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Posted Date: 9 February 2026

doi: 10.20944/preprints202602.0573.v1

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Reformulation of a Consumable Meat and Plant-Based Product to Improve Its Health Benefits

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Abstract

The aim of the research was to develop an innovative meat and plant-based product in the form of a paste with potential beneficial health properties. The verification of beneficial health properties was carried out based on the results of the nutritional analysis with respect to the meat and plant-based reference products. The quality assessment considered both physical and sensory characteristics. The results showed that the meat and plant-based product had a reduced content of fat, saturated and monounsaturated fatty acids, cholesterol and a lower energy value compared to the reference meat-based product, with a simultaneous increase in the proportion of polyunsaturated fatty acids and dietary fibre. In terms of plant-based products, the meat-plant hybrid prototype distinguished itself with a higher protein content and a more favourable amino acid profile. Sensory evaluation confirmed the high desirability of the aroma, taste, and overall acceptability of the meat-plant product compared to reference products. Reformulation enabled the development of an innovative product with balanced nutritional and sensory characteristics, providing a valuable, health-promoting alternative to traditional meat-based products and classic plant-based pastries.

Keywords: meat and plant-based product; paste; nutritional value; quality

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1. Introduction

Increased awareness of the impact of diet on human health by consumers, as well as limited time available for meal preparation, are important factors that contribute to the development and marketing of new convenient products with high nutritional value [1–3]. Reformulation of meat products, which involves partial replacement of meat with plant-based ingredients rich in protein and biologically active compounds, and replacement of animal fat with vegetable oils, is currently seen as one of the strategies for the development of meat processing [4,5]. This approach is in line with the concept of hybrid meat products, which combine animal and plant-based raw materials to achieve a compromise between nutritional value, functionality and consumer acceptance [3,6–9]. The appeal of 'mixed' products comes from the fact that their aim is not to eliminate meat from the diet, but to adapt the composition of the product to the current needs and preferences of consumers [10,11]. Reformulated meat and plant-based products, as innovative products, can also create new business opportunities for the meat industry [9,12–15].

An important difference between reformulated hybrid meat products and traditional meat products with added plant ingredients is the deliberate design of the composition, including the appropriate proportions of meat and plant proteins and the presence of biologically active ingredients [3,4,6,16–19]. In traditional meat processing, plant components are used mainly as fillers or binders for economic and technological reasons. In reformulated meat products, the emphasis is on improving the health and functional properties of the product [3,20].

The types of non-meat ingredients used in enriched products are varied and include legume seeds, fruits, vegetables, vegetable oils, herbs, and spices [21–23]. In recent years, there has been increasing interest in research on the use of legumes and selected vegetables called 'superfoods' in meat processing. Red pepper is a source of capsaicinoids, carotenoids, and phenolic compounds, which determine its antioxidant and biological activity [24–26]. Dried tomatoes are characterised by a high concentration of minerals, vitamins and lycopene, which is responsible for their health-promoting properties [27–29]. Fermented black garlic has a higher content of polyphenols, melanoidins, and antioxidant activity compared to fresh garlic [30–32]. Chickpeas are a valuable source of plant protein, dietary fibre, and bioactive components, including unsaturated fatty acids, vitamins, and minerals [33–35]. Due to the presence of functional proteins and starch, they are used as a health-promoting ingredient in food products, capable of beneficially modifying the technological properties of meat proteins, including their water binding, gelling, and emulsifying capabilities [33,36].

In recent years, chickpea-based products, such as classic hummus, have gained widespread acceptance in many countries and are now considered one of the most important categories of ready-to-eat products [36,37]. Despite the high popularity and consumer acceptance of fully plant-based products, hybrid products are currently attracting a great deal of interest. Meat-plant products offer potential nutritional and sensory benefits that may give them an advantage over plant-based spreads based solely on chickpeas [38,39]. The combination of animal and plant protein promotes a more complete amino acid profile and higher biological quality of protein compared to plant products based on a single ingredient. Hybrid meat plant products can particularly meet the needs of consumers who declare flexitarian attitudes, that is, those who seek to reduce their meat consumption without completely giving up its taste, technological and nutritional qualities [8,40]. In this context, these products fill the gap between traditional meat products and 100% plant-based products, offering a compromise between sensory quality, nutritional value, and convenience [6,8–10,12]. It should be emphasised that sandwich spreads, including ready-to-eat products, are very popular among consumers looking for quick and convenient solutions, further justifies the choice of this product form as the subject of research.

In the process of designing innovative meat plant products, it is crucial to maintain a balance between technological challenges and potential health benefits, while ensuring the high sensory quality of the finished product [6,9,41]. When reformulating food products, consumer acceptance must be considered, as even a product with high nutritional value will not achieve market success if its sensory characteristics do not meet consumer expectations [8,10,14]. Therefore, the effectiveness of activities related to the development and implementation of innovative meat products depends on close cooperation between meat processing plants and scientific institutions [12,42].

The purpose of the study was to evaluate the quality of a consumer-ready meat and a plant-based product in the form of a paste, obtained as a result of reformulating a traditional meat product. The quality assessment was carried out, comparing it with a reference meat product (classic poultry pâté in the form of a paste) and with a vegetable product (hummus-type paste). The purpose of the study was to develop an innovative health-promoting product.

2. Materials and Methods

The subject of the research was a prototype of an innovative meat and plant-based product in the form of a paste, developed according to an original recipe aimed at increasing its potential health benefits. Research was carried out as part of the project "Technology that improves the health benefits of poultry meat products". The innovative product was developed under conditions similar to those of real life, using a trial production line at a meat processing facility. Plant-based raw materials were selected deliberately, taking into account their nutritional value, content of biologically active compounds, and taste. The plant ingredients were introduced into the recipe as a partial substitute for animal-based raw materials and as a component modifying the nutritional and functional profile of the final product. The final composition of the recipe was optimised in terms of technological and sensory properties. The prototype of the innovative meat plant product in the form of a paste was evaluated by a research group (P_{MR}). The quality assessment was carried out in relation to the reference meat product, the classic chicken pâté in the form of a paste (P_M) and comparatively in relation to the plant product, the classic 'hummus' paste (P_R).

2.1. Raw Materials and Recipe Composition

The preparation of raw materials, the meat plant product trial, and its reference equivalents took place under conditions similar to those found in a real meat processing plant.

The raw meat material used for the production of the prototype was the breast meat of slaughter turkeys, without skin and bones, purchased directly from the producer (a local slaughterhouse for turkeys, Poland). The raw breast meat of slaughter turkeys contained 24.10% protein, 1.67% fat, 1.27% total ash, with an energy value of 113 kcal/100 g. The plant components were chickpeas, red peppers, white onions, fresh garlic heads, dried tomatoes, fermented black garlic, linseed oil, and hemp oil. Gluten-free chickpeas from Bio Planet, certified organic product PL-EKO-07; dried tomatoes from Nat Vita; fermented black garlic from Juleko and BIG Nature cold-pressed linseed oil from organically grown seeds; cold-pressed hemp seed oil from organically grown crops from Bio Planet, purchased from an organic food store. Vegetables: peppers, onions and garlic from a local producer; other ingredients, such as natural non-iodised salt from 'Kłodawska', black pepper, and cayenne pepper from 'Dary Natury', purchased from a natural food store.

The preparation of raw meat material in the plant-based meat product trial involved the following steps: steaming the raw material in water in a brew kettle at 90±5°C until the temperature inside the muscle tissue reached 76±2°C, as measured by a Testo 104 temperature metre (Testo SE & Co. KGaA, Lenzkirch, Germany); grinding in a meat grinder (RM160P, PSS Svidnik, Slovakia) using a 5 mm mesh screen; cooling to a temperature of 20 ± 2°C and weighing according to the recipe with a precision of ± 0.02 kg, using a scale (Electronic platform DIBAL PVC-50, Spain). To remove anti-nutritional substances, improve digestibility and bioactive and physicochemical profile of chickpeas, they were pretreated. Treatment consisted of soaking in cold water (12 hours), rinsing, draining (stainless steel sieve for loose fractions) and steaming in water (brew kettle), steaming time 60 min and cooling to a temperature of 20º±2ºC. The vegetables included sweet red peppers, unpeeled onions and garlic bulbs, which were roasted (in a Rational combi steamer, Germany) for 40 minutes and then cooled to 20ºC±2ºC. Pre-shredded animal and plant raw materials (particle size $0.02 \leq \Phi \leq 0.50$ mm) were homogenised to obtain a homogeneous mass (M1200 pass-through cutter, PSS Svidnik, Slovakia). Flaxseed oil, hemp oil, fermented black garlic, and spices (salt, black pepper, cayenne pepper) were used as additional ingredients. All raw materials and additives were then thoroughly mixed (K80F bowl cutter, PSS Svidnik, Slovakia). The resulting mixture was poured into heat shrinkable casings and portioned (150 g) (F-line 190 continuous portioning stuffer, Frey, Herbrechtingen, Germany) and clipped (PA-91-J clipping machine (BECK Clip System, Komirniki, Poland). The brewing process of the finished products was carried out in a brewing chamber (Zasada, Poland) until a temperature of 72ºC±2ºC was reached in the geometric centre of the product (Termoprodukt DT-34 reference thermometer). A metal and foreign body detector (RAYCON EX1 (Bizerba, Balingen, Germany) was used to detect foreign bodies. A weighing label printer (GLM – E maxx Bizerba, Balingen, Germany) was used to verify the weight of the finished product after heat treatment. The test meat and plant product in the form of a pâté was stored at a temperature of 5-6°C. After brewing, the products were cooled to a temperature of 5ºC±2ºC (Refrigeration chamber for fresh products, temperature from 0ºC to 4ºC).

The reference pastes were produced in the same way as described above. The recipe for the reference meat product was based on the recipe for classic chicken pâté in paste form. The recipe for the plant-based reference product was based on the recipe for the classic plant-based paste of the type 'hummus'. The reference meat product contained 75.00% by weight of the total amount of raw materials, including steamed meat from the breasts of slaughtered turkeys and steamed pork jowl, and additional ingredients: hydrated wheat bread, roasted onion, roasted garlic, and spices: salt,

 doi:10.20944/preprints202602.0573.v1

black pepper, and ice water. The plant-based reference product contained 75.00% chickpeas by weight of the total amount of raw materials and additional ingredients: rapeseed oil, roasted onion, roasted garlic, and spices (salt, black pepper, ice water).

After 12 hours of storage (Liebherr LKPv 6527 MediLine refrigerator, Germany) of the meat and plant-based trial product and its reference counterparts, tests were conducted on their physical and chemical properties, and a sensory evaluation was performed.

2.2. Assessment of Physical Properties

The acidity level of the products was determined using a HI 99163 digital pH metre (Hanna Instrument Company, Woonsocket, USA), equipped with an FC232 composite electrode (Hanna Instrument Company, Woonsocket, USA). Before each measurement, the device was calibrated using standard buffer solutions with pH values of 4.01 and 7.01, according to the manufacturer's recommendations. The pH measurement was performed by inserting the electrode to a depth of approximately 2/3 of its length into the tested product at an angle of 45 °. Measurements were carried out at a temperature close to that of the samples to limit the influence of thermal differences on the stability of the electrode signal. The reading was taken after stable readings were obtained from the device. The average pH value for the test group was determined on the basis of ten measurements taken for the same batch of product, using a uniform test methodology for all samples.

The colour of the raw meat material was evaluated according to the reflection method using a Chrome Metre colorimeter (Konica Minolta Sensing, Inc., Japan) equipped with a CR-400 measuring head. D65 lighting and a standard colorimetric observer with a viewing angle of 2 ° were used to determine the colour. The colour of the raw material was presented as lightness (L*), redness (a*) and yellowness (b*) according to the colour system developed by the International Commission on Illumination (CIE) [43]. Measurement was performed on a freshly cut surface of the product by applying the head and reading the value. Each sample was analysed at three different points on the surface and then the average value of each colour parameter was calculated. Each measurement was made in ten repetitions, following an identical test procedure. The analyses were carried out under controlled environmental conditions, in a lit room, at a temperature of 20 °C ± 2 °C.

2.3. Assessment of Chemical Properties

The total ash content in meat and meat-based products was determined using the gravimetric method (Nobetherm P330 muffle furnace, Lilienthal, Germany) according to the methodology described by Augustyńska-Prejsnar et al. [43].

The total protein content in meat and meat-based products was determined using the Kjeldahl method, based on the determination of total nitrogen [44]. The samples were mineralised in the presence of concentrated H_2SO_4 (VI) and a catalyst, and then, after alkalization with NaOH, the released ammonia was distilled with steam into a boric acid solution (automatic apparatus, BUCHI Labortechnik AG, Switzerland). The distillate obtained was titrated with a HCl solution. The determinations were performed in two replicates and the protein content was calculated using the nitrogen-protein conversion factor (F = 6.25).

The amino acid content in the products was determined by chromatography in accordance with EU Regulation 1169/2011 [44].

The free fat content in meat and meat-based products was determined using the extraction weight method with a Soxhlet extractor (Soxtherm, Gerhardt, Königswinter, Germany). Diethyl ether with a boiling point of 40–60°C was used for extraction. The extract was dried in an electric oven at 103±2°C to a constant weight. The fat content was determined using the AOAC 920.39 method and the fatty acid profiles were determined in a similar manner [43]. The composition of fatty acids (percentage of total fatty acids) was determined by gas chromatography using a standard-based procedure [45–47].

Cholesterol levels in the products were determined by gas chromatography with FID detection on a GC 7820A gas chromatograph (Agilent Technologies, Inc., Agilent, Santa Clara, California, USA).

 doi:10.20944/preprints202602.0573.v1

Sterols were isolated from the matrix and then the samples were derivatised using gas chromatography with flame ionisation detection.

The determination of total dietary fibre in the tested products was performed using the enzymatic-gravimetric method (Kjeldatherm mineralisation block from Gerhardt, Königswinter, Germany, with controlled temperature regulation, Vapodest Carousel automatic distiller from Gerhardt, Germany, vacuum filtration kit from Foss Analytical A/S, Denmark). The samples were dried overnight and defatted with petroleum ether, then ground to particles smaller than 0.3 mm. MES/TRIS buffer, c=0.05 mol/l, was added and adjusted to pH 8.3. The samples were incubated with successive additions of ⊚-amylase, protease, and amyloglucosidase solutions. After the enzymatic decomposition stage, the sample was poured with heated ethyl alcohol (78%) to precipitate the sediment and filtered under vacuum through a glass filter crucible. The crucible with the sediment was dried for 12 hours at 103±2°C and then weighed. In one crucible, the ash content was determined by calcination in an oven at 550±25°C, while in the other, nitrogen was determined in the same way as for protein determination. The dietary fibre content in the test sample was calculated from the values obtained [43].

2.4. Sensory Evaluation

The sensory evaluation of the products was carried out in accordance with the methodology provided by Augustyńska-Prejsnar [43], taking into account the PN-EN ISO 8589:2010 standard [48].

2.5. Statistical Analysis

The data obtained were statistically analysed by calculating the mean values ($\bar{x}$) and the corresponding standard deviations ($\bar{x}$). The normality of the data distribution was assessed using the Shapiro–Wilk test, while the homogeneity of variance was verified using the Levene test. The significance of the differences between the studied groups was analysed using one-way analysis of variance (ANOVA). In the case of significant effects, Tukey's test was used as a multiple comparison procedure. A p-value ≤ 0.05 was accepted as the level of statistical significance. Analyses were performed using the Statistica 13.3 software package [49].

3. Results and Discussion

The study found a significantly ($p \le 0.05$) higher pH value in products containing plant components compared to the reference meat-based product (Table 1). The observed increase in pH may result from the reaction of the plant-based raw materials used, in particular, parched chickpeas, which constitute a significant proportion of the reformulation. According to Augustyńska-Prejsnar et al. [43], the process of chickpea promotes the leaching of soluble acidic compounds, leading to an increase in pH and, consequently, in the final product. Furthermore, the high content of alkaline amino acids, such as arginine and lysine, present in chickpea proteins, may have contributed to the effect obtained [3]. The results obtained are consistent with the data from the literature, which show an increase in the pH of meat products with an increase in the proportion of various forms of chickpeas in the recipe [43,50–54]. As indicated by data in the literature [55], the addition of peppers to the meat paste had no significant effect on the pH of the product containing it.

Table 1. Physical characteristics of the meat-plant product in paste form and the reference meat product and vegetable product ($\bar{x} \pm s$).

Parameter	Product			*p-value*
	P_M	P_{MR}	P_R	
pH	5.88^a ± 0.01	6.10^b ± 0.01	6.30^c ± 0.02	0.012
Colour cross-section: CIE				
L*	78.16^a ± 3.00	68.00^b ± 0.89	72.84^c ± 1.60	0.008
a*	3.53^a ± 0.13	10.06^b ± 0.52	5.53^c ± 0.49	0.000

b*	18.80ᵃ ± 0.14	33.84ᵇ ± 0.51	38.64ᶜ ± 0.84	0.000

P_M – reference meat product, P_{MR} – meat-plant product, P_R– reference plant product; Explanation: mean values marked with different letters in rows differ statistically at p ≤ 0.05.

Significant differences (p < 0.05) differences in colour parameters in the CIE L*a*b* system between the tested products resulted from the different composition and colour formation properties of the raw plant materials used (Table 1). The decrease in the L* brightness parameter, particularly noticeable in the meat and plant product (P_{MR}), can be attributed to the presence of peppers and tomatoes in the recipe, which are sources of intense carotenoid pigments, as well as to the oxidative reactions and non-enzymatic browning that occur during heat treatment. The largest increase in red colour saturation (a*) in the pilot meat and plant-based product (P_{MR}) was mainly due to the presence of typical carotenoids of peppers and tomatoes. Capsanthin and capsorubin, which are the main red xanthophylls in peppers [27,28], are characterised by high thermal stability and a strong ability to intensify the red colour, which contributed to a significant increase in the value of a* [55]. In addition, lycopene, a lipophilic carotenoid with an intense red colour present in tomatoes, may have enhanced the effect of shifting the colour toward red-orange tones, despite the partial dilution of this effect by the presence of chickpeas in the product matrix. The highest b* values were recorded in the reference plant-based product (P_R), which can be attributed to the dominant share of chickpeas, whose natural color after heat treatment is described as creamy yellow. Traces of carotenoids present in chickpeas, such as lutein and β-carotene, give the product a light yellowish hue, which becomes clearly noticeable in the colour parameters when the proportion of this raw material is high [54]. Furthermore, the presence of phenolic compounds (including catechins, ferulic acids, and gallic acids) and the formation of melanoidins as a result of the Maillard reaction during steaming and cooking may have contributed to a slight darkening of the colour [56]. Similar relationships were observed by Augustyńska-Prejsnar et al. [43] in products with a similar raw material composition. Kasaiyan et al. [54] demonstrated an increase in the yellow colour component in cooked chickpea-enriched lamb sausages, as did Kasaiyan et al. [53], who noted a similar effect in pork chops.

Improving the nutritional value of food is one of the fundamental aspects of its health-promoting effects and is directly related to the content and quality of protein, fat, vitamins, and minerals [43,54,57,58]. In the case of meat products, efforts are focused on modifying the composition of raw materials, including reformulating recipes to include plant-based components [5,59]. Protein, as one of the basic nutrients provided in the diet, plays a fundamental role in maintaining proper metabolic functions of the body. Our own studies have shown that partial substitution of raw meat materials did not lead (p>0.05) to a reduction in the overall supply of this component (Table 2).

Table 2. Nutritional value of a meat-plant product in paste form and a reference meat product and plant product ($\bar{x} \pm s$).

Parameter	Product			*p-value*
	P_M	**P_{MR}**	**P_R**	
Basic chemical composition:				
Dry matter (g/100g)	38.05ᵃᵇ ± 1.91	36.95ᵃ ± 3.61	41.40ᵇ ± 0.50	0.011
Total ash (g/100g)	1.15 ± 0.10	1.14 ± 0.06	1.14 ± 0.20	0.214
Fat (g/100g)	18.25ᵃ ± 2.12	8.51ᵇ± 0.81	13.50ᶜ ± 0.52	0.006
Protein (N x 6.25) (g/100g)	15.40ᵃ± 0.07	15.10ᵃ ± 0.14	7.40ᵇ ± 0.10	0.021
Fibre (g/100g)	0.71ᵃ ± 0.14	3.34ᵇ ± 0.08	7.97ᶜ ± 0.50	0.000
Vitamin E alpha-tocopherol (mg/kg)	4.94ᵃ ± 0.06	11.40ᵇ ± 0.02	39.05ᶜ ± 0.75	0.000
Salt (g/100g)	0.80ᵃ ± 0.01	0.60ᵇ ± 0.01	0.64ᵇ ± 0.01	0.021
Cholesterol (mg/100g)	51.90ᵃ ± 2.50	23.40ᵇ ± 1,16	3.28ᶜ ± 0.52	0.001

P_M – reference meat product, P_{MR} – meat-plant product, P_R– reference plant product; Explanation: mean values marked with different letters in rows differ statistically at p ≤ 0.05

At the same time, the reformulated meat plant product was shown to be characterized by a higher protein content (Table 2) and a higher biological value (Table 3) compared to the reference plant-based product. The results of the study indicate a favourable balance of the amino acid profile in the test meat and plant-based product compared to a typical plant-based spread of type hummus. Compared to the reference meat product, the meat and plant product had a higher content of aspartic acid glutamic acid, and lysine, which may indicate a higher nutritional value resulting from the combination of meat and plant ingredients.

Table 3. Amino acid profile of an innovative meat-plant product in paste form and a reference meat product and plant product (g/100g).

Parameter	Product			*p-value*
	P_M	P_{MR}	P_R	
Aspartic acid	1.24ᵃ ± 0.08	1.42ᵇ ± 0.04	0.86ᶜ ± 0.01	0.022
Lysine	1.16ᵃ ± 0.09	1.27ᵇ ± 0.01	0.55ᶜ ± 0.01	0.032
Methionine expressed as methionine sulfone	0.32ᵃ ± 0.01	0.35ᵃ ± 0.01	0.13ᵇ ± 0.01	0.029
Cystine	0.14ᵃ ± 0.01	0.14ᵃ ± 0.01	0.09ᵇ ± 0.01	0.034
Threonine	0.58ᵃ ± 0.04	0.62ᵃ ± 0.02	0.30ᵇ ± 0.01	0.024
Seryna	0.57ᵃ ± 0.04	0.62ᵃ ± 0.01	0.40ᵇ ± 0.01	0.031
Glutamic acid	1.99ᵃ ± 0.18	2.12ᵇ ± 0.05	1.16ᶜ ± 0.20	0.036
Proline	0.78ᵃ ± 0.02	0.53ᵇ ± 0.01	0.32ᶜ ± 0.01	0.022
Glycine	0.82ᵃ ± 0.04	0.61ᵇ ± 0.01	0.31ᶜ ± 0.01	0.025
Alanine	0.83ᵃ ± 0.06	0.84ᵃ ± 0.01	0.34ᵇ ± 0.01	0.041
Valine	0.56ᵃ ± 0.03	0.63 ᵃ ± 0.02	0.32ᵇ ± 0.02	0.032
Isoleucine	0.52ᵃ ± 0.02	0.60 ᵃ ± 0.03	0.31ᵇ ± 0.03	0.026
Leucine	0.99ᵃ ± 0.06	1.10 ᵃ ± 0.03	0.57ᵇ ± 0.02	0.032
Tyrosine	0.43ᵃ ± 0.04	0.47 ᵃ ± 0.01	0.21 ᵇ ± 0.01	0.036
Phenylalanine	0.53ᵃ ± 0.03	0.63ᵃᵇ ± 0.01	0.43ᶜ ± 0.02	0.041
Histidine	0.44ᵃ ± 0.08	0.45 ᵃ ± 0.01	0.20ᵇ ± 0.03	0.040
Arginine	0.91ᵃ ± 0.02	0.95 ᵃ ± 0.04	0.59 ᵇ ± 0.02	0.042

P_M – reference meat product, P_{MR} – meat-plant product, P_R – reference plant product; Explanation: mean values marked with different letters in rows differ statistically at $p \leq 0.05$.

Kasaiyan et al. [53] found no significant changes in the protein, lipid, or moisture content of the reformulated pork chops with a 25% addition of cooked chickpea paste. In contrast, studies by Motamedi et al. [51] and Asmae and Admassu [60] showed an increase in the protein content of meat-based products enriched with chickpea or lentil flour. Similar results have also been described regarding the beneficial effect of plant protein on amino acid content and amino acid profile in studies on the addition of pea, lentils, and beans to beef burgers, where an increase in the total content of essential amino acids, including glutamate, lysine, and aspartic acid, was confirmed as a result of substituting traditional meat protein with plant protein [61]. Furthermore, Ribes et al. [61] showed that substituting part of beef protein with fava bean protein concentrate increased total protein content and improved the availability of selected essential amino acids in burgers, confirming that the inclusion of plant proteins in the recipes analysed can optimise the amino acid composition of meat products.

The studies showed that reformulation resulted in a significant ($p < 0.05$) reduction in fat content in the test meat and plant-based product compared to the reference products. The fat content was reduced by more than 50% compared to the reference meat-based product and by more than 36% compared to the reference plant-based product (Table 2). A major advantage of the meat and plant-based paste was its beneficial fatty acid profile, characterised by a low saturated fatty acid (SFA) content, a high polyunsaturated fatty acid (PUFA) content, and a high omega-3 content compared to the reference products (Table 4).

Table 4. Fatty acid profile of an innovative meat-plant product in paste form and a reference meat product and plant product (g/100g).

Parameter	Product			*p-value*
	P_M	P_{MP}	P_R	
∑ saturated fatty acids (SFA)	7.33ᵃ ± 1.50	1.31ᵇ ± 0.13	1.18ᵇ ± 0.02	0.001
∑ monounsaturated fatty acids (MUFA)	8.32ᵃ ± 1.16	2.66ᵇ ± 0.34	7.59ᵃ ± 0.20	0.011
∑ polyunsaturated fatty acids (PUFA)	2.06ᵃ ± 0.67	4.26ᵇ ± 0.37	4.13ᵇ ± 0.15	0.014
Omega-3 fatty acids FA	0.21ᵃ ± 0.09	1.79ᵇ ± 0.16	1.06ᶜ ± 0.02	0.044
Omega-6 fatty acids FFA	1.85ᵃ ± 0.48	2.47ᵇ ± 0.23	3.08ᶜ ± 0.14	0.024

P_M – reference meat product, P_{MR} – meat-plant product, P_R– reference plant product; Explanation: mean values marked with different letters in rows differ statistically at $p \leq 0.05$.

The studies found that the content of saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) in the pilot meat and plant-based product was significantly lower compared to the reference meat-based product (classic chicken pâté in paste form). At the same time, an increase in the PUFA content was observed, which further increased the nutritional value of the product. The fat of the meat and plant-based product (Table 5) was characterized by a lower content of myristic acid (C14:0), palmitic acid (C16:0), and stearic acid (C18:0), which are the main SFA acids in animal products. At the same time, the fat of the meat and plant-based product contained high levels of linoleic acid (C18:2n6t), gamma-linolenic acid (C18:3n6) and linolenic acid (C18:3n3), giving it a balanced PUFA profile that exceeded the classic meat-based product in terms of health benefits. Compared to the reference plant-based product, the prototype had a comparable saturated fatty acid (SFA) content and a favourable ratio of omega-6 to omega-3 fatty acids. The study showed that the reference meat product had the highest and most unfavourable omega-6/omega-3 ratio (>8–10: 1), which reduced its health value. The plant-based reference product had an omega-6/omega-3 ratio (~3:1) in line with nutritional recommendations, but with a predominance of omega-6. The innovative meat and plant-based product had the most balanced omega-6 to omega-3 ratio (1.4-1.6:1), surpassing both reference products. This fatty acid profile is optimal from a nutritional point of view and may help prevent lifestyle diseases. The beneficial effects of plant components (chickpeas, tomatoes and peppers, linseed oil and hemp oil) have been confirmed, among others, Augustyńska-Prejsnar [43], Skwarek and Karwowska [62], Karslıoğlu et al. [63], Castro et al. [63], Al-Madhagy et al. [65], Dąbrowski et al. [66], Mueed et al. [67], Nowak and Jeziorek [68], and Augustyńska-Prejsnar et al. [57,58], as well as other authors dealing with the issue of functional modifications of the fat composition of meat products [1,69].

Table 5. Fatty acid content in an innovative meat-plant product in paste form and in a reference meat product and plant product (% in fat).

Parameter	Product			*p-value*
	P_M	P_{MR}	P_R	
Capric acid (C10:0)	0.06 ± 0.01	<0.05	<0.05	-
Lauric acid (C12:0)	0.07 ± 0.01	<0.05	<0.05	-
Myristic acid (C14:0)	1.10ᵃ ± 0.02	0.24ᵇ ± 0.03	0.09ᶜ ± 0.02	0.001
Palmitic acid (C16:0)	22.70ᵃ ± 0.28	9.44ᵇ ± 0.01	5.72ᶜ ± 0.20	0.001
Palmitoleic acid (C16:1)	1.87ᵃ ± 0.04	0.63ᵇ ± 0.01	0.25ᶜ ± 0.01	0.022
Heptadecanoic acid (C17:0)	0.30ᵃ ± 0.01	0.11ᵇ ± 0.02	0.06ᵇ ± 0.02	0.032
Stearic acid (C18:0)	14.60ᵃ ± 0.57	4.89ᵇ ± 0.06	1.92ᶜ ± 0.03	0.000

Oleic acid (C18:1n9c)	37.90[a] ± 0.57	21.75[b] ± 0.07	49.30[c] ± 1.02	0.035
Linoleic acid (C18:2n6c)	9.21[a] ± 0.16	27.80[b] ± 0.01	22.70[c] ± 0.18	0.002
Arachidic acid (C20:0)	0.23[a] ± 0.02	0.36[b] ± 0.04	0.55[c] ± 0.02	0.031
γ-linolenic acid (C18:3n6)	<0.05	0.65 ± 0.02	<0.05	-
cis-11-Eicosenoic acid (C20:1)	0.62[a] ± 0.08	5.38[b] ± 00.1	1.91[c] ± 0.18	0.017
Linolenic acid (C18:3n3)	1.12[a] ± 0.19	21.05[b] ± 0.21	7.82[c] ± 0.50	0.001
cis-11.14-Eicosadienoic acid (C20:2)	0.49[a] ± 0.01	0.13[b] ± 001	0.09[b] ± 0.01	0.022
Behenic acid (C22:0)	0.07[a] ± 0.01	0.23[b] ± 0.01	0.32[c] ± 0.02	0.031
cis-8.11.14-Eicosatrienoic acid (C20:3n6)	0.11[a] ± 0.03	0.08[ab] ± 0.01	<0.05[b]	0.044
Erucic acid (C22:1n9)	0.16[a] ± 0.01	0.10[b] ± 0.01	0.18[a] ± 0.01	0.041
Arachidonic acid (C20:4n6)	0.44[a] ± 0.09	0.36[a] ± 0.01	<0.05[b]	0.024
Lignoceric acid (C24:0)	<0.05[a]	0.12[b] ± 0.01	0.12[b] ± 0.02	0.036
Nervonic acid (C24:1)	<0.05[a]	<0.05[a]	0.12[b] ± 0.01	0.036
Omega-3 Sum FA	1.12[a] ± 0.19	21.05[b] ± 0.21	7.82[c] ± 0.55	0.000
Omega-6 Sum FA	10.25[a] ± 0.07	29.00[b] ± 0.14	22.80[c] ± 1.20	0.011
Trans isomers C18:1	0.14[a] ± 0.01	<0.05[b]	<0.05[b]	0.003
cis-11-Octadecenoic acid (C18:1n11c)	4.46[a] ± 0.35	2.00[b] ± 0.01	4.45[a] ± 0.02	0.022
Cis-trans isomers of linoleaidic acid	<0.05	0.09 ± 0.01	<0.05	-

P_M – reference meat product, P_{MR} – meat-plant product, PR– reference plant product; Explanation: mean values marked with different letters in rows differ statistically at $p \leq 0.05$.

A significant reduction in cholesterol content ($p \leq 0.05$) was found in the pilot meat and plant compared to the reference meat product (Table 2). The reduction was more than 50%. The results obtained should be considered significant and potentially beneficial from the perspective of consumer health. According to current scientific reports, the impact of dietary cholesterol on its concentration in the blood serum of people with normal lipid metabolism is negligible. However, in people with dyslipidaemia, reducing cholesterol intake can lead to an improvement in the lipid profile and promote beneficial health effects. The reduced cholesterol content in meat and plant-based products was directly related to the partial replacement of animal-based raw materials with plant-based components, which are naturally cholesterol-free [58,70]. Similar processes were described in the study by Fernández-Rodríguez et al. [71]. Furthermore, meat and plant products with reduced cholesterol content often contain a higher proportion of dietary fibre and bioactive plant components, such as phytosterols, which can further reduce cholesterol absorption in the gastrointestinal tract [72].

Dietary fibre is an important component of the diet, exhibiting multifaceted health benefits [73]. In food technology, especially in meat processing, it is used to improve the functional and quality properties of products [6]. Its consumption is associated with a reduced risk of lifestyle diseases, among other things, reduced lipid absorption, modulation of blood sugar levels, regulation of blood pressure, and a beneficial effect on intestinal peristalsis and intestinal microflora [72]. Our own research has shown that reformulation of the meat and plant-based pate prototype resulted in a significant ($p<0.05$) increase in fibre content compared to the reference meat-based product (Table 2). At the same time, it was possible to maintain the fibre content in the innovative meat and plant-based product at 40% compared to the reference plant-based product. The confirmed increase in fibre content in meat products has been demonstrated in numerous studies on enrichment with plant-based ingredients [6,15,43,57,60,72,74,75]. The addition of chickpea dietary fibre to pork improved its emulsifying and gelling properties, while also increasing the dietary fibre content of the final product [6]. A similar effect was demonstrated after adding tomato fibre to poultry products, where even a small addition of 1–3% fibre increases the total fiber content and improves texture parameters and water-binding capacity [73]. Review articles in the literature [43,70,74] indicate that enriching meat products with plant-based ingredients, including vegetables, fruits, and legumes, is an effective strategy not only to increase the fibre content but also for improving the functional properties of meat-based products, provided the appropriate profile of other nutrients is maintained [34,76].

The caloric value of food refers to the total amount of energy contained in nutrients that the body can release and use in metabolic processes [16]. Our own research has shown that the trial meat and plant-based product had a lower ($p \leq 0.05$) energy value (both in kJ and kcal) compared to both the reference meat-based product and the plant-based product (Table 6). The innovative meat and plant-based product provided less fat energy than the reference products. The sugar profile of the tested products was varied and reflected the nature of the raw materials used in their production. The meat and plant-based product was shown to be distinguished by a significant proportion of fructose, indicating the influence of plant components. The lowest sugar content was found in the plant-based reference product, where sucrose was dominant. The reference meat product was distinguished by the presence of maltose, which was absent in the other variants. The sugar profile reflected the nature of the raw materials used in their production [19]. The results obtained are consistent with those of other authors, indicating a reduction in the energy value of hybrid meat and plant products, which is in line with current nutritional trends [77]. The results indicate that substituting some meat ingredients with plant components can lead to a reduction in the energy value of food products. Comparative studies have shown that plant-based protein alternatives often have a lower energy value than their meat counterparts, which is due, among other things, to the lower fat content and the higher fibre content in plant-based or hybrid products [75].

Table 6. Caloric and energy value of meat-plant products and reference meat products and plant products ($\bar{x} \pm s$).

Parameter	Product			*p-value*
	P_M	**P_{MR}**	**P_R**	
Energy value				
Available carbohydrates (g/100g)	5.42[a] ± 0.35	8.91[b] ± 2.68	11.40[c] ± 0.50	0.003
Energy (kJ) kJ/100g	1010.00[a] ±77.78	750.00[b] ± 77.78	884.00[b] ± 0.41	0.001
Energy (kcal) kcal/100g	254.00[a] ± 16.97	174.00[b] ± 18.38	218.00[a] ± 5.20	0.004
Energy from fat (kJ) kJ/100g	674.50[a] ± 77.00	315.00[b] ± 29.70	500.00[c] ± 20.00	0.001
Energy from fat (kcal) kcal/100g	161.00[a] ± 18.38	75.30[b] ± 7.07	119.00[c] ± 5.12	0.002
Sugar profile (g/100g):				
Glucose	0.28[a] ± 0.01	0.33[a] ± 0.05	0.19[b] ± 0.01	0.022
Galactose	<0.05	<0.05	<0.05	-
Fructose	0.17[a] ± 0.02	0.41[b] ± 0.01	0.15[a] ± 0.02	0.011
Saccharose	0.13[a] ± 0.01	0.16[ab] ± 0.02	0.28[b] ± 0.01	0.021
Maltose	0.12 ± 0.03	<0.05	<0.05	-
Lactose	<0.05	<0.05	<0.05	-
Total sugars	0.71[a] ± 0.06	0.83[a] ± 0.01	0.32[b] ± 0.03	0.024

P_M – reference meat product, PMR – meat-plant product, P_R– reference plant product; Explanation: mean values marked with different letters in rows differ statistically at $p \leq 0.05$.

Sensory evaluation is a basic tool that is used to assess the quality of raw materials, semifinished products, and finished products, enabling their complete characterisation. In addition, it is used in the process of developing new products, modifying them, and introducing them to the market [16,42,75]. From the consumer's point of view, sensory evaluation is considered one of the key factors determining the choice of innovative products [2]. The studies conducted showed that the pilot meat and plant product was significantly ($p<0.05$) higher in intensity and smell desirability and flavor compared to the reference products (Table 7). The smell is one of the basic characteristics that determine product acceptance, as its intensity and character influence sensory appeal and consumption propensity. Therefore, a more favourable odour profile of a meat and plant-based product may indicate its greater market potential. Flavor, on the other hand, is a parameter that

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determines the selection of the repeatability of the product by consumers. A greater acceptance of the flavor of a meat-plant product indicates that the combination of meat and plant-based raw materials has contributed to improving sensory qualities and reducing the barrier associated with the acceptance of alternative protein sources. A comparative analysis of the tested products did not reveal any significant (p>0.05) differences in colour (p> 0.05) between the variants evaluated. The colour of the tested products corresponded to the characteristics typical for a given type of product, indicating that the expected visual properties were maintained. In terms of consistency, the meat-based reference product received the highest scores. The innovative meat and plant-based product and the plant-based reference product were rated at a similar level, indicating comparable structural properties of these samples. The comparable level of spreadability of the innovative meat and plant-based product compared to reference products suggests that the use of plant components did not cause any adverse changes in the structural system or phase interactions of the product. Spreadability, which is a key functional characteristic of paste-type products, significantly affects their consumer acceptance and functionality during application (for example, spread on bread). This may indicate the correct selection of plant raw materials and their contribution to the rheological and textural properties of the food matrix.

Table 7. Sensory characteristics of an innovative meat-plant product in paste form and a reference meat product and plant product (points).

Parameter	Product			p-value
	P_M	P_{MR}	P_R	
Odor (intensity)	3.83[a] ± 0.33	4.88[b] ± 0.23	4.38[c] ± 0.51	0.021
Odor (desirability)	3.50[a] ± 0.38	4.83[b] ± 0.25	4.38[c] ± 0.47	0.032
Flavor (intensity)	3.50[a] ± 0.37	4.79[b] ± 0.26	4.00[ab] ± 0.37	0.025
Flavor (desirability)	3.42[a] ± 0.42	4.92[b] ± 0.19	4.13[c] ± 0.31	0.025
Colour	4.04 ± 0.26	4.50 ± 0.21	4.54 ± 0.45	0.032
Consistency	4.83[a] ± 0.25	3.75[b] ± 0.34	3.67[b] ± 0.39	0.004
Spreadability	3.63[a] ± 0.29	4.38[b] ± 0.43	4.42[b] ± 0.45	0.021
General acceptability	3.84[a] ± 0.47	4.65[b] ± 0.39	4.42[ab] ± 0.33	0.037

P_M – reference meat product, P_{MR} – meat-plant product, P_R – reference plant product; Explanation: mean values marked with different letters in rows differ statistically at p ≤ 0.05. Sensory scale: Odor: 5—highly desirable, strong, 4—desirable, strong; 3—moderately desirable, 2—slightly undesirable, 1—very undesirable, too intense/imperceptible; Flavor: 5—very desirable, 4—desirable 3—moderately desirable, 2—less desirable; 1—very undesirable; Colour: 5—very desirable, uniform, 4—desirable, less uniform; 3—moderately desirable, uneven, 2—slightly undesirable, uneven; 1—very undesirable, uneven, altered in places; Consistency: 5—very desirable, compact, smooth, homogeneous, 4—desirable, compact, homogeneous, 3—moderately desirable, less compact, heterogeneous, 2—slightly undesirable, too weak/too strong; 1—very undesirable, weak/strong; Spreadability: 5—very desirable, 4—desirable, 3—moderately desirable, 2—slightly undesirable; 1—very undesirable; General acceptability: 5—very desirable, 4—desirable, 3—moderately desirable, 2—slightly undesirable; 1—very undesirable [43].

Pathiraje et al. [15] indicate that legumes, used in various forms, can act as binding agents in reformulated meat products by forming complex gel structures with meat proteins. Raziuddin et al. [55] showed that the use of paprika as an additive to goat meat paste reduced its spreadability, but did not adversely affect the overall quality assessment of the product. Research by Grasso et al. [16] showed that partially replacing meat with plant-based ingredients, including soy protein, did not negatively affect the taste, texture, or overall acceptability of beef meatballs. The products developed under this new concept were generally well received by consumers who regularly eat meat. In a study by Grasso and Jaworska [9] on consumer attitudes toward hybrid meat products, it was shown to be the most important factor in the evaluation of the product, followed by health and practical aspects, such as convenience of consumption. The general results obtained in the study showed that the pilot meat plant product received higher scores compared to reference products, indicating its high application potential and the possibility of use in industrial practice as an alternative to traditional meat products. In their study, Asmare and Admassu [60] found that dry fermented sausages containing 20% chickpea flour achieved the highest level of acceptability on a hedonic scale. Riadinskaja et al. [78], who demonstrated high consumer ratings for poultry-based meat and vegetable preserves enriched with legumes, obtained similar results.

5. Conclusions

The research carried out showed that the partial substitution of meat-based raw materials with plant-based components (chickpeas, peppers, tomatoes, vegetable oils) is an effective strategy to improve the nutritional and sensory quality of meat paste products. Reformulation affected the physicochemical properties of the product, leading to an increase in pH, which was mainly related to the nature of the plant raw materials used and the process of their technological treatment. The changes in the raw material composition were reflected in the colour parameters of the CIE L * a * b *, which differed significantly between the product variants and resulted from the presence of natural plant pigments. The pilot meat and plant-based product had a favourable colour profile that was accepted by the sensory panel.

The results of the study confirm the improvement in the health benefits of the innovative meat and vegetable spread that results from the reformulation. Compared to classic plant-based spreads such as hummus, the product has a lower fat content and energy value, while increasing the protein content and maintaining a favourable amino acid profile. Compared to the reference meat-based product, the meat and plant-based prototype product has a reduced fat content, including saturated and monounsaturated fatty acids, an increased dietary fibre content, and a lower cholesterol level.

Sensory evaluation confirmed the high acceptability of the pilot meat and plant-based product, which scored higher in terms of smell, taste, and overall evaluation compared to reference products. These results indicate that the combination of meat and plant-based raw materials can effectively overcome the acceptance barriers associated with alternative products to traditional meat-based products.

In summary, the developed meat and plant-based product is characterised by a high nutritional value and a high sensory acceptability, which confirms its potential for application.

Author Contributions: Conceptualization, A.A.-P, methodology, A.A.-P., M.O. and J.T.; software, J.T.; validation, B.R. formal analysis, A.A.-P., B.R; investigation, A.A.-P.; resources, A.A.-P. and J.T.; data curation, A.A.-P., M.O.; writing—original draft preparation, A.A.-P. and M.O.; writing—review and editing, A.A.-P. and M.O.; visualization, A.A.-P. and J.T.; supervision, A.A.-P.; project administration, A.A.-P.; funding acquisition, A.A.-P. All authors have read and agreed to the published version of the manuscript.

Funding: This scientific publication resulted from the project carried out under the grant programme for R&D works of scientific entities, Call IV, Competition No. 1/2024 Project title „Technology that improves the health benefits of poultry meat products" Grant agreement number n4/UR/1/DP/PCI/2024, co-financed under the project "Podkarpackie Center for Innovation 2029" implemented under the regional programme European Funds for Podkarpacie 2021-2027, priority: FEPK.01 Competitive and digital economy, measure: FEPK.01.01, Research and development, Type of project: Building the potential of innovation centers Podkarpackie Center for Innovation.

Institutional Review Board Statement: Ethical review and approval were waived for this study due to: The sensory tests were carried out using standard sensory evaluation methods, in which participants assessed safe food products prepared exclusively from ingredients approved for human consumption. The tests were conducted in accordance with the following standards: PN-EN ISO 8589:2010 [53] and PN-EN ISO 8586:2023 [76]. The study involved no invasive procedures and did not pose any health risk to participants. According to national regulations and institutional policy, such sensory tests do not require approval from the Ethics Committee or Institutional Review Board. The study did not involve any biomedical intervention or collection

doi:10.20944/preprints202602.0573.v1

of personal data; it was anonymous. Therefore, the Declaration of Helsinki is not applicable to this type of sensory evaluation.

Data Availability Statement: The datasets presented in this article are not readily available because the data are part of an ongoing study. Requests to access the datasets should be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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