumer acceptance. Moreover, it meets the growing demand for convenient, nutritious, and shelf-stable foods. The study holds technological and economic relevance by optimizing drying parameters and slice thickness, thereby promoting the sustainable production of innovative food products with strong potential for inclusion in the market of animal-based protein snacks.

2 MATERIAL AND METHODS

2.1 Raw material and processing

The experiments were conducted at the Meat Processing Pilot Plant and the Bromatology Laboratory of the Federal Institute of Education, Science and Technology of Triângulo Mineiro (Uberaba, Brazil) during the second semester of 2019. Sheep (*Longissimus dorsi*) muscles were obtained from animals raised at the institution's experimental facilities. Cuts were trimmed to remove excess fat and connective tissue, frozen, and partially thawed before processing. Meat slices of different thicknesses (3, 4, 5, and 6 mm) were prepared using an electric slicer (Skymsen®, Brazil).

2.2 Formulation and marination

Sliced meat was marinated according to the following formulation: 89.6% sheep meat (Longissimus dorsi), 3.58% water, 1.49% salt, 0.22% curing salt, 0.45% black pepper, 0.17% onion powder, 0.17% garlic powder, 0.17% liquid smoke, and 0.1% chili flakes. The slices were placed in plastic bags with all ingredients, sealed without a vacuum, and manually massaged to promote uniform contact. The marinated samples were stored under refrigeration (4 °C ± 1 °C) for 24 h before drying.

2.3 Drying process

Marinated slices were distributed on perforated trays and dried in a forced-air oven at two different temperatures (60 and 70 °C) until reaching a water activity (aw) of 0.80–0.85. The dried products were cooled to room temperature, packaged in polystyrene trays covered with polyethylene film, and stored until analysis.

2.4 Physicochemical analyses

Physicochemical analyses were performed following standardized procedures. Water activity (aw) was determined in duplicate at 25 ± 0.3 °C using an AquaLab 4TE meter (Decagon Devices, USA). The pH was measured in triplicate by homogenizing minced samples with distilled water and recording the values with a digital pH meter (T-1000, TEKNAL, Brazil), previously calibrated with buffer solutions at pH 4.0 and 7.0. Color was assessed using a colorimeter (CR-400, Konica Minolta, Japan) under the CIELAB system, with parameters L* (lightness), a* (red-green), and b* (yellow-blue), averaging five random readings per sample. Proximate composition was determined according to AOAC International (2005) methodologies, where moisture content was obtained by oven-drying at 105 °C until constant weight, ash content by incineration in a muffle furnace at 550 °C, protein content by the Kjeldahl method using a nitrogen-to-protein conversion factor of 6.25, and lipid content by Soxhlet extraction. Texture was evaluated through shear force measurements performed in triplicate using a texture analyzer (TA.XT2 Plus, Stable Micro Systems, UK) equipped with a Warner-Bratzler blade (1 mm thickness) operating at a crosshead speed of 200 mm/min.

2.5 Process variables

Drying time was recorded as the interval (min) from the start of drying until the samples reached the target aw. Yield was calculated as the ratio of dried product weight to the initial batch weight (raw meat plus ingredients), expressed as a percentage.

2.6 Experimental design and statistical analysis

The experiment followed a completely randomized design with a 2 × 4 factorial arrangement: two drying temperatures (60 °C and 70 °C) and four slice thicknesses (3, 4, 5, and 6 mm), with three replicates ($n = 24$). Data were analyzed using analysis of variance (ANOVA), and mean comparisons were performed by Tukey's test at a 5% significance level. Regression analysis was applied when appropriate. Statistical analyses were performed using SISVAR software (v. 5.6, UFLA, Brazil).

3 RESULTS AND DISCUSSION

The sheep jerky analog produced in this study visually resembled traditional beef jerky. However, the lack of antifungal preservatives led to fungal growth during ambient storage, underscoring the need for antimicrobial hurdles beyond dehydration. While drying reduces water activity, it is not sufficient for fungal control—strategies such as clean-label natural additives (e.g., lactates, diacetates), active packaging, bacteriocins embedded in packaging, or modified-atmosphere techniques are essential to extend shelf life (Al-Mohammadi, 2025; Bodie et al., 2024; Carneiro et al., 2024; Mediani et al., 2022; Yu et al., 2021).

Analysis of variance (Table 1) revealed significant interactions ($p < .05$) between drying temperature and slice thickness for drying time, yield, pH, instrumental color (a and b*), ash, lipid, and protein contents, indicating that both factors jointly influenced the technological properties of the product. Drying kinetics followed the expected trend: increasing slice thickness extended drying time, while higher temperatures accelerated moisture removal (Figure 1). A similar trend was demonstrated in thin-layer convective drying of beef, where drying time increased with thickness and decreased with temperature (Mewa et al., 2018). Reviews on meat drying kinetics further confirm that temperature and sample geometry critically modulate diffusion rates, processing time, and final quality attributes (Álvarez et al., 2021).

Table 1. Analysis of variance summary for sheep jerky analog produced with different slice thicknesses and drying temperatures.

Variable	Effect	df^1	*p*-value
Drying time	Temperature (T)	1	< .0001*
	Thickness (E)	3	< .0001*
	T × E	3	< .0001*
Yield	Temperature (T)	1	< .0001*
	Thickness (E)	3	< .0001*
	T × E	3	< .0001*
Water activity	Temperature (T)	1	.1984 ns
	Thickness (E)	3	< .0001*
	T × E	3	.3193 ns
pH	Temperature (T)	1	< .0001*
	Thickness (E)	3	< .0001*
	T × E	3	< .0001*
Color L*	Temperature (T)	1	.0939 ns
	Thickness (E)	3	.0579 ns
	T × E	3	.2947 ns
Color a*	Temperature (T)	1	.0012*
	Thickness (E)	3	.0226*
	T × E	3	.0038*
Color b*	Temperature (T)	1	.0066*
	Thickness (E)	3	.0098*
	T × E	3	.0009*
Moisture	Temperature (T)	1	.0006*
	Thickness (E)	3	.0002*
	T × E	3	.1882 ns
Ash	Temperature (T)	1	< .0001*
	Thickness (E)	3	< .0001*
	T × E	3	.0166*
Lipids	Temperature (T)	1	.2458 ns
	Thickness (E)	3	.0090*
	T × E	3	.0006*
Proteins	Temperature (T)	1	.0005*
	Thickness (E)	3	.0443*
	T × E	3	0.0008*
Texture	Temperature (T)	1	0.0196*
	Thickness (E)	3	0.9126 ns
	T × E	3	0.8408 ns

df^1: degrees of freedom; ns: not significant; *significant at $p < .05$.

Yield was also strongly affected by the interaction of slice thickness and drying conditions (Figure 2). Thinner slices (< 5 mm) dried at 60 °C showed higher yield, whereas thicker slices benefited from drying at 70 °C, likely due to reduced exposure time at elevated temperatures. Regardless of temperature, increased slice thickness led to lower yield, reflecting longer drying durations and greater weight loss. These trends align with findings from drying kinetics research: multifactor analysis confirms that temperature and exposure time critically influence yield in meat drying (Kim et al., 2021), and higher temperatures promote moisture diffusion and reduce processing time in beef jerky (Shi et al., 2021).

Water activity (a_w) values across treatments ranged from 0.80 to 0.85, as illustrated in Figure 3A. This range is critical for controlling most pathogenic bacteria but remains insufficient to guarantee fungal stability without the application of additional hurdles. Slice thickness exerted a significant effect on aw, with thicker slices showing lower values, likely due to a

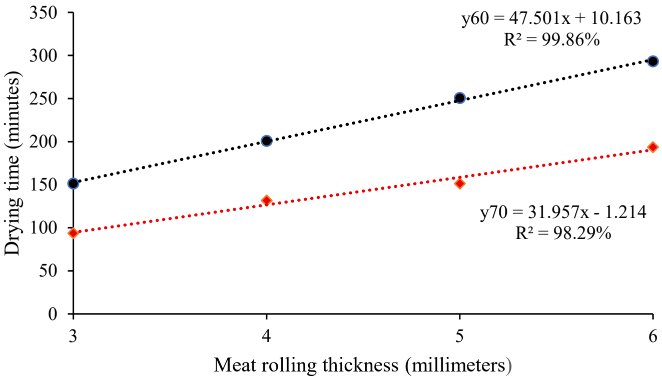

Figure 1. Drying time of sheep jerky analog produced with different slice thicknesses and drying temperatures (60 °C and 70 °C).

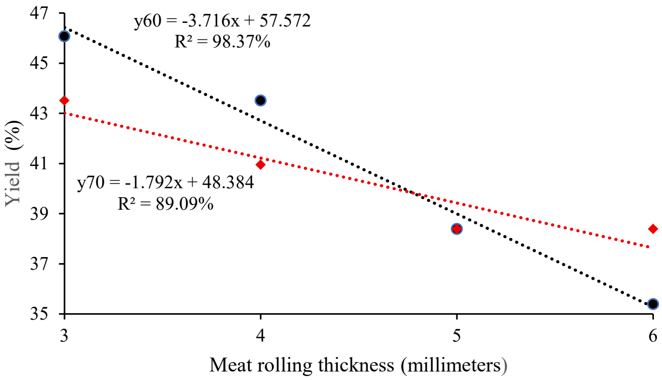

Figure 2. Yield of sheep jerky analog produced with different slice thicknesses and drying temperatures (60 °C and 70 °C).

greater retention of bound water while losing more free water during drying. Water activity values between 0.80 and 0.85 are characteristic of intermediate-moisture foods, including jerky, which generally inhibit the growth of pathogenic bacteria but remain permissive to xerophilic molds and osmotolerant yeasts. Therefore, complementary hurdles such as salt addition, acidification, or advanced packaging systems are required to ensure microbial stability (Beuchat, 1983; Yu et al., 2021). This finding underscores that water activity alone cannot ensure fungal stability, reinforcing the concept of hurdle technology, which combines multiple preservation factors—such as reduced aw, acidification, and packaging interventions—to improve microbial safety and shelf life (Barbosa-Cánovas et al., 2020; Leistner, 1995). Recent advances further highlight the potential of multitarget preservation strategies, including the integration of physical processes and natural antimicrobial agents, as promising alternatives for clean-label meat products (Kaur et al., 2022). The observation that thicker slices exhibited lower aw is consistent with drying-kinetics research, which demonstrates that sample geometry and thickness significantly influence dehydration rates and the quality attributes of dried meat (Álvarez et al., 2021; Shi et al., 2021). Furthermore, this behavior can be explained by the differential loss of free water rather than total moisture, since aw predominantly reflects the fraction of thermodynamically available water for microbial activity (Barbosa-Cánovas et al., 2020).

The pH of the samples increased slightly with slice thickness, particularly at 70 °C (Figure 3B). Although values remained within the typical range for dried meat products, the trend may indicate concentration effects or proteolytic activity during prolonged drying. Instrumental color analysis showed no significant changes in lightness (L*), confirming the naturally dark appearance of ovine meat.

Redness (a*) and yellowness (b*) were influenced by both temperature and thickness (Figures 4A and 4B, respectively). At 70 °C, samples generally exhibited higher a* values, suggesting greater retention of red pigments, in contrast to the expected stronger browning at elevated temperatures. This apparent discrepancy can be explained by complex interactions between Maillard reactions, pigment oxidation, and dehydration rates, as also reported in jerky products dried under advanced technologies such as super-heated steam (Kim et al., 2021). Similar patterns linking sample geometry, drying conditions, and quality attributes—including pH and color—have been described in thin-layer beef drying experiments (Mewa et al., 2018).

Proximate composition results are presented in Table 2. Moisture content was lower in samples dried at 70 °C compared with those dried at 60 °C, reflecting the greater efficiency of moisture removal at higher drying temperatures. Lipid contents showed minor variations among treatments, with slight differences observed depending on slice thickness and drying temperature. Protein values ranged from approximately 42% to 46%, which is consistent with values commonly reported for dehydrated meat products such as jerky (Lim et al., 2014; Kim et al., 2021). Ash contents tended to be higher in samples dried at 70 °C, likely due to the concentration effect associated

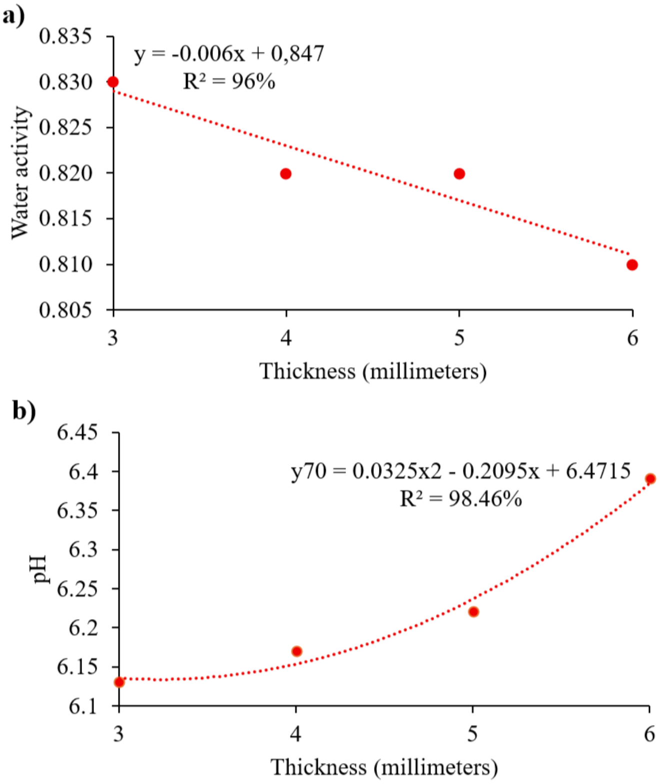

Figure 3. Water activity **(a)** and pH **(b)** of sheep jerky analog produced with different slice thicknesses at 70 °C.

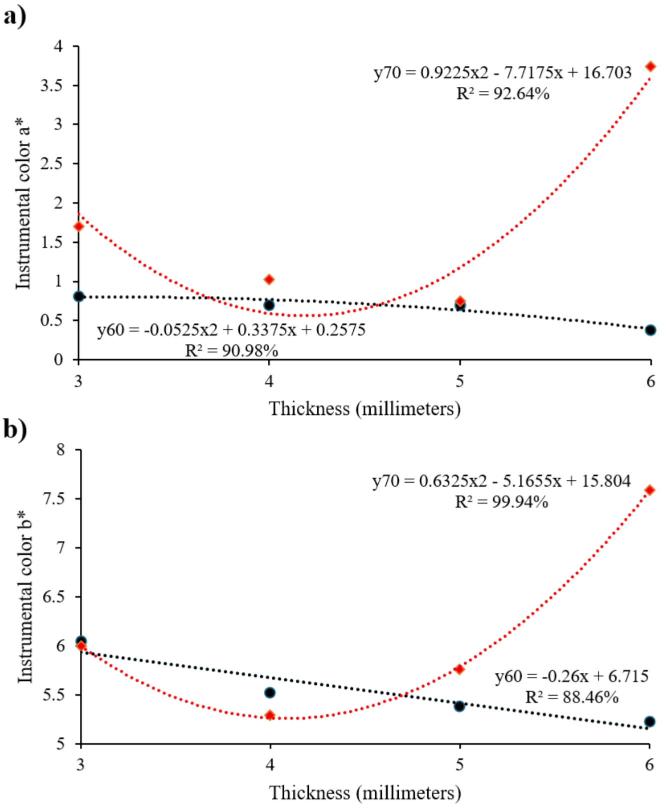

Figure 4. Instrumental color parameters a* **(a)** and b* **(b)** of sheep jerky analog produced with different slice thicknesses and drying temperatures (60 °C and 70 °C).

Table 2. Proximate composition (g/100 g) of sheep jerky analogue produced with different slice thicknesses and drying temperatures.

Temperature	Moisture	Lipids				Proteins				Ashes			
		3 mm	4 mm	5 mm	6 mm	3 mm	4 mm	5 mm	6 mm	3 mm	4 mm	5 mm	6 mm
60 °C	38.74^{a}	3.62^{a}	2.53^{a}	3.49^{a}	2.50^{b}	45.50^{a}	42.88^{b}	43.11^{a}	43.37^{b}	5.55^{b}	6.47^{b}	6.41^{b}	7.22^{b}
70 °C	34.48^{b}	2.91^{b}	2.89^{a}	2.72^{b}	3.07^{a}	44.28^{a}	46.24^{a}	43.95^{a}	46.25^{a}	6.25^{a}	7.07^{a}	7.33^{a}	9.03^{a}

Means followed by the same letter within each column do not differ significantly according to Tukey's test ($p < .05$).

with increased moisture loss during drying. Overall, the results demonstrate that drying temperature influences the concentration of some compositional components, primarily through the reduction of moisture during the dehydration process. The drying temperature significantly influenced the shear force of the sheep jerky analog. Samples dried at 60 °C showed an average shear force of 6.92 kg, which was significantly higher than the value observed for samples dried at 70 °C (4.62 kg, $p < .05$), contrary to expectations. These results indicate that increasing the drying temperature resulted in products with lower cutting resistance. This finding contrasts with the general association between moisture loss and increased toughness (Bourne, 2002) but may be explained by structural modifications induced by prolonged drying at lower temperatures. Similar patterns have been reported in jerky studies, where drying conditions affected protein aggregation and microstructural collapse, ultimately increasing toughness at extended drying times (Kim et al., 2021; Shi et al., 2021). Additional microstructural and sensory investigations are warranted to confirm these hypotheses.

Overall, the results demonstrate that both drying temperature and slice thickness strongly influence the technological and quality attributes of sheep jerky analogs. Optimization of these parameters is essential to balance yield, texture, and color, while ensuring microbiological stability. Future studies should integrate natural antimicrobials, improved packaging, and sensory analysis to support the development of sheep-based jerky as a viable alternative to traditional beef jerky in the functional snack market.

4 CONCLUSIONS

This study demonstrated that both drying temperature and slice thickness significantly affected the physicochemical and technological properties of sheep jerky analogs. Higher drying temperature (70 °C) reduced drying time and resulted in products with lower moisture content, softer texture, and higher yield at greater slice thicknesses, while 60 °C preserved yield at lower thicknesses but required extended drying times. Color parameters were influenced by both factors, although sheep jerky maintained the inherently darker appearance of ovine meat. Despite these promising results, the absence of antifungal preservatives led to fungal growth during storage, underscoring the need for additional preservation strategies to ensure microbiological stability.

Overall, sheep jerky analogs represent a viable alternative to traditional beef jerky, offering opportunities for diversification and added value in the sheep meat industry. Future research should focus on incorporating natural antimicrobials, optimizing packaging technologies, and conducting sensory analyses to validate consumer acceptance and ensure product stability during extended storage.

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