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DEVELOPMENT OF A NEXT-GENERATION MEAT PRODUCT ENRICHED WITH *Astragalus membranaceus* AND EXPLORING ITS POTENTIAL

Bianca-Georgiana ANCHIDIN, Mihai-Cătălin CIOBOTARU, Diana-Remina MANOLIU, Adnana-Gabriela SANDU, Cristina TĂBUREANU, Marius-Mihai CIOBANU, Paul-Corneliu BOIȘTEANU

"Ion Ionescu dela Brad" Iasi University of Life Sciences, 3 Mihail Sadoveanu Alley, 700490, Iasi, Romania

Corresponding author email: marius.ciobanu@iuls.ro

Abstract

The food industry, and especially the meat industry, is in a constant search for new, innovative products that meet the increasingly demanding requirements of consumers who are looking for functional products, rich in benefits and without synthetic additives, in line with the trends of recent years. With this idea in mind, we developed this new type of beef product in the form of sticks, which would incorporate both the benefits of the meat and the added Astragalus membranaceus, an antioxidant superfood, and meet the demand for innovation that consumers are demanding. For this study, three batches of products were produced: a control batch without added Astrogalus membranaceus and two experimental batches with added Astrogalus in 1 and 3%. All three batches were evaluated for physicochemical characteristics, instrumental colour, texture, antioxidant activity, bioactive compound profile, and sensory properties, including hedonic assessment, QDA, and PCA. The results showed that Astragalus membranaceus powder significantly influenced most quality parameters, particularly antioxidant activity, phytochemical composition, colour, texture, and sensory descriptors, with the strongest effects generally observed at the 3% addition level.

Key words*: antioxidants, beef meat products, functional foods, innovative meat products, sensory evaluation.*

INTRODUCTION

The meat industry is one of the largest industries worldwide and, due to strong consumer demand and intense market competition, new products are continuously being developed (Boișteanu et al., 2025)

Having nutritional components of major importance, including essential amino acids, fatty acids, vitamins, and minerals that are crucial for regular physiological and biochemical activities, meat and meat products are valuable foods in the diet (Anchidin et al., 2024a, 2024b; Ciobanu et al., 2025; Manoliu et al., 2023). However, consumers frequently characterize meat in an unfavorable way, describing it as a food that promotes the occurrence of cancer and is rich in fat. Nevertheless, this perspective minimizes the vital role that meat plays in preserving human health (Anchidin et al., 2023, 2025b; Ciobotaru et al., 2025).

In recent years, the way in which consumers perceive meat products from a health perspective has changed (Sirini et al., 2022). The increased interest in the beneficial attributes of meat, which meet the nutritional needs of consumers, has been supported by recent studies on consumers' perceptions and attitudes toward meat (Boișteanu et al., 2024; Flocea et al., 2024). Also, because it combines flavor, tenderness, and nutritional value, meat quality is crucial for both producers and consumers (Mădescu et al., 2025).

Consumers are increasingly aware of the link between health and nutrition nowadays (Manoliu et al., 2024) and of the need to meet the growing consumer demand for healthier options (Ciobotaru et al., 2024). Therefore, the food industry conducts extensive research and develops new products in response to the growing consumer demand for these products (Gucianu et al., 2025). The reformulation of meat products that deliberately include animal proteins and valuable bioactive components obtained from plants has been driven by the global movement toward a sustainable and health-promoting diet (Manoliu et al., 2025b). In

addition, these functional additives may have two purposes: they can improve nutritional and energy intake, while at the same time providing some protection against the occurrence of chronic diseases (Gucianu et al., 2023; Manoliu et al., 2025a).

Beyond improving the nutritional profile, the reformulation of meat products must also respond to essential technological requirements, such as maintaining oxidative stability, extending shelf life, and preserving sensory characteristics, because these are significantly influenced by oxidative stability. Undesirable alterations in sensory qualities and nutritional value result from the oxidation of proteins and lipids (Torres-Martínez et al., 2026).

At the same time, these technological and nutritional concerns must be integrated into a broader perspective on sustainability and food security. Food preservation has represented and continues to represent one of the fundamental objectives of food security, considering the need to ensure physical and economic access to essential foods (Petcu et al., 2023). Due to its substantial effects on the economy, ecology, and society, food waste represents a key challenge for global food security (Gucianu et al., 2024), including the control of chemical contaminants that may originate from processing, packaging, or from food contact with different materials (Matei & Pop, 2023).

Antioxidants, vitamins, minerals, or fibers generated from plants and plant materials with a high content of bioactive components, such as phenolic compounds, are examples of natural substances that are increasingly used for preserving and improving meat quality (Anchidin et al., 2025). Since lipid and protein oxidation simultaneously impacts odor, taste, color, nutritional content, and sensory acceptability, it continues to be one of the most important causes of meat product deterioration from a technological point of view (Manessis et al., 2020; Pateiro et al., 2021).

Recent research on meat preservation supports this strategy, demonstrating that plant extracts, essential oils, and other bioactive substances derived from plants are investigated for their antimicrobial and antioxidant qualities, which can help prevent oxidation, prevent the development of microorganisms that cause spoilage, and extend the shelf life of meat products. In this food system, plant bioactive compounds include polyphenols, flavonoids, tannins, terpenes, alkaloids, saponins, and coumarin. These compounds can act as preservation agents and can have an impact on the physical and chemical properties of meat products when used under appropriate conditions and concentrations (Akacha et al., 2023; Campolina et al., 2023; Chang et al., 2022; Elgadir et al., 2025; Olvera-Aguirre et al., 2023; Shah et al., 2014).

Astragalus membranaceus is a plant species of interest for this type of use. This plant includes a variety of bioactive compounds, such as polysaccharides, saponins, flavonoids, amino acids, and trace elements. Astragalosides I-IV, formononetin, isorhamnetin, quercetin, kaempferol, and calycosin are mentioned in the specialized literature (Yao et al., 2024; Zhang et al., 2024). These elements have been associated with hepatoprotective, immunomodulatory, anti-inflammatory, and antioxidant properties (Guo et al., 2019). According to these points of view, *Astragalus membranaceus* is a viable source of bioactive components for functional foods, and research demonstrating its antioxidant effects and improvement of physiological status in a variety of biological and food systems supports its potential (Dong et al., 2023).

The capacity of *Astragalus membranaceus* to improve the oxidative stability and nutritional functionality of products justifies the interest in it from the perspective of food applications. Research on *Astragalus* supplementation in animal diets and in meat has shown improvements in their quality and antioxidant capacity, indicating that the components of this plant may also be useful in the creation of functional meat products (Luo et al., 2020; Qiao et al., 2022).

Simultaneously, research on meat snacks demonstrates that the addition of natural ingredients can considerably modify the physicochemical characteristics, oxidative stability, color, texture, and sensory acceptance (Aşkın et al., 2022; Aykın-Dinçer et al., 2026). Thus, the nutritional profile and shelf life of meat products can be considerably improved through the addition of plant bioingredients (Flocea et al., 2025). Plant-based ingredients have been efficiently incorporated into products

such as dried meat and meat sticks to improve their functional profile and to encourage the creation of more attractive substitutes for consumers seeking healthier options (Aşkın et al., 2022; Peulić et al., 2025).

In addition, meat snacks, such as dried meat and meat snacks, have become a significant category of products due to consumer demand for ready-to-eat foods with high protein content and long shelf life. However, the quality of the final product depends largely on the control of the technological process and oxidative stability (Aşkın et al., 2022; Peulić et al., 2025).

Natural additives from plant products can provide oxidative stability and can support consumer-friendly formulations, according to findings reported in the specialized literature for dried meat products and other meat products. However, the result ultimately depends on the dosage, the type of functional ingredient added, and the way in which it interacts with proteins and lipids in the meat matrix (Das et al., 2021; Domínguez et al., 2020; Gullón et al., 2020).

The addition of plant ingredients to meat snacks can have two different effects: on the one hand, it can increase the amount of phenolic compounds and antioxidant activity; on the other hand, it can modify texture parameters, such as elasticity, tenderness, and chewiness, requiring a careful balance between functional benefit and sensory quality (Aykın-Dinçer et al., 2026; Yiğit & Dinçer, 2025).

Based on these premises, the present study aims to develop an innovative beef-based snack product enriched with *Astragalus membranaceus* and to evaluate its technological and functional potential by determining color and texture, as well as physicochemical, sensory, antioxidant, and bioactive compound analyses. The main purpose is to determine whether the addition of this plant can support the development of an innovative meat product with improved properties and potential application in the category of meat products.

MATERIALS AND METHODS

Three different beef-based product variations were made for the experiment: two experimental formulations that were supplemented with 1% and 3% *Astragalus membranaceus* root powder, respectively, and one control formulation that did not contain the powder. The items were acquired in the IULS microproduction workshop for processing meat and meat products.

The meat raw materials used for product manufacture consisted of beef round and beef shoulder, purchased from Selgros Cash & Carry SRL, Iași, Romania. Semolina flour produced by La Molisana was purchased from a local retail store in Iași and was used as a technological ingredient in the formulation. The bioactive plant ingredient, represented by *Astragalus membranaceus* root powder, was purchased from Paradisul Verde, Brașov, Romania, under the commercial form of raw organic *Astragalus membranaceus* powder. The seasoning mixture and auxiliary ingredients were supplied by a local company from Iași County, Romania.

The experimental batches and the ingredients included in their formulation are presented in Table 1, expressed in percentage form.

Table 1. Experimental formulation of beef snack samples enriched with *Astragalus membranaceus* powder

Batch code	Composition of raw materials and ingredients										
	Beef round	Beef chuck	Semola flour	*Astragalus* root powder	Salt	Smoked paprika	Garlic powder	Ground pepper	Onion powder	Ground cumin	Chili flakes
SA0	51.00	35.50	11.00	0.00	1.30	0.25	0.28	0.18	0.18	0.16	0.10
SA1	50.40	34.90	11.20	1.00			0.27			0.17	
SA3	49.20	34.10	11.30	3.00		0.24	0.25			0.15	

SA0 – control sample without *Astragalus membranaceus* powder; SA1 – sample supplemented with 1% *Astragalus membranaceus* powder; SA3 – sample supplemented with 3% *Astragalus membranaceus* powder.

The beef snack samples were obtained through a series of steps in the technological process. The meat raw materials were first combined with the auxiliary ingredients, and then they were coarsely ground in a meat grinder. After that, the mixture was finely ground in a cutter to combine the spice mixture, semolina flour, and *Astragalus membranaceus* powder in

accordance with each batch's formulation. After the mixture was homogenised, it was moved to a dosing machine and formed into beef sticks using a filling nozzle that was about 20 cm long and had an 18 mm diameter. The created samples were put into the smoking and heat-treatment room after being arranged on stainless steel racks.

Table 2 presents the thermal processing parameters applied to all experimental batches.

Table 2. Thermal processing parameters applied to beef snack samples

Stage	Technological operation	Temperature	Time
I	Preliminary drying	60°C	30 min
II	Smoking	70°C	35 min
III	Heat treatment	-	Until reaching 72°C in the thermal center
IV	Final drying	75°C	90 min

Following the thermal treatment, the samples were vacuum-packed, chilled in a refrigerator, and kept at 2-4°C until additional laboratory testing.

The analytical evaluation of the beef snack samples included physicochemical, phytochemical, antioxidant, and sensory determinations. The physicochemical and instrumental analyses consisted of pH measurement, instrumental color assessment, texture profile analysis and Warner-Bratzler shear force test, and the determination of proximate composition, including moisture, protein, fat, carbohydrate, and ash contents. In addition, the phytochemical profile and antioxidant potential of the samples were evaluated by determining total phenolic content and radical-scavenging activity using DPPH and ABTS assays. A portable pH meter HI98163 (SC Hanna Instruments SRL) with a penetration electrode was used to measure the pH directly in the product, and the CIE L*a*b* method was used to determine colour parameters in accordance with the guidelines for evaluating meat colour (King et al., 2023). To better characterise the colour variance among the experimental samples, derived colour parameters such as Chroma (C*), hue angle (h°), and total colour difference (ΔE*) were computed in addition to the primary colour coordinates L*, a*, and b*.

Chroma (C*), hue angle (h°), and total color difference (ΔE*) were calculated according to Girolami et al. (2013), (Song et al., 2022), and (Tkacz et al., 2020), using the following equations:

$$\text{Chroma (C*)} = \sqrt{(a^*)^2 + (b*)^2} \quad (1)$$

$$\text{Hue angle (h*)} = tan^{-1} \times b^*/a^* \quad (2)$$

$$\Delta E^* = \sqrt{\Delta a^{*2} + \Delta b^{*2} + \Delta L^{*2}} \quad (3)$$

Moisture, protein, fat, and ash contents were determined using standard analytical procedures, namely the drying oven method, Kjeldahl method, Soxhlet extraction method, and muffle furnace method, respectively, according to AOAC Internațional (Horwitz & International, 2000). Carbohydrate content was calculated by difference (Vulić et al., 2024).

The antioxidant activity and bioactive compound content were determined according to (Echegaray et al., 2021), using the DPPH and ABTS assays for antioxidant activity and spectrophotometric methods for total polyphenols, flavonoids, total carotenoids, lycopene, and β-carotene. The absorbance was measured using a UV–Vis spectrophotometer, Specord Plus 210 (Analytik Jena, Germany).

In order to ensure that food products meet the necessary quality requirements, sensory testing is a crucial tool that helps identify defects, off-flavors, and other quality issues that could compromise the overall attractiveness of a product (Ciobanu et al., 2023). In the present study, sensory analysis was performed using hedonic evaluation, Quantitative Descriptive Analysis (QDA), and Principal Component Analysis (PCA), according to Boișteanu et al. (2025) with the participation of 20 semi-trained assessors.

The statistical processing of the experimental data was carried out using XLSTAT software.

One-way ANOVA was applied for the physicochemical, color, texture, and sensory parameters, while two-way ANOVA was used for antioxidant activity and bioactive compound content. The overall *p*-value was used to evaluate the significance of the tested factors. When significant differences were observed, Tukey's post hoc test was applied for multiple comparisons among samples, while Dunnett's test was used to compare each experimental sample with the control sample. Differences were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSIONS

Physicochemical characteristics of beef snack samples

The incorporation of *Astragalus membranaceus* powder significantly affected all physicochemical parameters of the beef snack samples (Table 3), as indicated by the global *p*-values ($p < 0.05$). Moisture, protein, fat, and pH decreased progressively with increasing levels of Astragalus, with both SA1 and SA3 differing significantly from the control according to Dunnett's test ($p < 0.05$). In contrast, dry matter and carbohydrate content increased significantly in the supplemented samples ($p < 0.05$), reflecting the contribution of the plant powder to the non-meat solid fraction of the formulation. Ash content showed a more moderate response: although the global effect was significant ($p = 0.014$), Dunnett's test indicated that only SA3 differed significantly from SA0, while SA1 remained statistically similar to the control. Similar effects have been reported in beef patties enriched with dried pumpkin pulp and seed mixture, where the addition of plant material decreased moisture and increased ash content, confirming that plant-based ingredients can modify the proximate composition of meat matrices (Serdaroğlu et al., 2018).

Table 3. Physicochemical characteristics of beef snack samples supplemented with *Astragalus membranaceus* powder

Parameter	Samples			Global	Dunnett	Dunnett
	SA0	SA1	SA3	*p*-value	SA0 vs. SA1	SA0 vs. SA3
Moisture (%)	57.51 ± 0.16^{a}	57.16 ± 0.07^{b}	56.90 ± 0.08^{c}	**<0.0001*** **	**0.001*** **	**<0.0001*** **
Dry matter (%)	42.49 ± 0.16^{c}	42.84 ± 0.07^{b}	43.10 ± 0.08^{a}	**<0.0001*** **	**0.001*** **	**<0.0001*** **
Protein (%)	18.26 ± 0.11^{a}	18.09 ± 0.05^{b}	17.85 ± 0.07^{c}	**<0.0001*** **	**0.015***	**<0.0001*** **
Fat (%)	22.82 ± 0.10^{a}	22.49 ± 0.06^{b}	22.17 ± 0.07^{c}	**<0.0001*** **	**<0.0001*** **	**<0.0001*** **
Carbohydrates	0.03 ± 0.05^{c}	0.81 ± 0.07^{b}	1.54 ± 0.17^{a}	**<0.0001*** **	**<0.0001*** **	**<0.0001*** **
Ash	1.37 ± 0.08^{b}	1.45 ± 0.06^{ab}	1.53 ± 0.06^{a}	**0.014***	0.188^{ns}	**0.008****
pH	6.42 ± 0.02^{a}	6.37 ± 0.02^{b}	6.32 ± 0.02^{c}	**<0.0001*** **	**0.002****	**<0.0001*** **

Data are presented as mean ± SEM (standard error of the mean). Different superscript letters in the same row indicate statistically significant differences among samples ($p < 0.05$). SA0, control sample; SA1, sample with 1% *Astragalus membranaceus* powder; SA3, sample with 3% *Astragalus membranaceus* powder. ns, not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Results of colour analysis

The incorporation of *Astragalus membranaceus* powder produced a selective effect on the instrumental colour of the beef snack samples (Table 4). The lightness parameter L* was not significantly affected by formulation, as shown by both the global *p*-value (p = 0.784) and Dunnett comparisons for SA0 vs. SA1 and SA0 vs. SA3, indicating that the addition of *Astragalus* did not substantially modify sample brightness. In contrast, a* decreased significantly from SA0 to SA3, showing a reduction in redness, while b* showed significant differences among samples, with SA1 presenting the lowest value and SA3 partially recovering yellowness. These changes were also reflected in the derived colour parameters: Chroma (C*) decreased significantly with *Astragalus* addition, suggesting lower colour saturation, whereas hue angle (h°) increased progressively, indicating a shift in colour tone. The total colour difference ΔE increased from SA1 to SA3, confirming that the 3% addition produced a more pronounced visual deviation from the control.

The Dunnett test supports this interpretation: except for L*, both supplemented samples differed significantly ($p < 0.05$) from the control for a*, C* and h°, while for b* the difference

was significant but stronger in SA3 than in SA1. Similar effects have been reported in meat systems supplemented with plant-derived ingredients, where the incorporation of botanical powders or polyphenol-rich extracts modified redness, yellowness, Chroma and hue angle due to pigment dilution, matrix interactions and the intrinsic colour of the added plant material.

The colour changes observed in the present study are consistent with previous findings on beef products supplemented with plant-derived antioxidant ingredients. Zahid et al. (2018) reported that grape seed extract and clove extract influenced the evolution of L*, a*, b*, Chroma, and hue angle in beef patties during refrigerated storage, indicating that natural antioxidant extracts may contribute to colour stability by limiting oxidative discoloration. In a similar meat matrix, Fruet et al. (2020) showed that the addition of tannin extract from Quebracho Colorado wood reduced redness and Chroma values and increased hue angle, suggesting a shift toward a less intense red colour and greater browning tendency, depending on the concentration and intrinsic colour of the extract used.

Table 4. Instrumental color parameters of beef snack samples supplemented with *Astragalus membranaceus* powder

Colour parameter	Samples			Global *p*-value	Dunnett SA0 vs. SA1	Dunnett SA0 vs. SA3
	SA0	SA1	SA3			
L*	46.81 ± 0.65^{a}	44.42 ± 0.48^{a}	44.13 ± 0.24^{a}	0.784^{ns}	0.830^{ns}	0.981^{ns}
a*	18.03 ± 0.37^{a}	16.16 ± 0.10^{b}	15.26 ± 0.27^{c}	**<0.0001*****	**<0.0001*****	**<0.0001*****
b*	18.47 ± 0.48^{b}	17.42 ± 0.16^{b}	18.13 ± 0.14^{a}	**<0.0001*****	**0.042***	**<0.0001*****
Croma (C*)	25.96 ± 0.26^{a}	24.86 ± 0.23^{b}	24.27 ± 0.16^{c}	**<0.0001*****	**<0.0001*****	**<0.0001*****
Hue angle (h°)	0.80 ± 0.01^{c}	0.88 ± 0.01^{b}	0.97 ± 0.01^{a}	**<0.0001*****	**<0.0001*****	**<0.0001*****
ΔE	-	2.26 ± 0.40	4.59 ± 0.36	**<0.0001*****	-	-

Data are presented as mean ± SEM. Different superscript letters in the same row indicate statistically significant differences among samples ($p < 0.05$). SA0, control sample; SA1, sample with 1% *Astragalus membranaceus* powder; SA3, sample with 3% *Astragalus membranaceus* powder. ns, not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Results of texture analysis

Texture analysis revealed marked changes in the mechanical behaviour of the beef snack samples supplemented with Astragalus membranaceus powder (Table 5). Warner–Bratzler shear force increased from SA0 to SA3, with a significant global effect ($p = 0.010$), although Dunnett's test indicated that only SA3 differed very significantly from the control ($p = 0.006$). Work of shear also increased significantly in both supplemented samples ($p = 0.000$), suggesting greater resistance of the product structure to cutting. This tendency can be associated with the physicochemical changes observed in the samples, particularly the reduction in moisture and the increase in dry matter and carbohydrate content, which may have contributed to a more compact meat matrix (Table 3).

The TPA parameters confirmed this trend. Hardness, cohesiveness, and gumminess increased significantly in SA1 and SA3 compared with SA0 ($p < 0.05$), indicating that the addition of *Astragalus powder* promoted a firmer and more cohesive structure. At the same time, springiness decreased significantly in the supplemented samples, suggesting a reduction in elasticity as the level of plant powder increased. In contrast, chewiness and adhesiveness were not significantly affected ($p > 0.05$), as shown by both the global *p*-values and Dunnett comparisons, indicating that the main structural effects were related to firmness, cohesion, and shear resistance rather than to all texture dimensions.

This behaviour is consistent with previous observations in meat products enriched with plant-derived ingredients, where fibre and carbohydrate-rich materials may modify water retention, increase the solid fraction of the formulation, and influence protein–matrix interactions, leading to changes in hardness, cohesiveness, gumminess, and shear force (Marczak & Mendes, 2024; Mehta et al., 2015).

Table 5.Warner-Bratzler and Texture Profile Analysis parameters of beef snack samples supplemented with *Astragalus membranaceus* powder

Texture test	Texture parameter	Samples			Global *p*-value	Dunnett SA0 vs. SA1	Dunnett SA0 vs. SA3
		SA0	SA1	SA3			
Warner-Bratzler	Shear force, N/cm^2	15.18 ± 0.97^{b}	16.71 ± 1.26^{ab}	17.49 ± 0.70^{a}	**0.010***	0.058^{ns}	**0.006****
	Work of shear, mJ	47.13 ± 4.67^{b}	55.72 ± 2.19^{a}	59.07 ± 1.34^{a}	**0.000*****	**0.002****	**0.000*****
Texture Profile analysis (TPA)	Hardness, N	33.36 ± 0.78^{b}	35.67 ± 1.16^{a}	36.72 ± 0.67^{a}	**0.000*****	**0.003****	**0.000*****
	Cohesiveness, -	0.46 ± 0.03^{b}	0.51 ± 0.02^{a}	0.52 ± 0.03^{a}	**0.002****	**0.006****	**0.001****
	Springiness, -	0.71 ± 0.07^{a}	0.59 ± 0.05^{b}	0.58 ± 0.06^{b}	**0.009****	**0.014***	**0.010***
	Gumminess, N	15.22 ± 1.13^{b}	18.20 ± 1.01^{a}	19.24 ± 0.94^{a}	**0.000*****	**0.001*****	**0.000*****
	Chewiness N	10.80 ± 1.56^{a}	10.71 ± 1.09^{a}	11.21 ± 1.46^{a}	0.833^{ns}	0.991^{ns}	0.858^{ns}
	Adhesiveness, mJ	0.52 ± 0.04^{a}	0.53 ± 0.02^{a}	0.56 ± 0.01^{a}	0.074^{ns}	0.987^{ns}	0.075^{ns}

Data are presented as mean ± SEM. Different superscript letters in the same row indicate statistically significant differences among samples ($p < 0.05$). SA0, control sample; SA1, sample with 1% *Astragalus membranaceus* powder; SA3, sample with 3% *Astragalus membranaceus* powder. ns, not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Results of antioxidant and bioactive compounds

The bioactive profile of *Astragalus membranaceus* root powder is presented in Table 6. The powder showed high antioxidant activity, with DPPH and ABTS inhibition values of 74.59% and 76.94%, respectively, indicating a strong radical-scavenging potential.

Table 6. Bioactive compounds and antioxidant activity of *Astragalus membranaceus* root powder

Parameters	*Astragalus membranaceus* root powder
DPPH inhibition (%)	74.59 ± 0.34
ABTS inhibition (%)	76.94 ± 0.17
Total flavonoids (mg CE/g DW)	0.86 ± 0.01
Total polyphenols (mg GAE/g DW)	3.16 ± 0.03
Total carotenoids (mg CT/g DW)	0.50 ± 0.01
β-caroten (mg/g DW)	0.32 ± 0.00
Lycopene (mg/g DW)	0.13 ± 0.00

Values are expressed as mean ± standard error of the mean. DPPH and ABTS results are expressed as inhibition percentage. CE: catechin equivalents; GAE: gallic acid equivalents; CT: carotenoid equivalents; DW: dry weight.

Among the quantified bioactive compounds, total polyphenols had the highest value (3.16 mg GAE/g DW), followed by total flavonoids (0.86 mg CE/g DW) and total carotenoids (0.50 mg CT/g DW).

The presence of β-carotene and lycopene further supports the contribution of *Astragalus membranaceus* powder as a plant ingredient with antioxidant and bioactive potential, justifying its use in the formulation of the experimental beef snack samples.

The results presented in Table 7 show that both *Astragalus membranaceus* concentration and thermal treatment influenced the antioxidant activity and the bioactive compound profile of the beef snack samples, but the magnitude of these effects depended on the analysed parameter. The percentage of *Astragalus powder* had a significant effect on all parameters evaluated (*p*-value Concentration < 0.0001), confirming that the progressive enrichment from SA0 to SA3 was the main factor responsible for the increase in DPPH and ABTS inhibition, total flavonoids, total polyphenols, carotenoids, β-carotene and lycopene. This result is consistent with the composition of the plant powder itself, which showed high DPPH and ABTS inhibition values and relevant contents of total polyphenols, flavonoids and carotenoids Table 6. Therefore, the increase observed in SA1 and SA3 can be directly associated with the bioactive contribution of *Astragalus membranaceus* root powder.

Thermal treatment had a more selective influence. It significantly affected DPPH inhibition, total polyphenols, total carotenoids, β-carotene and lycopene ($p < 0.05$), while its effect was not significant for ABTS inhibition and total flavonoids ($p > 0.05$). This indicates that heating did not uniformly reduce the antioxidant potential of the samples; in some cases, heat-treated samples showed higher DPPH, ABTS or polyphenol values than untreated samples. Similar observations have been reported in studies on plant-derived antioxidants and meat systems, where phenolic-rich ingredients may increase antioxidant capacity and where processing can modify the availability and activity of bioactive compounds. Similar effects were reported by Xu

et al. (2007), who showed that heat treatment increased the free fraction of phenolic acids and the total antioxidant activity of citrus peel extracts. Călinoiu & Vodnar (2019) also reported that thermal processing improved total phenolic content in wheat and oat bran by 22.49% and 25.84%, respectively, supporting the idea that heating can promote the release of phenolic compounds from plant matrices. Therefore, in the present study, the higher DPPH, ABTS, and polyphenol values observed in some heat-treated samples may be associated with the thermal release of bioactive compounds from *Astragalus membranaceus* powder and their improved extractability within the meat matrix.

Table 7. Bioactive compounds and antioxidant activity of untreated and heat-treated beef snack samples supplemented with *Astragalus membranaceus* powder

Parameter	Thermal treatment	Samples			*p*-value Treatment	*p*-value Concentration	*p*-value % × Treatment
		SA0	SA1	SA3			
DPPH inhibition (%)	Untreated	15.76 ± 0.20	28.54 ± 0.15	32.65 ± 0.20	**<0.0001*** **	**<0.0001*** **	**<0.0001*** **
	Heat-treated	16.94 ± 0.12	30.54 ± 0.17	35.75 ± 0.12			
ABTS inhibition (%)	Untreated	16.74 ± 0.23	24.87 ± 13.47	34.41 ± 0.33	0.067^{ns}	**<0.0001*** **	0.455^{ns}
	Heat-treated	17.84 ± 0.23	32.15 ± 0.14	37.75 ± 0.12			
Total flavonoids (mg CE/g DW)	Untreated	0.20 ± 0.02	0.34 ± 0.16	0.76 ± 0.01	0.772^{ns}	**<0.0001*** **	**0.001*** **
	Heat-treated	0.24 ± 0.01	0.46 ± 0.01	0.62 ± 0.01			
Total polyphenols (mg GAE/g DW)	Untreated	0.18 ± 0.02	0.64 ± 0.02	0.90 ± 0.02	**0.003** *	**<0.0001*** **	**<0.0001*** **
	Heat-treated	0.22 ± 0.02	0.71 ± 0.03	0.72 ± 0.01			
Total carotenoids (mg CT/g DW)	Untreated	–	0.29 ± 0.01	0.41 ± 0.01	**<0.0001*** **	**<0.0001*** **	**<0.0001*** **
	Heat-treated	–	0.26 ± 0.01	0.32 ± 0.01			
β-caroten (mg/g DW)	Untreated	–	0.17 ± 0.01	0.27 ± 0.01	**0.022***	**<0.0001*** **	**<0.0001*** **
	Heat-treated	–	0.20 ± 0.01	0.22 ± 0.01			
Lycopene (mg/g DW)	Untreated	–	0.04 ± 0.01	0.07 ± 0.00	**<0.0001*** **	**<0.0001*** **	**<0.0001*** **
	Heat-treated	–	0.07 ± 0.01	0.08 ± 0.01			

Values are expressed as mean ± standard error of the mean. DPPH and ABTS results are expressed as inhibition percentage. CE: catechin equivalents; GAE: gallic acid equivalents; CT: carotenoid equivalents; DW: dry weight. SA0, control sample; SA1, sample with 1% *Astragalus membranaceus* powder; SA3, sample with 3% *Astragalus membranaceus* powder. ns, not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The significant Concentration × Treatment interaction observed for DPPH inhibition, total flavonoids, total polyphenols, total carotenoids, β-carotene and lycopene indicates that the effect of thermal treatment depended on the concentration of *Astragalus* powder. For example, total polyphenols increased after heat treatment in SA0 and SA1, but decreased in SA3, suggesting that higher levels of plant powder may behave differently during thermal processing. Similarly, carotenoids and β-carotene showed concentration-dependent changes after heating, which may reflect both thermal degradation and enhanced release from the plant–meat matrix. In contrast, the interaction was not significant for ABTS inhibition ($p > 0.05$), indicating a more stable response of this assay across thermal conditions. Studies on *Astragalus membranaceus* also support its relevance as a source of phenolic and antioxidant compounds, with recent research reporting antioxidant activity and phenolic compounds in *A. membranaceus* extracts and

modified plant materials (Liu et al., 2024; Shahrivari-Baviloliaei et al., 2024).

Overall, the data indicate that *Astragalus membranaceus* root powder acted as an effective source of bioactive compounds in the beef snack formulation, with the 3% addition generally producing the highest antioxidant and phytochemical values. However, the significant interactions for several parameters show that the final bioactive profile was not determined only by concentration, but also by the way in which the plant powder responded to thermal processing within the meat matrix.

Hedonic analysis

The hedonic analysis of beef meat sticks supplemented with *Astragalus* showed a generally favourable sensory perception across all evaluated attributes (Figure 1). SA0 presented the highest scores, while SA1 remained very close to the control, indicating that the lower level of *Astragalus* incorporation maintained a balanced hedonic profile in terms of appearance, odour, taste, texture, and overall perception. Although SA3 showed slightly lower scores, the values remained within an acceptable sensory range, suggesting that *Astragalus* addition was compatible with the product matrix, with only moderate changes in consumer perception at the higher inclusion level. A similar trend was reported by Lee et al. (2021)who observed that the use of herbal medicinal extracts, including *Astragalus membranaceus*, in cooked meat products did not negatively affect key visual and eating-quality attributes, supporting the potential use of herbal ingredients in meat product development.

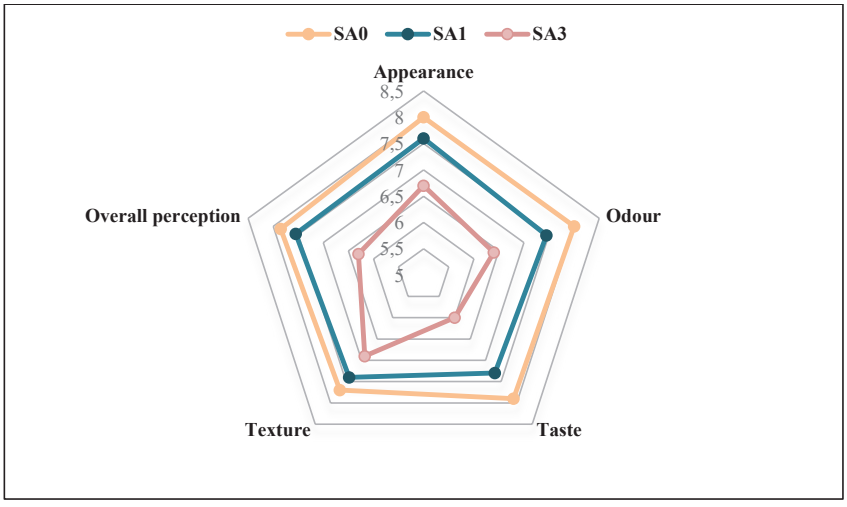

Figure 1. Hedonic analysis of samples

Quantitative Descriptive Analysis

The QDA results (Table 8) showed that the incorporation of *Astragalus membranaceus* powder induced a differentiated sensory profile in beef meat sticks, mainly by increasing the intensity of yellowish-brown colour, herbal odour, herbal taste, bitterness, astringency, and aftertaste. These changes were dose-dependent, with SA3 showing the most pronounced sensory differentiation from the control. However, the core meat-related attributes, including brown colour, cooked meat odour, specific beef odour, cooked meat aroma, texture, and juiciness, remained at relatively high intensity levels, indicating that the beef matrix was still sensorially recognizable after supplementation. The non-significant differences observed for spicy odour and texture suggest that *Astragalus* addition did not substantially alter these dimensions of the product. Similar findings were reported by Lee et al. (2021), who observed that herbal medicinal extracts, including *Astragalus membranaceus*, could be incorporated into cooked meat systems without impairing key quality traits, while producing specific changes in colour, flavour, and

palatability. In addition, Szymandera-Buszka et al. (2020) showed that plant-derived extracts can modify the aroma and taste profile of meat products, particularly through herbal, spicy, essential-oil-like or bitter notes, while the final acceptability depends on the balance between these added sensory notes and the characteristic meat flavour.

Table 8. Sensory attributes evaluated by Quantitative Descriptive Analysis (QDA) in beef snack samples supplemented with *Astragalus membranaceus* powder

Sensory attribute	Samples			*p*-value
	SA0	SA1	SA3	
Brown colour	8.10 ± 0.85^{a}	7.65 ± 1.23^{ab}	7.10 ± 1.12^{b}	**0.034***
Yellowish-brown colour	1.20 ± 0.41^{c}	2.35 ± 1.04^{b}	4.10 ± 0.97^{a}	**<0.0001****
Cooked meat odour	8.05 ± 0.76^{a}	7.60 ± 1.19^{ab}	6.90 ± 1.02^{b}	**0.004****
Specific beef odour	7.85 ± 0.99^{a}	7.45 ± 1.05^{ab}	6.75 ± 1.12^{b}	**0.009****
Herbal odour	1.10 ± 0.31^{c}	3.10 ± 1.07^{b}	5.70 ± 0.92^{a}	**<0.0001****
Spicy odour	3.80 ± 1.06^{a}	3.95 ± 1.23^{a}	4.10 ± 0.97^{a}	0.732^{ns}
Off-odour	1.05 ± 0.22^{b}	1.20 ± 0.41^{ab}	1.55 ± 0.60^{a}	**0.007****
Cooked meat aroma	8.00 ± 0.73^{a}	7.55 ± 1.28^{ab}	6.80 ± 1.01^{b}	**0.004****
Herbal taste	1.10 ± 0.31^{c}	3.05 ± 0.94^{b}	5.70 ± 0.92^{a}	**<0.0001****
Bitterness	1.25 ± 0.64^{c}	2.40 ± 0.99^{b}	4.75 ± 1.16^{a}	**<0.0001****
Astringency	1.15 ± 0.49^{c}	2.20 ± 1.01^{b}	4.40 ± 0.99^{a}	**<0.0001****
Texture	7.60 ± 1.19^{a}	7.35 ± 1.09^{a}	6.85 ± 0.88^{a}	0.070^{ns}
Juiciness	7.20 ± 1.06^{a}	7.00 ± 0.86^{ab}	6.45 ± 1.10^{b}	**0.050***
Aftertaste	1.40 ± 0.75^{c}	2.75 ± 1.21^{b}	5.10 ± 1.02^{a}	**<0.0001****
Overall acceptability	7.85 ± 0.99^{a}	7.65 ± 1.23^{a}	6.35 ± 1.14^{b}	**0.000****

Data are presented as mean ± SD. Different superscript letters in the same row indicate statistically significant differences among samples ($p < 0.05$). SA0, control sample; SA1, sample with 1% *Astragalus membranaceus* powder; SA3, sample with 3% *Astragalus membranaceus* powder. ns, not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Principal Component Analysis

The PCA biplot (Figure 2) revealed a well-defined association between the beef meat stick formulations and the sensory descriptors generated by QDA. SA0 was mainly correlated with conventional meat-related attributes, including brown colour, cooked meat odour, cooked meat aroma, and specific beef odour, confirming the predominance of the typical beef sensory profile in the control sample. SA1 was closely associated with overall acceptability, juiciness, texture, and spicy odour, suggesting that the lower level of *Astragalus membranaceus* powder supported a balanced sensory configuration, in which the meat matrix and the added botanical ingredient were sensorially well integrated. SA3 was primarily correlated with descriptors reflecting the contribution of *Astragalus membranaceus*, such as herbal odour, herbal aroma, herbal taste, slightly green colour, aftertaste, bitterness, astringency, and off-odour. These associations indicate that increasing the addition level enhanced the perception of plant-derived sensory notes and contributed to a more differentiated sensory identity of the product. Overall, the PCA confirms that sample discrimination was governed mainly by the interaction between the beef matrix and the intensity of *Astragalus*-related sensory attributes.

The PCA partially supports the QDA results presented in Table 8, but also highlights some differences in the way sensory attributes contributed to sample discrimination. According to the QDA data, SA0 showed higher intensities for brown colour, cooked meat odour, specific beef odour, and cooked meat aroma, whereas SA3 presented significantly higher values for yellowish-brown colour, herbal odour, herbal taste, bitterness, astringency, aftertaste, and off-odour. These trends are generally reflected in the PCA, where SA0 was positioned in relation to meat-related descriptors, while SA3 was associated with attributes linked to the sensory contribution of *Astragalus membranaceus*.

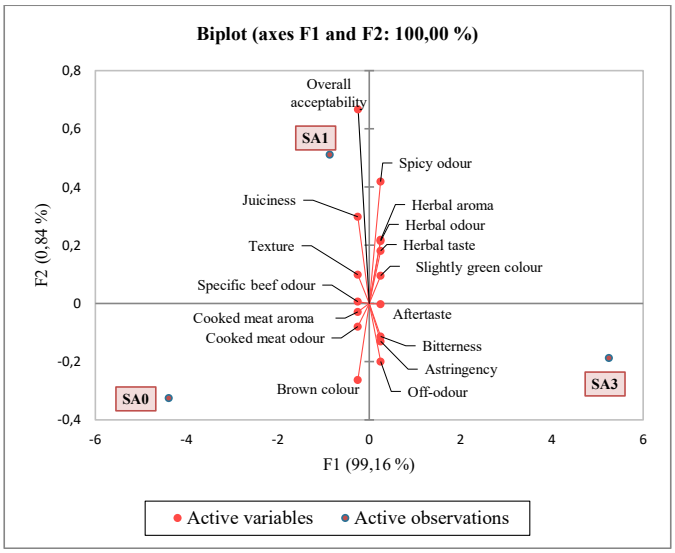

Figure 2. PCA biplot of QDA sensory attributes in beef meat sticks supplemented with *Astragalus membranaceus* powder

However, some attributes with significant differences in the QDA table, such as juiciness and off-odour, had a weaker contribution to the graphical separation in the PCA compared with herbal, bitter, astringent, and aftertaste descriptors. In contrast, texture and spicy odour, which were not significantly different among samples in the QDA analysis, appeared closer to SA1 in the PCA, suggesting that their role was more related to the overall sensory configuration of this sample rather than to strong statistical discrimination among formulations. Thus, PCA complements the univariate QDA results by showing how the attributes act together in defining the sensory identity of each beef snack formulation.

CONCLUSIONS

The incorporation of *Astragalus membranaceus* powder influenced the physicochemical, bioactive, textural, colour, and sensory characteristics of beef snack samples in a concentration-dependent manner. Increasing levels of *Astragalus* slightly reduced moisture, protein, fat, and pH, while increasing dry matter, carbohydrates, and ash content, indicating a clear contribution of the plant powder to the solid fraction of the formulation.

Instrumental colour and texture analyses showed that *Astragalus* addition modified redness, colour saturation, hue angle, shear resistance, hardness, cohesiveness, and gumminess, while lightness, chewiness, and adhesiveness were less affected. These changes suggest that the plant powder interacted with the meat matrix, contributing to a slightly firmer and more structured product.

From a bioactive perspective, *Astragalus membranaceus* root powder improved the antioxidant and phytochemical profile of beef snacks, mainly in a concentration-dependent manner. SA3 generally showed the highest values, confirming the contribution of the plant powder. Thermal treatment frequently increased DPPH and ABTS inhibition, suggesting a possible enhancement of antioxidant compound release or extractability within the meat matrix. Thus, the bioactive potential of the samples was influenced by both *Astragalus* concentration and thermal processing.

The sensory results confirmed that the supplemented samples maintained acceptable sensory characteristics. Hedonic analysis showed that SA1 remained close to the control sample, indicating good consumer perception at the lower inclusion level. QDA and PCA further demonstrated that SA0 was associated with typical beef-related attributes, SA1 with balanced sensory characteristics and overall acceptability, while SA3 was more strongly associated with plant-derived descriptors such

as herbal odour, herbal taste, bitterness, astringency, and aftertaste.

REFERENCES

Akacha, B.B., Michalak, M., Najar, B., Venturi, F., Taglieri, I., Kačániová, M., Saad, R. B., Mnif, W., Garzoli, S., & Hsouna, A.B. (2023). Recent Advances in the Incorporation of Polysaccharides with Antioxidant and Antibacterial Functions to Preserve the Quality and Shelf Life of Meat Products. *Foods*, *12*(8). https://doi.org/10.3390/foods12081647.

Anchidin, B. G., Ciobanu, M. M., Ciobotaru, C., Gucianu, I., & Boișteanu, C. (2024a). Enhancing Antioxidant Capacity in Functional Meat Products Through Infusion with Sea Buckthorn Oil to Combat Inherent Antioxidant Deficiency. *Scientific Papers. Series D. Animal Science*, *LXVII*(1), 366-380.

Anchidin, B. G., Gucianu, I., Lipșa, F.-D., Ciobanu, M. M., Flocea, E.-I., & Boișteanu, P. C. (2024b). From Waste to Valuable Food: Development and Qualitative Differential Characterization of Bone Broths from Juvenile and Adult Cattle. *Scientific Papers. Series D. Animal Science*, *LXVII*(1), 355-365.

Anchidin, B.-G., Gucianu, I., Munteanu, M., Ciobanu, M.-M., & Boișteanu, P.-C. (2025a). Quality Characterisation and Consumer Perception of a Novel Functional Beef Snack Enriched with Maca (*Lepidium Meyenii*). *Scientific Papers. Series D. Animal Science*, *LXVIII*(1), 647-661.

Anchidin, B.-G., Manoliu, D.-R., Ciobanu, M. M., Gucianu, I., & Boișteanu, P. C. (2023). Development of a Functional Meat Product with Sea Buckthorn Oil and Analysis of its Sensory and Physicochemical Quality. *Scientific Papers. Series D. Animal Science, LXVI*(1), 370-376.

Anchidin, B.-G., Manoliu, D.-R., Munteanu, M., & Ciobanu, M.-M. (2025b). Formulation of a Functional Meat Product with a Compact Structure by Incorporating *Cetraria Islandica*, a Underexploited Ingredient, and Evaluation of its Potential in the Meat Industry. *Scientific Papers. Series D. Animal Science*, *LXVIII*(1), 629-646.

Aşkın, O. O., Kaynarca, G. B., Solak, M., & Samancı, M. (2022). Turkey Jerky as a Potantial Meat Snack. *International Journal of Innovative Approaches in Agricultural Research, 6*(2), 129-143. https://doi.org/10.29329/ijiaar.2022.451.6.

Aykın-Dinçer, E., Yiğit, C., Işık, H., Gücüöz, A., & Dinçer, C. (2026). Pomegranate Peel Powder as an Antioxidant and Natural Colorant in Snack Meat Sticks. *Journal of Food Quality, 1*, 7462871. https://doi.org/10.1155/jfq/7462871.

Boișteanu, P.C., Anchidin, B.-G., & Ciobanu, M.M. (2025). Exploring Sensory Attributes in Spinach- and Offals-Filled Chicken Roulades: An Empirical Analysis. *Foods*, *14*(2). https://doi.org/10.3390/foods14020303.

Boișteanu, P.C., Flocea, E.I., Anchidin, B.G., Mădescu, B.M., Matei, M., Murariu, O. C., Frunză, G., Postolache, A. N., & Ciobanu, M.M. (2024). Essential and toxic elements analysis of wild boar tissues from north-eastern Romania and health risk implications. *Frontiers in Sustainable Food Systems*, *8*. https://doi.org/10.3389/fsufs.2024.1406579.

Campolina, G. A., Cardoso, M. D. G., Caetano, A. R. S., Nelson, D. L., & Ramos, E. M. (2023). Essential Oil and Plant Extracts as Preservatives and Natural Antioxidants Applied to Meat and Meat Products: A Review. *Food Technology and Biotechnology, 61*(2), 212-225. https://doi.org/10.17113/ftb.61.02.23.7883.

Călinoiu, L. F., & Vodnar, D. C. (2019). Thermal Processing for the Release of Phenolic Compounds from Wheat and Oat Bran. *Biomolecules*, *10*(1), 21. https://doi.org/10.3390/biom10010021.

Chang, X., Chen, X., Guo, Y., Gong, P., Pei, S., Wang, D., Wang, P., Wang, M., & Chen, F. (2022). Advances in Chemical Composition, Extraction Techniques, Analytical Methods, and Biological Activity of Astragali Radix. *Molecules*, *27*(3). https://doi.org/10.3390/molecules27031058.

Ciobanu, M. M., Manoliu, D. R., Ciobotaru, M. C., Flocea, E. I., Anchidin, B. G., Postolache, A. N., & Boișteanu, P. C. (2023). Sensorial Characterization of Mutton Products in Membrane Made in the Meat *Processing. Scientific Papers. Series D. Animal Science*, *LXVI*(2), 453-458.

Ciobanu, M.M., Frunză, G., Anchidin, B.G., & Munteanu, M. (2025). Substitution of Soybean with Chickpea in the Development of a Functional Poultry Meat Product. *Scientific Papers. Series D. Animal Science*, *LXVIII*(1), 662-675.

Ciobotaru, M.C., Ciobanu, M.M., Manoliu, D.R., & Boișteanu, P.C. (2025). Enhancing Pork Tenderloin Quality Parameters Through Soy Protein Isolate Brine-Injection. *Scientific Papers. Series D. Animal Science*, *LXVIII*(1), 684-690.

Ciobotaru, M. C., Manoliu, D.-R., Matei, M., Calcan, R. A., Boișteanu, P. C., & Ciobanu, M. M. (2024). Qualitative Differences Caused by the Addition of Liquid Smoke in Meat Products with Different Structures Compared to Traditional Smoking. *Scientific Papers. Series D. Animal Science*, *LXVII*(1), 404-413.

Das, A. K., Nanda, P. K., Chowdhury, N. R., Dandapat, P., Gagaoua, M., Chauhan, P., Pateiro, M., & Lorenzo, J. M. (2021). Application of Pomegranate by-Products in Muscle Foods: Oxidative Indices, Colour Stability, Shelf Life and Health Benefits. *Molecules*, *26*(2). https://doi.org/10.3390/molecules26020467.

Domínguez, R., Gullón, P., Pateiro, M., Munekata, P. E. S., Zhang, W., & Lorenzo, J. M. (2020). Tomato as Potential Source of Natural Additives for Meat Industry. A Review. *Antioxidants*, *9*(1). https://doi.org/10.3390/antiox9010073.

Dong, M., Li, J., Yang, D., Li, M., & Wei, J. (2023). Biosynthesis and Pharmacological Activities of Flavonoids, Triterpene Saponins and Polysaccharides Derived from Astragalus membranaceus. *Molecules*, *28*(13). https://doi.org/10.3390/molecules28135018.

Echegaray, N., Pateiro, M., Munekata, P. E. S., Lorenzo, J. M., Chabani, Z., Farag, M. A., & Domínguez, R. (2021). Measurement of Antioxidant Capacity of Meat and Meat Products: Methods and Applications.

Molecules, *26*(13). https://doi.org/10.3390/molecules26133880.

Elgadir, M. A., Alhudhaibi, A. M., Abdallah, E. M., & Adiletta, G. (2025). Plant-based preservation of meat: A critical narrative review of bioactive extracts, essential oils, and next-generation delivery systems. *Frontiers in Sustainable Food Systems*, *9*. https://doi.org/10.3389/fsufs.2025.1722227.

Flocea, E.I., Ciobanu, M.M., Anchidin, B.G., Ciobotaru, C., Manoliu, D.R., Gucianu, I., Matei, M., & Boișteanu, C. (2024). Evaluation of the Impact of Artificial Additive on Physicochemical Quality Parameters in a Functional Meat Product with Heterogeneous Structure. *Scientific Papers. Series D. Animal Science, LXVII*(1), 443-450.

Flocea, E.I., Gucianu, I., Manoliu, D.R., Anchidin, B.G., Ciobanu, M.M., & Boișteanu, P.C. (2025). Functional Effects of Vegetable Bioingredients in Fish-Based Products: A Systematic Review. *Scientific Papers. Series D. Animal Science*, *LXVIII*(1), 620-628.

Fruet, A. P. B., Giotto, F. M., Fonseca, M. A., Nörnberg, J. L., & De Mello, A. S. (2020). Effects of the Incorporation of Tannin Extract from Quebracho Colorado Wood on Color Parameters, Lipid Oxidation, and Sensory Attributes of Beef Patties. *Foods*, *9*(5), 667. https://doi.org/10.3390/foods9050667.

Girolami, A., Napolitano, F., Faraone, D., & Braghieri, A. (2013). Measurement of meat color using a computer vision system. *Meat Science*, *93*(1), 111-118. https://doi.org/10.1016/j.meatsci.2012.08.010.

Gucianu, I., Anchidin, B. G., Manoliu, D.-R., Ciobotaru, M. C., Boișteanu, P. C., Postolache, A. N., & Ciobanu, M. M. (2023). Smoking Temperature Characteristics and Influence of Quality Indicators on Phytophagus Fillet. *Scientific Papers. Series D. Animal Science*, *LXVI*(2), 512-516.

Gucianu, I., Flocea, E.I., Anchidin, B.G., Ciobanu, M.M., & Boișteanu, P. C. (2025). Analysis of a Functional Product from Carp (*Cyprinus Carpio*) Waste in the Context of the Circular Economy. *Scientific Papers. Series D. Animal Science*, *LXVIII*(1), 591-597.

Gucianu, I., Lipșa, F.D., Anchidin, B.G., Flocea, E.I., Boișteanu, P.C., & Ciobanu, M.M. (2024). Combating Food Waste by Making a Functional Product from a Slaughterhouse By-Product and Profiling its Nutritional Value. *Scientific Papers. Series D. Animal Science*, *LXVII*(1), 457-464.

Gullón, P., Astray, G., Gullón, B., Tomasevic, I., & Lorenzo, J. M. (2020). Pomegranate Peel as Suitable Source of High-Added Value Bioactives: Tailored Functionalized Meat Products. *Molecules*, *25*(12). https://doi.org/10.3390/molecules25122859.

Guo, Z., Lou, Y., Kong, M., Luo, Q., Liu, Z., & Wu, J. (2019). A Systematic Review of Phytochemistry, Pharmacology and Pharmacokinetics on Astragali Radix: Implications for Astragali Radix as a Personalized Medicine. *International Journal of Molecular Sciences*, *20*(6). https://doi.org/10.3390/ijms20061463.

Horwitz, W., & International, A. (2000). Official Methods of Analysis of AOAC International. AOAC International.

King, D. A., Hunt, M. C., Barbut, S., Claus, J. R., Cornforth, D. P., Joseph, P., Kim, Y. H. B., Lindahl, G., Mancini, R. A., Nair, M. N., Merok, K. J., Milkowski, A., Mohan, A., Pohlman, F., Ramanathan, R., Raines, C. R., Seyfert, M., Sørheim, O., Suman, S. P., & Weber, M. (2023). American Meat Science Association Guidelines for Meat Color Measurement. *Meat and Muscle Biology*, *6*(4). https://doi.org/10.22175/mmb.12473.

Lee, B., Park, C. H., Kim, J. Y., Hyeonbin, O., Kim, D., Cho, D. K., Kim, Y. S., & Choi, Y. M. (2021). Effects of *Astragalus membranaceus*, *Adenophora triphylla*, and *Ulmus pumila* Extracts on Quality Characteristics and Storage Stability of Sous-Vide Cooked Chicken Breasts. *Korean Journal for Food Science of Animal Resources*, *41*(4), 664-673. https://doi.org/10.5851/kosfa.2021.e24.

Liu, N., An, X., Wang, Y., Qi, J., Jia, Y., Li, X., Zhang, Z., & Chen, X. (2024). Polyphenol composition and antioxidant activity of fermentation combined with enzymatic hydrolysis modified *Astragalus membranaceus* stems. *Chemical and Biological Technologies in Agriculture*, *11*(1), 153. https://doi.org/10.1186/s40538-024-00674-x.

Luo, Y., Su, L., Su, R., Wang, B., Liu, C., Wang, Z., Zhao, L., & Jin, Y. (2020). Effects of *Astragalus membranaceus* supplementation on oxidative stability of Cashmere goat. *Food Science & Nutrition, 8*(10), 5550-5556. https://doi.org/10.1002/fsn3.1786.

Manessis, G., Kalogianni, A. I., Lazou, T., Moschovas, M., Bossis, I., & Gelasakis, A. I. (2020). Plant-Derived Natural Antioxidants in Meat and Meat Products. *Antioxidants*, *9*(12). https://doi.org/10.3390/antiox9121215.

Manoliu, D.R., Ciobanu, M.M., Ciobotaru, M.C., Anchidin, B.G., & Boișteanu, P.C. (2024). The Impact of Fruit Fiber on Meat Products: A Mini Review. *Scientific Papers. Series D. Animal Science, LXVII*(1), 481-489.

Manoliu, D.R., Ciobanu, M.M., Ciobotaru, M.C., Postolache, A.N., Anchidin, B.G., & Boișteanu, P.C. (2023). Physico-Chemical and Sensory Evaluation of Three Types of Pork Mortadella Manufactured in the IULS Meat Processing Microsection. *Scientific Papers. Series D. Animal Science*, *LXVI*(2), 527-531.

Manoliu, D.R., Ciobotaru, C., Anchidin, B.G., Ciobanu, M.M., & Boișteanu, P.C. (2025a). Reformulation of an Organ-Based Meat Product with Pumpkin Powder: A Strategy for Fiber Enrichment. *Scientific Papers. Series D. Animal Science*, *LXVIII*(1), 438-477.

Manoliu, D.R., Ciobotaru, M.C., Ciobanu, M.M., & Boișteanu, P.C. (2025b). Development and Characterization of Meat-Based Pasta Enriched with Apple and Sugar Beet Fibers. *Foods*, *14*(22). https://doi.org/10.3390/foods14223837.

Marczak, A., & Mendes, A. C. (2024). Dietary Fibers: Shaping Textural and Functional Properties of Processed Meats and Plant-Based Meat Alternatives. *Foods*, *13*(12), 1952. https://doi.org/10.3390/foods13121952.

Matei, M., & Pop, I.M. (2023). Mineral Oil Hydrocarbons (MOH) Analysis in Animal Feed: A Characterization

Based on Modern Pollution. *Scientific Papers. Series D. Animal Science*, *LXVI*(1), 113-122.

Mădescu, B. M., Matei, M., Davidescu, M. A., Bolohan (Acornicesei), I., Lazăr, R., Ciobanu, M. M., Simeanu, D., & Boișteanu, P. C. (2025). Exploring Aubrac Cattle as a Benchmark for Sustainable and Nutritious Beef Production. *Animals*, *15*(20). https://doi.org/10.3390/ani15202966.

Mehta, N., Ahlawat, S. S., Sharma, D. P., & Dabur, R. S. (2015). Novel trends in development of dietary fiber rich meat products - A critical review. Journal of *Food Science and Technology, 52*(2), 633-647. https://doi.org/10.1007/s13197-013-1010-2.

Olvera-Aguirre, G., Piñeiro-Vázquez, Á. T., Sanginés-García, J. R., Sánchez Zárate, A., Ochoa-Flores, A. A., Segura-Campos, M. R., Vargas-Bello-Pérez, E., & Chay-Canul, A. J. (2023). Using plant-based compounds as preservatives for meat products: A review. *Heliyon*, *9*(6). https://centaur.reading.ac.uk/112563/.

Pateiro, M., Gómez-Salazar, J. A., Jaime-Patlán, M., Sosa-Morales, M. E., & Lorenzo, J. M. (2021). Plant Extracts Obtained with Green Solvents as Natural Antioxidants in Fresh Meat Products. *Antioxidants*, *10*(2). https://doi.org/10.3390/antiox10020181.

Petcu, C. D., Mihai, O. D., Tăpăloagă, D., Gheorghe-Irimia, R.-A., Pogurschi, E. N., Militaru, M., Borda, C., & Ghimpețeanu, O.-M. (2023). Effects of Plant-Based Antioxidants in Animal Diets and Meat Products: A Review. *Foods*, *12*(6). https://doi.org/10.3390/foods12061334.

Peulić, T., Jokanović, M., Delić, J., Rakita, S., Županjac, M., Škaljac, S., & Ikonić, P. (2025). Development and Characterization of Dry Beef Jerky Products. *Meat Technology*, *66*(3), 490-494. https://doi.org/10.18485/meattech.2025.66.3.84.

Qiao, Y., Guo, Y., Zhang, W., Guo, W., Oleksandr, K., Bozhko, N., Wang, Z., & Liu, C. (2022). Effects of Compound Polysaccharides Derived from *Astragalus* and Glycyrrhiza on Growth Performance, Meat Quality and Antioxidant Function of Broilers Based on Serum Metabolomics and Cecal Microbiota. *Antioxidants*, *11*(10). https://doi.org/10.3390/antiox11101872.

Serdaroğlu, M., Kavuşan, H. S., İpek, G., & Öztürk, B. (2018). Evaluation of the Quality of Beef Patties Formulated with Dried Pumpkin Pulp and Seed. Food *Science of Animal Resources*, *38*(1), 1-13. https://doi.org/10.5851/kosfa.2018.38.1.001.

Shah, M. A., Bosco, S. J. D., & Mir, S. A. (2014). Plant extracts as natural antioxidants in meat and meat products. *Meat Science*, *98*(1), 21-33. https://doi.org/10.1016/j.meatsci.2014.03.020.

Shahrivari-Baviloliaei, S., Erdogan Orhan, I., Abaci Kaplan, N., Konopacka, A., Waleron, K., Plenis, A., & Viapiana, A. (2024). Characterization of Phenolic Profile and Biological Properties of *Astragalus membranaceus* Fisch. Ex Bunge Commercial Samples. *Antioxidants*, *13*(8), 993. https://doi.org/10.3390/antiox13080993.

Sirini, N., Munekata, P. E. S., Lorenzo, J. M., Stegmayer, M. Á., Pateiro, M., Pérez-Álvarez, J. Á., Sepúlveda, N., Sosa-Morales, M. E., Teixeira, A., Fernández-López, J., Frizzo, L., & Rosmini, M. (2022). Development of Healthier and Functional Dry Fermented Sausages: Present and Future. *Foods*, *11*(8). https://doi.org/10.3390/foods11081128.

Song, D. H., Yang, N. E., Seomoon, K. M., Jang, I. S., Chin, K. B., & Kim, H. W. (2022). Sous-vide cooking as a practical strategy to improve quality attributes and shelf stability of reduced-salt chicken breast ham. *Poultry Science*, *102*(3), 102444. https://doi.org/10.1016/j.psj.2022.102444.

Szymandera-Buszka, K., Waszkowiak, K., Jędrusek-Golińska, A., & Hęś, M. (2020). Sensory Analysis in Assessing the Possibility of Using Ethanol Extracts of Spices to Develop New Meat Products. *Foods*, *9*(2), 209. https://doi.org/10.3390/foods9020209.

Tkacz, K., Modzelewska-Kapituła, M., Więk, A., & Nogalski, Z. (2020). The Applicability of Total Color Difference ΔE for Determining the Blooming Time in *Longissimus Lumborum* and *Semimembranosus* Muscles from Holstein-Friesian Bulls at Different Ageing Times. *Applied Sciences*, *10*(22). https://doi.org/10.3390/app10228215.

Torres-Martínez, B. del M., Sánchez-Escalante, A., Torrescano-Urrutia, G. R., & Vargas-Sánchez, R. D. (2026). Natural Ingredients to Enhance the Antioxidant Capacity in Different Meat Products: A Review. *Foods*, *15*(5). https://doi.org/10.3390/foods15050852.

Vulić, A., Cvetnić, Ž., Kos, I., Vnučec, I., Vahčić, N., Lešić, T., Simonović, D., Kudumija, N., & Pleadin, J. (2024). Comparison of the Nutritional Composition of Meat Products Derived from Croatian Indigenous Pig Breeds. *Foods*, *13*(24). https://doi.org/10.3390/foods13244175.

Xu, G., Ye, X., Chen, J., & Liu, D. (2007). Effect of heat treatment on the phenolic compounds and antioxidant capacity of citrus peel extract. Journal of Agricultural and *Food Chemistry*, *55*(2), 330-335. https://doi.org/10.1021/jf062517l.

Yao, J., Peng, T., Shao, C., Liu, Y., Lin, H., & Liu, Y. (2024). The Antioxidant Action of Astragali radix: Its Active Components and Molecular Basis. *Molecules*, *29*(8). https://doi.org/10.3390/molecules29081691.

Yiğit, C., & Dinçer, E. A. (2025). Karadut (*Morus nigra*) ve Hibiskus (*Hibiscus sabdariffa* L.) Ekstraktlari Kullanilarak Biyoaktif Bileşenlerce Zengin ve Karmine Alternatif Olarak Renklendirilmiş Fonksiyonel Et Çubuğu Üretimi. *Gıda*, *50*(1), 87-101. https://doi.org/10.15237/gida.GD24088.

Zahid, A., Seo, J.K., Park, J.Y., Jeong, J.Y., Jin, S.K., Park, T.S., & Yang, H.S. (2018). The Effects of Natural Antioxidants on Protein Oxidation, Lipid Oxidation, Color, and Sensory Attributes of Beef Patties during Cold Storage at 4°C. Korean Journal for *Food Science of Animal Resources*, *38*(5), 1029-1042. https://doi.org/10.5851/kosfa.2018.e36.

Zhang, Y., Chen, Z., Chen, L., Dong, Q., Yang, D.-H., Zhang, Q., Zeng, J., Wang, Y., Liu, X., Cui, Y., Li, M., Luo, X., Zhou, C., Ye, M., Li, L., & He, Y. (2024). Astragali radix (Huangqi): A time-honored nourishing herbal medicine. *Chinese Medicine*, *19*(1), 119. https://doi.org/10.1186/s13020-024-00977-z.