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REFORMULATION OF AN ORGAN-BASED MEAT PRODUCT WITH PUMPKIN POWDER: A STRATEGY FOR FIBER ENRICHMENT

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Abstract

The development and manufacturing of food products, across all sectors of the industry, that align with contemporary dietary habits and meet consumers' nutritional requirements have become a permanent interest of the food industry. This study aims to combine elements of sustainability, superior valorization and the concept of functional products by optimizing the valorization of poultry organs through the reformulation of conventional Leberwurst. To achieve this, pumpkin powder (Cucurbita maxima) was incorporated at concentrations of 0.1%, 3%, and 5% into the product made with liver and chicken thigh, to enrich the product with dietary fibers - an essential nutritional element absent in conventional meat products - while preserving its sensory acceptability and improving its functional and nutritional profile. After production, the batches were subjected to physicochemical evaluations, and characterized in terms of pH, color, texture, and sensory perception. The addition of pumpkin powder results in an improvement in the fiber content, with a good sensory acceptability for all the formulations. This research supports the development of functional meat products with improved nutritional quality and sustainability by valorizing underused ingredients.

***Key words**: fiber-rich food, meat product innovation, pumpkin flour.*

INTRODUCTION

In a brief historical overview of the concept of functional foods, Alongi & Anese (2021) mention the first appearance of this term in 1984, in Japan, where the government defined a new category of products, Food for Specific Health Uses, as those foods that contain an ingredient involved in specific functions and physiological effects on human health.

In recent years, numerous authors have highlighted the trend in food industry towards the development of functional products formulated with various additions of bioactive ingredients, such as flax seeds and tomato powder (Ghafouri-Oskuei et al., 2020), quinoa (Fernández-López et al., 2020), chia flour (Fernández-López et al., 2019), sea buckthorn oil (Anchidin et al., 2023), citrus by-products (Nieto & Peñalver, 2021). Moreover, these functional additives can serve a dual role, enriching the nutritional and energy intake and ability to provide a certain degree of protection against the development of chronic diseases (Ampofo & Abbey, 2021; Aziz et al., 2021).

From a scientific perspective, meat is defined as skeletal muscle and the associated tissues, such as adipose, epithelial, connective, and nervous tissues, with the main component being muscle tissue, derived from mammals, birds, reptiles, amphibians, and aquatic species, and harvested for human consumption. Edible organs are also considered meat, consisting of organs and non-skeletal muscle tissues (Boler & Woerner, 2017; Seman et al., 2018). The liver is included in the category of edible organs, which, along with meat, is an important source of micronutrients such as vitamin A and essential minerals including iron, zinc, copper, and manganese (Choe et al., 2019; Boișteanu et al., 2024).

Considering the growth observed in the poultry slaughtering sector - driven by increased consumption associated with population and income growth - there is a growing interest in identifying solutions for the superior valorization of all by-products generated during this process (Gucianu et al., 2024). One of the most effective approaches to utilizing liver is represented by the production of pâté or sausages, well-appreciated varieties in many European countries, such as Denmark, France, Germany, and Spain (Estévez et al., 2005;

Cairncross, 2020). Traditionally, meat products are valued for their high protein content, known as "high-quality" proteins due to the substantial amounts of essential amino acids and elevated bioavailability (Bohrer, 2017; Anchidin et al., 2024). However, these products are naturally low in dietary fibre, a key component for maintaining digestive health (Boișteanu et al., 2023; Haque et al., 2025).

Among the plant fiber sources used in the reformulation of meat products, pumpkin (*Cucurbita maxima*) represents a promising option due to its high dietary fibers content, antioxidants, and bioactive compounds. Pumpkin pulp not only improves the nutritional value of the product but can also contribute to optimizing its texture and stability during thermal treatment and storage (Batool et al., 2021). Several studies in the literature have demonstrated the positive effects of adding pumpkin powder on the functional and technological properties of various food products, such as meatballs (Öztürk & Turhan, 2020), ham (Galenko et al., 2021), sausages (Choi et al., 2012; Hleap-Zapata et al., 2020), and burgers (Hartmann et al., 2020; de Melo et al., 2024). The addition of pumpkin flour to the manufactured product falls into the category of food ingredients rather than food additives, enhancing consumer acceptability, particularly in the context of consumer perception that "synthetic equals dangerous" (Zugravu et al., 2017).

Although a general uniformity in eating behavior has been observed at the national level, with minimal differences between urban and rural areas in terms of meat consumption, meat continues to represent an important component of the population's diet. However, the average consumption remains below nutritional recommendations, especially among women (Pogurschi et al., 2018).

In recent years, consumer interest in poultry meat has increased for various reasons such as accessibility, ease of culinary processing, high protein content, lack of religious restrictions, and the lower environmental impact of the poultry industry compared to the beef sector (Tudorache et al., 2022; Popa et al., 2022; Grigore et al., 2023).

In this context, the development of innovative products, such as chicken sausages enriched pumpkin flour, can contribute to the diversification of the meat product varieties and improve their nutritional profile (through the additional intake of dietary fibers, natural antioxidants, and bioactive compounds derived from plant-based raw materials).

This study aims to investigate the impact of adding pumpkin flour on the physicochemical and sensory characteristics of chicken liver sausages, with the goal of formulating a fibre-enriched meat product with superior nutritional benefits. The reformulation tested the incorporation of three levels of pumpkin flour (1%, 3%, 5%) and a control batch without the additive, monitoring changes in chemical composition, physicochemical properties, and consumer acceptability.

MATERIALS AND METHODS

The study involved two stages: the production stage of the formulations and the qualitative analysis stage of the finished product, carried out in the production departments and laboratories of the "Ion Ionescu de la Brad" Iași University of Life Sciences.

The production process was carried out according to the procedures described in previous studies (Ciobanu et al., 2023a; Manoliu et al., 2023; Flocea et al., 2024), with some modifications specific to the type of emulsified product. The necessary raw and auxiliary materials were purchased from local suppliers, and the pumpkin flour was purchased from Bio Market (Bio Intercom SRL, Cluj-Napoca).

The quantities used for producing the four sausage variants are presented in Table 1. The percentages of pumpkin flour added (1%, 3%, and 5%) were reported to the total amount of raw material used.

The main production stages involved the coarse grinding of meat (using a Grinder WP - 105, equipped with a 3 mm sieve), followed by fine grinding in a Cutter Titane V 45 L, emulsification, addition of dry ingredients, stuffing into natural casings, and thermal treatment, performed according to the protocol outlined in Table 2. After production, the products were cooled and stored at refrigeration temperature (0-3°C) until the subsequent analysis stages.

Table 1. Formulations of liver sausages (chicken Leberwurst) with different concentrations of pumpkin flour

Sample code \ Ingredients	Chicken liver (kg)	Chicken deboned thigh (kg)	Pumpkin flour (g)	Salt (g)	Onion powder (g)	Black pepper (g)	Sweet paprika (g)
Control, 0%	1.2	0.8	0	30	20	4	2
CLS, 1%			20				
CLS, 3%			60				
CLS, 5%			100				

Table 2. The heat treatment scheme for the formulations of chicken Leberwurst

Heat treatment stage	Time	Temperature inside the cell	Temperature in the thermal centre	Humidity
	minutes	°C	°C	%
Air drying	30	60	52	30
Smoking	20	70	65	30
Boiling	30	78	72	99
Hot air drying	5	80	70	20

The final products were subjected to physicochemical and sensory evaluations at the Meat and Meat Products Technology Laboratory and Sensory Analysis Laboratory.

The instrumental colour parameters (L*, a* and b*) were assessed using Chroma Meter CR-410 instrument (Konica Minolta Inc., Japan), with the following characteristics: D65 light source, with a 2° observation angle and a 50 mm diameter measurement area. The color attributes chroma (C*), hue angle (H*) and total color difference (ΔE) were calculated using equations (1), (2), and (3), as described in a previous study (Ciobanu et al., 2024a).

$$H(*) = tan^{-1}(\frac{b^*}{a^*}) \quad (1)$$

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

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

The acidity of the products, expressed as pH value, was measured using a direct insertion pH meter (HI98163, Hanna Instruments Romania).

For the determination of textural parameters, a Lloyd Instruments TA1Plus texture analyzer (AMETEK, UK) equipped with a 500N load cell was used. Cutting tests were applied using the Warner-Bratzler knife, and compression tests were conducted using a cylindrical probe. The obtained results describe parameters such as shear force (N), work of shear (mJ), and the textural profile analysis attributes: hardness (maximum force during the first compression); cohesiveness, elasticity, gumminess, chewiness, and adhesiveness.

Sample preparation for the Warner-Bratzler shear test involved longitudinally slicing the sausages into 30 × 15 mm strips, both with and without membrane, while for the compression test, sections of approximately 3 cm height were formed.

The raw chemical composition was determined using the NIR FoodCheck analyzer (Bruins Instruments, OmegAnalyzer), and the total fiber content was determined by the AOAC 991.43 method (AOAC, 2000).

Consumer behavior towards a new product does not always correspond to their real needs, but is based on various attitudes and perceptions influenced by: psychological factors (such as product familiarity and openness to innovation) (Ciobotaru et al., 2024), which affect the acceptance decision; and environmental factors that include economic, social, cultural, or consumption context criteria (Ciobanu et al., 2023b).

The sensory analysis was conducted using the method described by Boișteanu et al. (2025), applying the hedonic ranking test for the main sensory attributes (surface appearance, section appearance, color, hardness, adhesiveness, flavor, taste, overall acceptability) to a group of 30 semi-trained panelists. The panelists were asked to rate each sensory attribute on a nine-point scale (1 - dislike very much and 9 - like very much).

The results for physicochemical and sensory quality evaluation of the four sausage samples were expressed as mean values (± standard deviation) and the experimental addes samples were compared with the control using analysis of variance (ANOVA) followed by Tukey's test at 5% significance level ($p < 0.05$), using IBM SPSS Statistics v.21.

RESULTS AND DISCUSSIONS

The results for chemical composition obtained for the chicken Leberwurst formulations are shown in Table 3. All compositional parameters (moisture, fat, protein, ash, fibre and carbohydrate) of chicken Leberwurst sausages were influenced by the addition of pumpkin flour, and the moisture and protein contents decreased as the amount of pumpkin flour increased, while fat, fibre, ash, and carbohydrate contents increased.

Moisture content in meat products is a parameter that influences shelf life and sensory characteristics (particularly texture and juiciness). The incorporation of pumpkin flour led to a progressive decrease in moisture content across all samples, from 72.26% in the control to 70.28% in the 5% supplemented sample. This trend is likely due to the low inherent moisture of pumpkin flour (10.96%, compared to 92.24% in fresh pumpkin) and its high water-binding capacity (Saeleaw & Schleining, 2011), which reduces free water in the meat matrix. Such findings align with previous studies where the addition of pumpkin flour to meat products resulted in decreased moisture levels, enhancing shelf stability (Öztürk & Turhan, 2020; de Melo et al., 2024). Öztürk & Turhan (2020) found that the inclusion of pumpkin (*Cucurbita pepo* L.) seed kernel flour into beef meatballs led to reduces moisture from 47.34% in control sample to 44.74% in the 12% added sample.

Interestingly, a slight but statistically significant ($p < 0.05$) reduction in protein content was observed with the increasing pumpkin flour levels (from 20.42% in the control to 20.06% at 5%). Hleap-Zapata et al. (2020) also reported this effect of reduced protein content in Frankfurt-type sausages after the addition of pumpkin flour (*Cucurbita moschata* Duch.), from a mean value of 34.55% (control sample) to 29.88% (in the 30% replacement of wheat flour with pumpkin flour). This can be explained by a dilution effect, as plant-based ingredients typically have lower protein levels than lean chicken meat. Contrarily, other studies by Öztürk & Turhan (2020) and de Melo et al. (2024) showed an increase in protein content when adding pumpkin seed flour.

The fat content showed a progressive and statistically significant ($p < 0.05$) increase in the supplemented chicken Leberwurst (from 4.94% in the control to 5.74% at 5% addition). This trend could be attributed to the lipid contribution of the pumpkin flour itself, or more likely, a concentration effect due to moisture reduction. A similar increase in fat concentration following pumpkin addition was noted by Zargar et al. (2014) in pumpkin-enriched chicken sausages.

A clear increasing trend was observed in carbohydrate, fibre and ash contents, reflecting the high content of non-digestible polysaccharides naturally present in pumpkin flour. The carbohydrate content increased from 0.96% in the control to 1.94% in the 5% added chicken Leberwurst, while dietary fibre rose from 0% (in the plain meat sausages) to a maximun result of 1.03%, with statistically significant differences between all samples ($p < 0.05$). Similar results were also reported by de Melo et al. (2024), who found an increase in total fibre content from 0% to 0.88% at a 5% level of pumpkin seed flour incorporated in beef burgers. These results confirm the functional enrichment achieved through pumpkin flour addition, which enhances the nutritional profile by introducing fermentable fibre known for its beneficial effects on gut health (Haque et al., 2025).

In terms of ash content, a marker of mineral content, the significant increase with pumpkin flour addition (from 1.42% to 1.98%) can be due to the natural mineral load of pumpkin pulp, which contains potassium, calcium, and magnesium (El Khatib & Muhieddine, 2020). This is consistent with other studies that also reported increased ash values in pumpkin-fortified meat products (Verma et al., 2015; Hartmann et al., 2020; Öztürk & Turhan, 2020).

Table 3. Analysis of chemical composition of control and pumpkin flour supplemented chicken Leberwurst

Analyzed parameter	Sample			
	Control, 0%	CLS, 1%	CLS, 3%	CLS, 5%
Humidity (%)	72.26 ± 0.18 [a]	71.32 ± 0.28 [b]	71.08 ± 0.16 [b]	70.28 ± 0.13 [c]
Dry Matter (%)	27.74 ± 0.18 [c]	28.68 ± 0.28 [b]	28.92 ± 0.16 [b]	29.72 ± 0.13 [a]
Fat (%)	4.94 ± 0.11 [c]	5.08 ± 0.04 [bc]	5.16 ± 0.11 [b]	5.74 ± 0.15 [a]
Protein (%)	20.42 ± 0.18 [a]	20.32 ± 0.13 [ab]	20.18 ± 0.04 [bc]	20.06 ± 0.05 [c]
Colagen*	19.56 ± 0.09 [a]	19.52 ± 0.04 [a]	19.48 ± 0.08 [a]	19.42 ± 0.13 [a]
Carbohydrate (%)	0.96 ± 0.05 [b]	1.56 ± 0.31 [a]	1.72 ± 0.24 [a]	1.94 ± 0.17 [a]
Fiber (%)	0.00 ± 0.00 [c]	0.71 ± 0.14 [b]	0.74 ± 0.12 [b]	1.03 ± 0.10 [a]
Ash (%)	1.42 ± 0.19 [c]	1.72 ± 0.08 [b]	1.86 ± 0.11 [ab]	1.98 ± 0.13 [a]

Values are given as means ± Standard deviation from five repeated determinations. Means with different superscripts in a row orientation indicate significant differences ($p < 0.05$) between samples determined by the Tukey test. *Colagen content is expressed as % from the total protein content.

Table 4 shows the mean results registered for pH and color parameters (L*, a*, b*, C*, h*, and ΔE) for the sausage samples, and also for the pumpkin flour. These phisical parameters are determinant of consumer acceptance, serving as key indicators of product quality.

The pH values remained relatively stable across all samples, ranging from 6.68 to 6.74, with no significant differences observed ($p > 0.05$), although it recorded a decrease with the increase in the level of pumpkin flour. This stability suggests that the addition of pumpkin flour, even at the highest concentrations, does not significantly modify the acidity or alkalinity of the product, maintaining the physicochemical environment essential for product stability and shelf life.

The general definition of the main color parameters is: L* = 0 (black); L* = 100 (white); negative a* = green color; positive a* = red color; negative b* = blue color; positive b* = yellow (Anchidin et al., 2023).

The lightness (L* values) and yellow/blue coordinate (b* value) of the chicken Leberwurst exhibited no significant changes ($p > 0.05$) with the addition of pumpkin flour, maintaining values of 40.89-41.55, respectively 10.80-11.13. This consistency indicates that pumpkin flour has a balanced color ant its incorporation does not affect the color characteristics of the meat product, preserving its visual brightness.

A significant decrease in a* values ($p < 0.05$) was observed with increasing levels of pumpkin flour, dropping from 24.70 in the control chicken Leberwurst to 22.93 in the 5% pumpkin flour supplemented formulation. This reduction in red color intensity could be attributed to the dilution of meat pigments, caused by the natural color of the flour, that registered a negative a* value (-0.73), due to pigments in pumpkin flour that influences the overall color balance of the meat product.

Chroma values (C*), representing color saturation, showed a decreasing tendency with higher pumpkin flour concentrations, from 27.03 in the control to 25.49 in the 5% sample.

While hue angle (h*) recorded a reverse trend compared to chroma, increasing significantly with higher levels of pumpkin flour, from 23.97 in the control to 25.90 in the 5% sample ($p < 0.05$). This decline in saturation indicates a slight reduction in color intensity, and an increased hue angle suggests a shift in color perception, potentially moving towards a more yellowish hue, which aligns with the natural color properties of pumpkin.

The ΔE values, which quantify the overall color difference between the experimental samples and the control, ranged from 0.91 to 1.97 across the samples. According to Wibowo et al. (2015), ΔE values between 0.5 and 1.5 are considered slightly visible, while values between 1.5 and 3.0 are noticeable. Therefore, the color changes observed with pumpkin flour addition are perceptible but remain within acceptable limits, the 3% and 5% levels producing a more evident color difference compared to the control sample. Similar results have also been reported by other authors who studied the potential of incorporating pumpkin flour into various meat products (e.g., beef burgers, beef meatballs, beef patties), demonstrating a slight increase in brightness and color intensity towards yellow (b* value) and a decrease in the a* value, through the dilution of the meat's red pigment (Ammar et al., 2014; Serdaroğlu et al., 2018; Öztürk & Turhan, 2020; de Melo et al., 2024).

Table 4. pH and colorimetric parameters of pumpkin flour and chicken Leberwurst (control and supplemented formulations)

Analyzed parameter	Pumpkin flour	Leberwurst sample			
		Control, 0%	CLS, 1%	CLS, 3%	CLS, 5%
pH	-	6.74 ± 0.08^{a}	6.71 ± 0.08^{a}	6.69 ± 0.07^{a}	6.68 ± 0.06^{a}
L*(D65)	70.49 ± 0.56	41.03 ± 0.73^{a}	40.89 ± 0.77^{a}	41.08 ± 0.59^{a}	41.55 ± 0.90^{a}
a*(D65)	-0.73 ± 0.20	24.70 ± 0.60^{a}	24.19 ± 0.29^{ab}	23.50 ± 0.73^{bc}	22.93 ± 0.27^{c}
b*(D65)	25.63 ± 0.18	10.98 ± 0.28^{a}	10.80 ± 0.11^{a}	10.89 ± 0.29^{a}	11.13 ± 0.29^{a}
C*(Chroma-Saturation index)	25.64 ± 0.17	27.03 ± 0.64^{a}	26.49 ± 0.31^{ab}	25.90 ± 0.75^{bc}	25.49 ± 0.13^{c}
h* (Hue angle)	91.64 ± 0.45	23.97 ± 0.31^{b}	24.07 ± 0.10^{b}	24.88 ± 0.59^{b}	25.90 ± 0.83^{a}
ΔE	-	-	0.91 ± 0.46	1.76 ± 0.73	1.97 ± 0.70

Values are given as means ± Standard deviation from five repeated determinations. Means with different superscripts in a row orientation indicate significant differences ($p < 0.05$) between samples determined by the Tukey test.

Textural attributes are important elements in the sensory perception and consumer acceptance of meat products, influencing attributes such as mouthfeel, chewiness, and slicing behavior. In this study, the effect of inclusion of pumpkin flour in varying concentrations (1%, 3%, and 5%) was measured instrumentally for shear test and textural profile parameters, on samples with and without membrane. As can be seen in Table 5, the presence of the membrane prevented the identification of significant differences between samples regarding TPA parameters, while the shear force (N/cm) of sausages with membrane displayed a gradual and significant reduction ($p < 0.05$) with increasing pumpkin flour addition - from 4.65 N/cm in the control sample to 3.14 N/cm in the 5% sample.

Despite the trend in shear resistance, the textural parameters hardness, cohesiveness, elasticity, gumminess, and chewiness values did not vary significantly ($p > 0.05$) between treatments, though a slight numerical decline was observed in most parameters with increased pumpkin flour.

The reverse trend was observed in samples without membrane, where shear force increased with increasing pumpkin flour content - from 1.18 N/cm (control) to 1.58 N/cm (5%), indicating a firmer internal meat matrix after the addition of pumpkin flour. The work of shear (mJ) also increased significantly ($p < 0.05$), suggesting that flour addition contributed to a stronger internal structure.

The hardness results followed a similar pattern, increasing from 3.86 N to 5.23 N, at the highest level of addition the sample being significantly firmer ($p < 0.05$). This may reflect the water-holding and swelling behavior of pumpkin flour within the protein gel, leading to increased matrix density. In terms of cohesiveness, elasticity and chewiness, the samples remained statistically similar, while gumminess has significantly decreased (from 1.21 N to 0.78 N), suggesting that the addition may have disrupted the viscoelastic matrix, facilitating easier breakdown during mastication.

The differences in behavior of the samples with and without membrane, at the instrumental measurement of texture parameters, can be attributed to the structural role of the natural casing and its interaction with the internal meat matrix. In the control samples (0% pumpkin flour), the natural pig membrane was elastic, and did not adhere tightly to the meat paste, resulting in higher shear force values due primarily to the resistance of the membrane itself. Moreover, the control chicken Leberwurst had a softer, light consistency, offering minimal internal resistance, which concentrated the cutting effort on penetrating the membrane.

In contrast, the addition of pumpkin flour enhanced the water-binding capacity and firmness of the meat matrix, promoting a more compact and cohesive internal structure. As a result, the membrane became better adhered to the surface of the meat paste and more integrated into the product, likely due to reduced moisture exudation and improved surface contact. This led to lower shear force values, as the cutting blade could move through a more continuous matrix with less membrane deformation.

On the other hand, after removing the membrane, the shear force increased with the level of pumpkin flour, reflecting the true internal firmness of the product. Without the natural membrane's influence, the cutting resistance was directly related to the structural integrity of the meat-pumpkin flour matrix.

Here, the progressive increase in shear force values and hardness demonstrates that pumpkin flour contributed to the densification and strengthening of the emulsion, resulting in a firmer core that required more energy to shear.

Table 5. Warner Bratzler shear forces and textural parameters of the control and pumpkin flour supplemented chicken Leberwurst

Analyzed parameter	Sample			
	Control, 0%	CLS, 1%	CLS, 3%	CLS, 5%
with membrane				
Shear force (N/cm^2)	4.65 ± 1.29 ^{a}	4.03 ± 0.64 ^{ab}	3.54 ± 0.25 ^{ab}	3.14 ± 0.35 ^{b}
Work of shear (mJ)	326.26 ± 9.35 ^{a}	276.68 ± 7.51 ^{b}	246.28 ± 5.21 ^{c}	197.99 ± 8.86 ^{d}
Hardness (N)	14.52 ± 3.81 ^{a}	12.63 ± 1.83 ^{a}	10.69 ± 0.78 ^{a}	10.84 ± 2.09 ^{a}
Cohesiveness (N)	0.33 ± 0.17 ^{a}	0.32 ± 0.03 ^{a}	0.27 ± 0.19 ^{a}	0.11 ± 0.03 ^{a}
Elasticity	0.36 ± 0.09 ^{a}	0.30 ± 0.05 ^{a}	0.22 ± 0.04 ^{a}	0.27 ± 0.17 ^{a}
Gumminess (N)	2.78 ± 0.69 ^{a}	2.56 ± 0.17 ^{a}	2.18 ± 0.22 ^{a}	2.09 ± 0.53 ^{a}
Chewiness (N)	1.04 ± 0.47 ^{a}	0.77 ± 0.18 ^{a}	0.49 ± 0.15 ^{a}	0.61 ± 0.52 ^{a}
Adhesiveness	-0.55 ± 0.01 ^{a}	-0.58 ± 0.03 ^{a}	-0.46 ± 0.01 ^{a}	-0.52 ± 0.15 ^{a}
without membrane				
Shear force (N/cm^2)	1.18 ± 0.23 ^{b}	1.27 ± 0.23 ^{ab}	1.42 ± 0.22 ^{ab}	1.58 ± 0.07 ^{a}
Work of shear (mJ)	87.99 ± 6.77 ^{c}	103.52 ± 8.51 ^{b}	103.89 ± 2.69 ^{b}	116.50 ± 8.60 ^{a}
Hardness (N)	3.86 ± 0.77 ^{b}	4.10 ± 0.86 ^{ab}	4.33 ± 0.72 ^{ab}	5.23 ± 0.17 ^{a}
Cohesiveness (N)	0.22 ± 0.13 ^{a}	0.13 ± 0.03 ^{a}	0.15 ± 0.02 ^{a}	0.16 ± 0.05 ^{a}
Elasticity	0.07 ± 0.01 ^{b}	0.07 ± 0.01 ^{b}	0.09 ± 0.01 ^{a}	0.10 ± 0.01 ^{a}
Gumminess (N)	1.21 ± 0.14 ^{a}	1.06 ± 0.29 ^{ab}	0.89 ± 0.17 ^{ab}	0.78 ± 0.16 ^{b}
Chewiness (N)	0.08 ± 0.02 ^{a}	0.07 ± 0.02 ^{a}	0.09 ± 0.01 ^{a}	0.07 ± 0.01 ^{a}
Adhesiveness	-0.97 ± 0.01 ^{a}	-0.72 ± 0.34 ^{a}	-0.71 ± 0.36 ^{a}	-0.47 ± 0.29 ^{a}

Values are given as means ± Standard deviation from five repeated determinations. Means with different superscripts in a row orientation indicate significant differences ($p < 0.05$) between samples determined by the Tukey test.

Table 6 shows the results received in the hedonic consumer test for chicken Leberwurst samples formulated with different levels of pumpkin flour (1%, 3%, and 5%) compared to the control sample. The evaluated attributes included appearance, section appearance, color, hardness, adhesiveness, flavor, taste, and overall acceptability. Given the numerous reports regarding the potential risk of synthetic additives, increasing emphasis is being placed on ”clean-label” products that replace synthetic additives with natural substitutes, offering healthier alternatives without significantly impacting sensory characteristics (Ciobanu, 2024b).

The results reveal that consumer perception on surface appearance, section appearance, and color remained relatively stable between the control and the 1% and 3% samples, with mean values consistently above 7. However, a notable decline was observed for the 5% sample, particularly for section appearance (6.50 ± 1.22) and color (6.43 ± 1.76), suggesting that higher levels of pumpkin flour may have negatively influenced the visual appeal of the product. This sensory perception aligns with the visible decrease in a* and C* values previously discussed in the instrumental color analysis. Textural attributes such as hardness and adhesiveness were positively perceived in the 1% and 3% supplemented samples, with adhesiveness showing a marked improvement from 3.03 ± 1.97 in the control to 6.80 ± 1.65 in the 1% sample. However, both parameters declined at the 5% inclusion level, suggesting that consumer-perceived texture was optimal at moderate enrichment. Considering that the evaluation scale was based on the degree of acceptability, the textural attributes of the control sample received lower scores from the panelists due to its soft consistency and high adhesiveness.

Regarding flavor and taste, all enriched samples show high hedonic scores, and the CLS3% sample scoring the highest acceptability regarding both flavor (8.20 ± 0.76) and taste (8.10 ± 0.88). The CLS5% sample maintained similar flavor and taste scores to that of the control, suggesting that, despite visual and textural changes, the sensory perception of flavor remained constant and palatable.

All samples were positively rated for overall acceptability, with the highest score (7.33 ±

0.80) going to the 3% sample, followed by 1% and 5% additions, and the control. This indicates that moderate amounts of pumpkin flour (1-3%) can improve the sensory profile of the product, while excess amount (5%) may interfere with certain sensory attributes (especially visual and textural features).

Table 6. Sensory attributes of control and pumpkin flour supplemented chicken Leberwurst

Evaluated attribute	Sample			
	Control, 0% ±	CLS, 1%	CLS, 3%	CLS, 5%
Appearance	7.33 ± 1.12 [a]	7.57 ± 1.33 [a]	7.40 ± 0.93 [a]	6.73 ± 1.17 [b]
Section appearance	7.20 ± 0.92 [ab]	7.33 ± 1.21 [a]	7.27 ± 0.91 [a]	6.50 ± 1.22 [b]
Color	7.53 ± 0.94 [a]	7.67 ± 1.03 [a]	7.60 ± 1.19 [a]	6.43 ± 1.76 [b]
Hardness	5.13 ± 1.31 [b]	6.47 ± 1.22 [a]	6.63 ± 1.13 [a]	5.50 ± 1.22 [b]
Adhesiveness	3.03 ± 1.97 [c]	6.80 ± 1.65 [a]	6.43 ± 1.74 [a]	4.77 ± 0.94 [b]
Flavor	7.73 ± 0.94 [a]	8.03 ± 1.03 [a]	8.20 ± 0.76 [a]	7.73 ± 1.01 [a]
Taste	7.90 ± 0.96 [a]	8.13 ± 0.94 [a]	8.10 ± 0.88 [a]	7.80 ± 0.85 [a]
Overall acceptability	7.07 ± 0.78 [a]	7.27 ±0.87 [a]	7.33 ± 0.80 [a]	7.13 ± 0.90 [a]

Values are given as means ± Standard deviation. Means with different superscripts in a row orientation indicate significant differences ($p < 0.05$) between samples determined by the Tukey test.

CONCLUSIONS

This study explored the effects of incorporating pumpkin flour into a organ-based chicken sausages (Leberwurst) in order to obtain a reformulated product with functional properties, specifically its enrichment with dietary fiber.

This study demonstrates the feasibility of using pumpkin flour (1%, 3%, and 5%) in the development of chicken Leberwurst with enhanced nutritional value, particularly through significant increases in dietary fibre, carbohydrate, and ash content. Meanwhile, the moisture and protein contents decreased slightly as a result of the additive's composition and moisture-binding properties. These results not only show an improvement in the nutritional profile, but also supports the posibility of developing a functional meat product.

From a technological perspective, pumpkin flour incorporation influenced both textural and color parameters. Color attributes such as green-red coordonate (a*) and saturation (C*) decreased slightly, while the hue angle increased, indicating a subtle but acceptable shift in color, which remained within consumer-acceptable limits based on ΔE values.

In terms of textural modifications, the addition of pumpkin flour resulted in a progressive increase in shear force, work of shear, and hardness, indicating a firmer and more cohesive product. These effects can be attributed to the water-holding and gel-forming abilities of the added flour, which enhanced the structural density of the product. At the same time, gumminess and elasticity were influenced by the addition, but the chewiness and cohesiveness remained stable, ensuring an acceptable sensory texture profile.

Overall, the results confirm that pumpkin flour can be used up to a 5% inclusion level to formulate a clean label, fibre-enriched chicken Leberwurst, without negatively affecting key quality attributes.

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