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The Effect of the Addition of Hemp Seeds, Amaranth, and Golden Flaxseed on the Nutritional Value, Physical, Sensory Characteristics, and Safety of Poultry Pâté

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Featured Application: Application of hemp seeds, amaranth and golden flaxseed in the meat industry as a method of producing delicatessen products based on animal and vegetable raw materials. Poultry pâtés prepared according to the recipe developed in the study are characterised by an increased nutritional value (higher content of protein and essential amino acids (lysine, aspartic acid, leucine, arginine) and polyunsaturated fatty acids, a favourable ratio of omega-6 to omega-3 acids (3:1), higher content of vitamin E and fibre) compared to their traditional counterparts, while at the same time maintaining desirable sensory qualities and an acceptable taste. The obtained pâtés can be recommended as health-promoting food for the prevention of diet-related diseases.

Abstract: Food producers' interest in improving the nutritional and pro-health values of meat products has grown. The study aims to assess the effect of replacing poultry pâté products wheat roll (24% group I) in recipes with a mixture of hemp seeds (8% each in groups II, III, IV), amaranth (10% group II, 6% group III, 8% group IV) and golden flaxseed (6% group II, 10% group III, 8% group IV). The quality assessment covered nutritional value, physical properties, the total number of bacteria and assessment of sensory characteristics. The findings indicate that replacing wheat roll with seed mixtures increased the nutritional value (protein, ash, fat, proportion of polyunsaturated and polyene acids) of pâtés in all groups while decreasing the proportion of saturated fatty acids and the ratio of omega-6/omega-3 acids (3:1). This resulted in enhanced brightness and hardness pâtés, as well as greater microbiological safety. Although the spread and firmness of pâtés with seed addition were rated lower than the control, their taste desirability and bonding were rated highest for pâté with 8% plant additives. Pâtés with 24% hemp, amaranth and flaxseed mixture fulfil the requirements to be referred to as functional meat products.

Keywords: poultry pâté; hemp seeds; amaranth; golden flaxseed; value assessment; total number of bacteria; physical traits; sensory traits

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1. Introduction

Consumers of processed meat, aware of the relationship between diet and health, are increasingly searching out meat products with higher nutritional value compared to their traditional counterparts. This is related to the growing awareness of the relationship between diet and the occurrence of chronic diet-related diseases [1]. The meat products market is trying to meet the needs of consumers and their high requirements regarding food quality by introducing new, enriched products with functional and health-promoting properties [1–3]. Functional foods are those products that, in addition to nutritional value, have a positive effect on the functioning of the body [4,5]. The meat industry essentially offers three options for the development of functional products, modification at the farm, raw material and meat product level. At the breeding stage, the activities include genetic selection; at the raw material stage, the choice of the method and level of nutrition, and dietary supplementation are chosen, most often controlling the fatty acid composition [6,7]. The enrichment of the nutritional value of poultry meat products can be achieved by using or increasing the share of ingredients considered functional in the processing of poultry meat, at the same time having a health-promoting effect, among others, fibre, essential fatty acids and vitamins [7]. The pro-health values of meat products can be increased by the addition of biologically active substances, probiotics, elimination of synthetic additives and lowering the cholesterol content and energy value [5]. Enriching meat products with natural bioactive compounds is one of the main trends used in the meat industry [7], leading to a better-balanced diet and compensating for nutritional deficiencies [3]. As indicated in the literature [8–19], due to the rich nutritional composition of hemp, amaranth and golden flaxseeds, they can be used for the production of food products with added value, and the ingredients contained in the bioactive substances predispose the production of healthy and functional food. Hemp seeds are considered to be one of the most nutritionally complete food sources. They are a rich source of fat with a favourable composition of fatty acids and protein. Hemp fat (oil) contains large amounts of bioactive compounds, among others, phytosterols, carotenoids and polyphenols of anti-carcinogenic and anti-inflammatory nature [13,14]. Protein in the form of estidine is characterised by a good amino acid composition and high digestibility and is a source of bioactive peptides with antioxidant activity. Hemp seeds are rich in natural antioxidants and other bioactive ingredients, such as phenolic compounds, tocopherols, carotenoids and phytosterols [15,16]. Amaranth seeds are characterised as having a high nutritional value, which results from the high protein content with a very favourable amino acid composition. Attention is drawn to the high content of dietary fibre and the presence of a valuable ingredient, squalene [17]. A compound with antioxidant and chemopreventive properties, capable of binding free radicals. They are characterised by a high content of minerals and the presence of vitamins (B_1, B_2, B_6, E and niacin), as well as polyphenolic compounds [18,19]. Flaxseeds are a rich source of many chemical ingredients, valuable from the point of view of human nutrition. They contain about 40% fat, of which almost 60% are omega-3 fatty acids and only 15% omega-6 fatty acids. A valuable ingredient is fibre, which constitutes 28% of dry matter, also vitamin E, which is a natural antioxidant and protects the body's cells against the harmful effects of free radicals. The mineral content of flaxseeds is 3–8% [8,10]. The amino acid composition of flaxseeds has unique biological properties. The high content of leucine, lysine and phenylalanine regulates hormonal activities, tryptophan has a positive effect on eyesight and also prevents skin diseases, and threonine participates in the transformation and absorption of other amino acids. Flaxseed and products derived from it contribute to lowering the content of triglycerides and LDL cholesterol while increasing HDL cholesterol [9,10].

Turkey meat obtained from the leg may be a valuable raw material for processed meat production due to its high nutritional value, favourable sensory features and broad processing possibilities [20–22].

The aim of this study was to replace wheat roll in the recipe composition of poultry pâtés with a mixture of hemp, amaranth and golden flaxseed and to assess the effect of their inclusion on the nutritional value, physical and sensory properties and safety of the finished product.

2. Materials and Methods

2.1. Component Specifications

The culinary elements (thigh muscles with skin and bone) were purchased in a retail chain, produced by the same manufacturer. For the production of poultry pâtés, the femoral muscles of meat turkeys with 20.47% protein content, 3.51% fat, 24.04% omega-6 and 3.80% omega-3 fatty acid, 1.04% total ash,1.93% lysine, 0.62% methionine, 0.24% cysteine and

0.24% tryptophan were used. In the study, hulled hemp seeds, amaranth and golden flaxseeds were used, acquired from the company "Bio Planet", with a PL-EKO-07 certificate of organic farming. The hemp seeds featured 33.02% protein content, 50.16% fat, 56.20% omega-6 and 17.30% omega-3 fatty acids, 5.20% total ash, 1.10% lysine, 0.76% methionine, 0.52% cysteine and 0.38% tryptophan. The amaranth seeds featured 15.85% protein content, 6.71% fat, 43.20% omega-6 and 21.40% omega-3 fatty acids, 3.50% total ash, 0.78% lysine, 0.20% methionine, 0.18% cysteine and 0.20% tryptophan. The golden flaxseeds featured 22.50% protein content, 35.91% fat, 22.90% omega-6 42.5% and omega-3 fatty acids, 3.72% total ash, 0.87% lysine, 0.41% methionine, 0.42% cysteine and 0.36% tryptophan. The wheat roll featured 6.96% protein content, 1.10% fat, 37.80% omega-6 and 4.80% omega-3 fatty acids, 2.61% ash, 0.12% lysine, 0.09% methionine, 0.10% cysteine and 0.05% tryptophan, and were purchased from a local bakery.

2.2. Preparation of Poultry Pâtés

The turkey legs, with skin and bone, were parboiled in water until the internal temperature reached 76 ± 2 °C, after which the bone and skin were removed. A total of 16 kg of raw meat material was ground twice in a meat grinder (Zelmer, Rzeszow, Poland) with a mesh with a hole diameter of 3 mm, weighed with an accuracy of 1 g and divided into 4 parts (4 kg each.) The flaxseeds were ground, with a particle size fraction of $0.02 \leq \phi \leq 2.00$ mm, hydrated and subjected to thermal treatment to a temperature of 90 °C and cooled down to a temperature of 20 ± 2 °C. The amaranth seeds were soaked in cold water for 30 min, subjected to steaming at a constant temperature of 90 °C for 10 min, and cooled down to a temperature of 20 ± 2 °C, then ground to a particle size fraction of $0.02 \leq \phi \leq 2.00$ mm. The hemp seeds were ground, with a particle size fraction of $0.02 \leq \phi \leq 2.00$ mm, hydrated and subjected to thermal treatment until reaching a temperature of 90 °C, and cooled down to a temperature of 20 ± 2 °C. The wheat roll was hydrated and ground with a particle size fraction of ≤2.00 mm. The recipe composition of the pâtés is presented in Table 1. Four variants of the pâtés were produced in two replications. Group 1 consisted of classic poultry pâtés with the addition of a wheat roll. Groups II–IV were experimental groups in which, as a substitute for wheat roll, the pâtés used the addition of a mixture of hemp seeds, amaranth and golden flaxseed in different proportions (Table 1). In each group, all ingredients were introduced into a mechanical meat mixer with a stainless-steel stirrer (Kenwood Major Titanium, Havant, UK) and stirred for 5 min until the ingredients were evenly distributed. The stuffing was placed in aluminium moulds (400 mL) and subjected to the baking process in an electric oven (at 180 °C to obtain a temperature in the geometric centre of 78 °C). The temperature of the products was measured using an HI 9804 bayonet thermometer (Hanna Instruments, Woonsocket, RI, USA). The pâtés were cooled at a temperature of 18–22 °C, after which they were placed in cold storage (4 ± 2 °C for 24 h).

Table 1. The recipe composition of the poultry pâtés (%).

Ingredients	**Variants of Product**			
	Group I	**Group II**	**Group III**	**Group IV**
Turkey meat (thigh muscles)	69.80	69.80	69.80	69.80
Roll featured (hydrated)	24.00	-	-	-
Hemp seeds	-	8.00	8.00	8.00
Amaranth seeds	-	10.00	6.00	8.00
Golden flaxseed	-	6.00	10.00	8.00
Fresh egg mass (chicken eggs)	5.00	5.00	5.00	5.00
Salt	1.00	1.00	1.00	1.00
Black pepper	0.20	0.20	0.20	0.20

3. Quality Parameters

3.1. Assessment of Physical Traits

The active acidity (pH) of the pâtés was determined using a combined electrode with an HI 99,163 pH meter (Hanna Instrument Company, Vöhringen, Germany), which was calibrated in pH 4 and pH 7 buffers. The mean pH value was determined from 10 measured values for the same product, and the procedures were the same for all samples. The water-holding capacity (WHC), understood as the ability of meat to hold all or part of its own and added water of the samples was determined based on the volume of free water squeezed from the sample using Whatman no. 2 filter papers and the Grau-Hamm method.

The colour parameters in the CIE L*a*b* assessment of the cross-sectional surface of pâtés were determined based on the reflection method, using a Chrome Meter colourimeter (Konica Minolta, Osaka, Japan) fitted with a CR 400 head (ø = 11 mm). The colourimeter was calibrated with a Konica Minolta calibration plate (observer 20, illuminant D_{65}). The colour evaluations were carried out on freshly obtained product samples. Brittleness was measured based on the cutting force (Fmax), using a Zwick/Roelltesting machine BT1-FR1.OTH.D14 (from ZwickCmbH& Co. KG., Ulm, Germany), applying a wide-width Warner–Bratzler (V-blade) with a head speed of 100 mm·min^{-1} and a 0.2 N pre-cut force. The cutting was carried out on product samples with a cross-section of 200 mm^2 and a length of 100 mm. Texture profile analysis (TPA) was performed using a Texture Analyser CT3 25 (Brookfield, Middleboro, MA, USA) equipped with a cylindrical probe with a diameter of 38.1 mm and a length of 20 mm [23]. The texture was determined in samples with dimensions of 20 × 20 × 20 mm. A test of the double compression of the samples to 50% of their height was made. The speed of the roller movement during the test was 2 m/s, and the gap between pressures was 2 s. Weight loss (%) was calculated according to the formula: weight before roasting pâtés—weight after roasting/weight before roasting pâtés × 100 [24].

3.2. Assessment of Chemical Traits

The determination of the protein content of raw materials and poultry pâtés was carried out on the basis of the determination of nitrogen content by the Kjeldahl method and conversion into protein using the distillation-titration method (Kjeldatherm mineralisation block from Gerhardt, Königswinter, Germany, with controlled temperature control, Vapodest Carousel automatic distiller from Gerhardt, Königswinter, Germany). The calculated amount of nitrogen determined in the tested samples was converted into protein using a conversion factor of 6.25. The amino acid content in raw materials and pâtés was determined by chromatography according to EC Regulation 152/2009, III F (Tryptophan III G) [25]. The determination of the free fat content in raw materials and pâtés was carried out by the extraction and weight method (Soxhlet—Soxtherm extraction apparatus from Gerhardt, Königswinter, Germany, with an electric dryer enabling the temperature to be maintained in the range of (103 ± 2) °C, light petroleum with a boiling point from 40 °C to 60 °C). The composition of fatty acids (percentage of fatty acids in total fatty acids) in raw materials and products were determined using the DGF C-VI 11a method: 2016 mod + DGF C VI 10a: 2016 mod (Agilent Technologies 7890A GC System with FID Detektor and a CP-Sil 88 Säule from the company Agilent, Santa Clara, CA, USA). The principle of the method was based on the separation of fatty acids (identification of fatty acids after retention time) by gas chromatography with flame-ionisation detection. The preparation of samples of fatty acid methyl esters and transesterification with BF3 trifluoride was carried out in accordance with PN-EN ISO 12966-2:2017-05 [26]. The sample was measured in accordance with PN-EN ISO 12966-4:2015-07 (GC-FID) [27]. Gas chromatography of fatty acid methyl esters was carried out by capillary gas chromatography. The transesterified sample solution was distributed through a gas chromatograph by injection with flux division in a CP-Sil column and analysed by a flame-ionisation detector. The determination of the total ash content was carried out by the weight method (muffle furnace Nobetherm P330, Lilienthal, Germany). The determination of total dietary fibre in the poultry pâtés was carried out by the enzymatic-weight method (Kjeldatherm mineralisation block from Gerhardt, Königswinter, Germany with controlled temperature control, Vapodest Carousel automatic distiller from Gerhardt, Germany, vacuum filtration set from Foss Analytical A/S, Denmark). The samples were dried overnight and degreased using light petroleum, then ground to a particle size of less than 0.3 mm. A MES/TRIS buffer was added, c = 0.05 mol/L and the pH was corrected to 8.3. The samples were incubated by adding a solution of α-amylase, protease and amyloglucosidase. After the enzymatic decomposition stage, the sample was doused with heated ethyl alcohol (78%) to precipitate the sediment and filtered under vacuum through a glass filter crucible. The crucible with sediment was dried for 12 h at a temperature of (103 $\pm$ 2) °C, and then weighed. In one crucible, the ash content was determined by heating it in the oven at (550 $\pm$ 25) °C, while in the other, the nitrogen content was determined in the same way as in the determination of protein. From the obtained values, the content of dietary fibre in the studied sample was determined. Vitamin E (DL-alpha-Tocoferolacetate and Tocoferol) in the products was determined by Chromatography REG(EC) 152/2009, IV, B: 2009-02 [28].

3.3. Microbiological Analysis

The microbiological quality assessment (total number of bacteria) of the pâtés was made after 48 h of refrigerated storage of the products (5 °C). With a sterile scalpel, 10 g of the product from each test group was taken and transferred to sterile dishes, which were stored in refrigerated conditions at 4 °C. The samples were homogenised in 45 mL of sterile saline (0.9% NaCl) in a BagMixer® laboratory homogeniser (stomacher), and serial dilutions of 10-3 and 10-4 were performed. Cultures were then made on Trypticasein Soy Lab-Agar TSA (Biocorp, Cournon-d'Auvergne, France) and incubated at 37 °C for 24 h to calculate the parameters of the colony-forming units (cfu/g).

3.4. Evaluation of the Sensory Properties

The evaluation of the sensory properties of the sample pâtés was performed using the scaling method. The sensory analysis panel consisted of 10 people with confirmed sensory sensitivity and with at least 3 years of experience. The selection of people for the assessment team, and the training to check the sensory sensitivity of the candidates for assessors, were carried out according to the ISO standards [29]. The samples were assessed according to a 5-point hedonic scale according to Baryłko-Pikielna [30]. For the proper evaluation, the pâté samples were cooled to room temperature and cut into slices of rectangular parallelepiped shape (15 $\times$ 15 mm $\times$ 30 m). All samples to be assessed were placed in covered vessels marked with numerical codes. The samples were randomly assessed. Each panellist assessed a sample of three replications. Between each sample testing, the assessors took a break for 30 s and rinsed their mouths using mineral water. The test was carried out in a properly prepared room free from foreign odours, with appropriate temperature and lighting, with all distracting factors eliminated, in accordance with the applicable standards [31].

3.5. Statistical Analysis

The obtained data were collated and submitted for statistical analysis using Statistica 13.3, taking account of the arithmetic mean ($\bar{x}$) and standard deviation (s). The results on the effect of the addition of hemp seeds, amaranth and golden flaxseed were verified using a one-way analysis of variance ANOVA. The collected data were checked for normality with the Kolmogorov–Smirnov test with Lilliefors correction. The homogeneity of variances was checked with the Brown–Forsythe test. To indicate the significance of differences between means in groups, using Tukey's test at a 95% confidence level (α = 0.05). Differences were considered as significant if $p < 0.05$. The results on the effect of the addition of hemp seeds, amaranth and golden flaxseed on the sensory properties of pâté were verified by the use of non-parametric Kruskal–Wallis tests.

4. Results and Overview

Yield is a processing feature that is mainly of economic importance and may affect the degree of water retention in the product and its juiciness. The additions of hemp seeds, amaranth and golden flaxseed used in the original recipe in all research groups significantly influenced ($p < 0.05$) an increase in the yield of poultry pâtés (Table 2). In studies by Bilek and Turhan [32], lower losses during heat treatment of the finished products with the addition of flaxseed flour were shown, which resulted from moisture retention in enriched products. In a study by Novello et al. [11], the addition of golden flaxseed lowered the water content of raw and boiled beef cutlets. In the study by Longato et al. [17], poultry burgers with the addition of amaranth seeds and pumpkin seeds had a higher efficiency compared to control poultry burgers. In the work by Ostoja et al. [19], it was shown that grits prepared from raw amaranth seeds had a positive effect on the ability to retain water in meat mass in pasteurised and sterilised canned meat, which allowed losses during cooking to be reduced. The better water retention capacity, consequently, had an effect on improving the tenderness, juiciness and taste of canned meat. Sharoba [33] showed that sausages in which the addition of amaranth flour was used were characterised by higher efficiency after thermal treatment compared to the control group. The research by Kotecka-Majchrzak et al. [15] shows that the addition of hemp in the form of dough did not have a significant effect on the culinary losses of pork and poultry meatballs.

Table 2. Effect of the addition of hemp seeds, amaranth and golden flaxseed on the physical characteristics and total number of bacteria of poultry pâtés ($\bar{x} \pm s$).

Parameter	Poultry Pâtés			
	Group I	**Group II**	**Group III**	**Group IV**
pH	6.42 ± 0.01	6.40 ± 0.03	6.41 ± 0.01	6.40 ± 0.01
Cooking yield (%)	90.03 ^{b} ± 4.24	93.29 ^{a} ± 3.20	92.52 ^{a} ± 2.44	93.58 ^{a} ± 3.35
Colour cross-section:				
L*—lightness	65.75 ^{b} ± 2.35	67.10 ^{a} ± 2.43	69.19 ^{a} ± 2.00	68.09 ^{a} ± 3.49
a*—redness	3.99 ^{a} ± 0.22	3.05 ± 0.20	2.58 ^{b} ± 0.51	2.64 ^{b} ± 0.13
b*—yellowness	15.03 ^{b} ± 0.68	17.18 ^{a} ± 0.73	16.96 ^{a} ± 1.12	17.20 ^{a} ± 0.58
Texture parameters: Warner–Bratzler shear force (N)	6.58 ^{c} ± 1.15	8.16 ^{b} ± 0.27	10.30 ^{a} ± 0.66	9.10 ^{a} ± 0.56
Texture profile analysis (TPA):				
Hardness (N)	4.18 ^{c} ± 0.98	5.30 ^{b} ± 0.78	6.90 ^{a} ± 0.96	5.36 ^{b} ± 0.86
Springiness (mm)	1.50 ^{b} ± 0.52	1.62 ^{b} ± 0.48	2.12 ^{a} ± 0.50	1.80 ^{b} ± 0.44
Gumminess	1.01 ^{c} ± 0.46	1.48 ^{b} ± 0.42	1.68 ^{a} ±0.56	1.55 ^{b} ± 0.58
Chewiness (mJ)	1.51 ^{c} ± 0.52	2.30 ^{b} ± 0.48	3.50 ^{a} ± 0.50	2.79 ^{b} ± 0.73
Total number of bacteria (log cfu/g)	2.35 ^{a} ± 0.39	1.91 ^{b} ± 0.20	1.96 ± 0.19	1.88 ^{b} ± 0.19

Explanations: Group I—wheat roll 24%; group II—hemp seeds 8%, amaranth 10%, golden flaxseed 6%; group III—hemp seeds 8%, amaranth 6%, golden flaxseed 10%; Group IV—hemp seeds, amaranth, golden flaxseed each in 8%; ^{a,b,c}—values in rows with different letters differ significantly, $p < 0.05$.

An important role in shaping the colour of finished meat products, apart from the raw meat, may be played by additives and proportions of all ingredients used in the recipe [11,13,15]. In our own research, the share of meat in all groups was the same, so it can be assumed that the colour changes of the finished products resulted from the amount and type of additives used. The obtained results of the assessment of the colour of the cross-section of poultry pâtés showed that the products with the addition of hemp seeds, amaranth and golden flaxseed in all tested groups were characterised by a brighter colour ($p < 0.05$), a higher brightness parameter L* and a higher ($p < 0.05$) degree of saturation towards yellow. Lower ($p < 0.05$) saturation of the red colour compared to the control group was noted in group III with a share of 10% of flax, 6% of amaranth and 8% of hemp seeds, and in group IV with 8% of all the seed additives (Table 2). Similar results of an increase in the brightness and saturation of the yellow colour and reduction of the red colour saturation of beef cutlets with the addition of 5% golden flaxseed seeds and 5% of flaxseed flour were obtained by Novello et al. [11]. The addition of golden flaxseeds and by-products from these seeds were obtained earlier in studies by Bilek and Turhan [32]. Colour changes resulting from the fact that the flavonoids present in flaxseeds react with proteins [34] to form active pro-oxidative isomers, which result in the oxidation of myoglobin or metmyoglobin [35]. In a study by Zając et al. [13], the colour parameters of pork pâtés changed depending on the hemp ingredient used. The addition of hulled hemp seeds did not significantly affect the brightness (L*) of the final product or its degree of saturation towards yellow, but it had an influence on the degree of saturation of the colour towards red (a*). In the work by Ostoja et al. [19], the colour of the content of canned meat was assessed after adding ground raw and expanded amaranth seeds. The addition of raw seeds reduced the redness of the meat mass to a greater extent than the expanded ones and the degree of saturation towards yellowness (b *) in both pasteurised and sterilised products. However, these visual changes were judged negative.

Texture assessment is of great importance for the acceptability of a product by consumers. The instrumental test of texture profile analysis (TPA) allows researchers to obtain parameters characterising the texture and complementing the sensory tests [23]. Our own research showed that poultry pâtés with the use of seeds in all research groups were characterised by significantly ($p < 0.05$) higher hardness compared to pâtés with the addition of wheat roll. The value of TPA parameters was influenced by the amount of ingredients used. The pâtés from group III, with 10% flaxseed content and 6% amaranth seed content, had higher hardness compared to other research groups. The analysis of the results of the Warner–Bratzler maximum shear showed a similar trend for the hardness of the pâté (Table 2). Increasing the firmness (increase in cutting force) of chicken meat burgers with the addition of flaxseed flour was reported by Cócaro et al. [8]. The authors showed that the hardness of the meat product increased with the increase in the content of the addition of flaxseed flour. In a study by Zając et al. [13], the addition of hemp ingredients (hemp flour, hemp protein and whole hemp seeds) increased the hardness of pork pâtés measured by the TPA test. In the authors' own research, it was noted that the changes in the parameters of the texture profile (springiness, gumminess and chewiness) depended on the amount and interaction between the ingredients of the pâtés. It can be assumed that the component having the greatest influence on the textural features was the addition of flaxseeds (Table 2). Similar results were obtained by Zając and Świątek [16] when evaluating pork-liver pâtés with the addition of hemp seeds and flaxseed. The effect of the addition of amaranth and quinoa flour on the springiness, gumminess and chewiness of meat nuggets was demonstrated by Verma et al. [18]. Cócaro et al. [8] indicated that the addition of golden flaxseed flour can be used as a healthy component of meat products, improving technological properties and the bio-functional potential of the product resulting from the content of bioactive compounds contained in the seed.

An indicator of the health safety of a meat product is the total number of aerobic bacteria. It was shown that the addition of a seed mixture allowed for obtaining products of good microbiological quality after 48 h of storage. In the conducted research, it was noted that the applied plant additives reduced the total number of microorganisms in poultry pâtés ($p < 0.05$) in groups II and IV with a higher proportion of amaranth seeds. This can be explained by the fact that amaranth seeds contain squalene, a substance with antioxidant properties. In studies by Longato et al. [17], it was reported that the addition of amaranth seeds ingredients increases the antioxidant properties of raw burgers.

Proteins are a basic nutrient, and their proper consumption, both in quantitative and qualitative terms, is of key importance for human health [36]. In the conducted research, the use of a mixture of hemp seeds, amaranth and golden flaxseed as a substitute for a wheat roll had a beneficial ($p < 0.05$) effect on increasing the share of protein in all research groups (Table 3) and maintaining the high biological value of the protein (Table 4). Poultry pâtés with a higher addition of golden flaxseeds (groups III and IV) had a higher content of essential amino acids (lysine, aspartic acid, leucine, isoleucine and arginine). An increase in protein content in meatballs with the addition of amaranth seeds was demonstrated by Verma et al. [18] in beef cutlets with flaxseed flour by Novello and Rodrigues Pollonio [10], and in pâtés with flaxseed by Novello et al. [11]. Conversely, after adding flaxseed flour to pâtés, Bilek and Turhan. [32] found a decrease in the protein content concurrent with an increase in the proportion of flaxseed flour.

Table 3. Effect of the addition of hemp seeds, amaranth and golden flaxseed on the basic chemical composition of poultry pâtés ($\bar{x} \pm s$).

Parameter	Poultry Pâtés			
	Group I	Group II	Group III	Group IV
Dry weight (%)	38.85 ^{c} ± 1.63	40.40 ^{b} ± 1.84	41.23 ^{a} ± 1.70	40.30 ^{b} ± 1.35
Protein N × 6.25 (%)	19.56 ^{b} ± 2.60	21.92 ^{a} ± 1.82	22.97 ^{a} ± 1.65	22.43 ^{a} ± 1.66
Fat (%)	7.90 ^{b} ± 0.98	11.96 ^{a} ± 1.10	12.40 ^{a} ± 1.09	11.70 ^{a} ± 0.90
Total ash (%)	1.51 ^{b} ± 0.60	1.78 ^{a} ± 0.11	1.85 ^{a} ± 0.55	1.82 ^{a} ± 0.11
Fiber (%)	1.08 ^{b} ± 0.11	1.80 ^{a} ± 0.18	1.88 ^{a} ± 0.23	1.84 ^{a} ± 0.19
Tocopherol content (mg/kg):				
Vitamin E, as DL-alfa-Tocoferolacetat	3.75 ^{b} ±0.12	6.25 ^{a} ± 0.20	6.31 ^{a} ± 0.10	6.61 ^{a} ± 0.42
Vitamin E, as, l-alfa-Tocoferol	3.41 ^{b} ± 0.10	5.51 ^{a} ± 0.12	5.74 ^{a} ± 0.14	6.02 ^{a} ± 0.39

Explanations: Group I—wheat roll 24%; group II—hemp seeds 8%, amaranth 10%, golden flaxseed 6%; group III—hemp seeds 8%, amaranth 6%, golden flax 10%; Group IV—hemp seeds, amaranth, golden flaxseed each in 8%; ^{a,b,c}—values in rows with different letters differ significantly, $p < 0.05$.

Table 4. Effect of the addition of hemp seeds, amaranth and golden flaxseed on the amino acid content of poultry pâtés ($\bar{x} \pm s$).

Parameter	Poultry Pâtés			
	Group I	Group II	Group III	Group IV
Lysine (%)	1.85 ^{b} ± 0.03	1.91 ± 0.02	2.05 ^{a} ± 0.03	2.01 ^{a} ± 0.01
Methionine, expressed as methionine sulfone (%)	0.59 ± 0.02	0.63 ± 0.03	0.67 ± 0.02	0.66 ± 0.01
Cysteine, expressed as cysteic acid (%)	0.25 ± 0.01	0.25 ± 0.02	0.26 ± 0.01	0.26 ± 0.02
Aspartic acid (%)	1.94 ^{b} ± 0.04	2.17 ± 0.03	2.32 ^{a} ± 0.06	2.24 ^{a} ± 0.04
Threonine (%)	0.92 ± 0.01	0.99 ± 0.04	1.07 ± 0.03	1.02 ± 0.01
Serine (%)	0.84 ± 0.01	0.92 ± 0.03	0.98 ± 0.02	0.96 ± 0.02
Glutamic acid (%)	3.50 ± 0.06	3.57 ± 0.12	3.84 ± 0.10	3.73 ± 0.08
Proline (%)	1.01 ± 0.01	0.90 ± 0.04	0.95 ± 0.03	0.98 ± 0.04
Glycine (%)	1.04 ± 0.02	1.07 ± 0.03	1.11 ± 0.04	1.13 ± 0.02
Alanine (%)	1.23 ± 0.02	1.25 ± 0.04	1.35 ± 0.03	1.32 ± 0.04
Valine (%)	1.06 ± 0.05	1.14 ± 0.08	1.23 ± 0.02	1.19 ± 0.01
Isoleucine (%)	1.02 ^{b} ± 0.02	1.09 ± 0.04	1.17 ^{a} ± 0.04	1.13 ^{a} ± 0.02
Leucine (%)	1.69 ^{b} ± 0.04	1.77 ± 0.10	1.90 ^{a} ± 0.08	1.88 ^{a} ± 0.12
Tyrosine (%)	0.66 ± 0.04	0.75 ± 0.08	0.80 ± 0.04	0.77 ± 0.03
Phenylalanine (%)	0.83 ± 0.08	0.85 ± 0.08	0.95 ± 0.05	0.92 ± 0.07
Histidine (%)	0.57 ± 0.01	0.62 ± 0.05	0.66 ± 0.04	0.65 ± 0.01
Arginine (%)	1.37 ^{b} ± 0.05	1.62 ± 0.10	1.69 ^{a} ± 0.09	1.67 ^{b} ± 0.18
Tryptophan (%)	0.25 ± 0.02	0.28 ± 0.01	0.29 ± 0.01	0.29 ± 0.04

Explanations: Group I—wheat roll 24%; group II—hemp seeds 8%, amaranth 10%, golden flaxseed 6%; group III—hemp seeds 8%, amaranth 6%, golden flaxseed 10%; Group IV—hemp seeds, amaranth, golden flaxseed each in 8%; ^{a,b} values in rows with different letters differ significantly, $p < 0.05$.

The type of plant additives used had an impact on the increase in fat content in pâtés that included them (Table 3) and had a positive effect on the quality of fats in products with the addition of seeds (Table 5). The use of hemp seeds, amaranth and flaxseed had a beneficial (modifying) effect on the profile of fatty acids in pâtés that included them. In the results of the evaluation of pâtés from all experimental groups compared to pâtés from the control group, a significantly lower ($p < 0.05$) share of saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) is noticeable. Among the SFA fatty acids, both in the pâtés from the control group and from the experimental groups, the highest share of palmitic and stearic acids was found, while among the monounsaturated acids, oleic acid was the highest. Similarly, in studies by Bilek and Turhan [32], Pelser et al. [37] and Novello et al. [11], palmitic and stearic acids predominated in the composition of saturated fatty acids, and oleic acid in the composition of MUFA. Reducing the proportion of saturated fatty acids in pâtés from the experimental groups by more than 20% is beneficial from a nutritional point of view because an excess of saturated fat in the diet may cause the development of cardiovascular diseases. The addition of our proprietary blend of oil seeds resulted in an over 60% increase in the content of polyunsaturated acids (PUFA), most abundantly including linoleic acid ($p < 0.05$), which reduced the risk of cardiovascular diseases and complications related to obesity and diabetes [38,39]. The share of trans fatty acids in pâtés with the addition of wheat roll and pâtés from the experimental groups was similar ($p > 0.05$). Therefore, the addition of the seed mixture instead of the wheat roll did not increase the proportion of trans fatty acids, which are unfavourable to human health and which may cause cardiovascular diseases [40]. The share of omega-3 fatty acids beneficial for health was more than three times higher ($p < 0.05$) in pâtés with the proprietary seed mix compared to pâtés from the control group, which may be related to the high content of alpha linolenic acid (C18: 3n-3) in flaxseeds [38]. An increase in the content of omega-3 fatty acids after the addition of flaxseed to ground beef cutlets was also found by Novello et al. [11].

In the conducted research, the ratio of omega-6/omega-3 fatty acids in the control group pâtés was unfavourable and amounted to 8:1, while in the pâtés with the proprietary mix of seeds, it was favourably narrowed, respectively, to 3:1 (group II), 2:1 (group III) and 3:1 (group IV). Due to these ratios of omega-6 to omega-3 fatty acids, pâtés with the proprietary seed mixture presented significantly higher nutritional value than pâtés with wheat roll. An improvement in the ratio of omega-6 to omega-3 fatty acids in beef cutlets with flaxseed flour was also found by Bilek and Turhan [32].

The addition of the seed mixture caused a significant ($p < 0.05$) increase in the ash content in all research groups (Table 3). In the studies by Bilek and Turhan [32] and Novello et al. [11], the addition of flaxseed in the form of seeds and by-products increased the ash content in meat products.

Fibre is considered a dietary component with a beneficial effect on health and is a commonly used additive to functional food [5]. Modern methods of producing meat products are based, inter alia, on adding dietary fibre to them [1]. In our own research, the addition of plant components caused a significant ($p < 0.05$) increase in the share of fibre in pâtés from groups II, III, IV compared to the product with the addition of wheat roll. Moreover, in studies by Zając et al. [13], the addition of hemp ingredients (hemp flour, hemp protein, hulled and whole hemp seeds) increased the fibre content. In studies by Verma et al. [18], to produce goat meat nuggets, amaranth (1.5%) and quinoa (3%) flour were used as a substitute for (refined) wheat flour. The result is high-fibre, gluten-free meat nuggets. The use of these additives had a positive effect on the quality of the physicochemical and sensory characteristics of the manufactured product.

Vitamins are organic compounds that do not provide energy, nor are they structural components of tissues but are necessary for the proper growth and development of the organism [41–43]. Among the vitamins found in meat products, vitamin E, which is a natural antioxidant, deserves special attention [41]. It prevents the oxidation of polyunsaturated fatty acids, the consumption of which should be correlated with the appropriate consumption of α-tocopherol [44,45]. In the conducted studies, poultry pâtés using a mixture of hemp seeds, amaranth and golden flaxseed from all research groups, compared to pâtés with the addition of wheat roll, were characterised by a significantly ($p < 0.05$) higher share of both forms of vitamin E. A twofold higher content of tocopherol in pâtés with the addition of seeds can be considered another pro-health value of these products. In studies by Dominguez et al. [46], the effect of replacing animal fat with olive oil was an increase in the content of α-tocopherol. However, there are few reports on the use of plant supplements as vitamin supplementation in meat products.

Table 5. Effect of the addition of hemp seeds, amaranth and golden flaxseed on the fatty acid profile of poultry pâtés ($\bar{x} \pm s$).

Parameter	Poultry Pâtés			
	Group I	Group II	Group III	Group IV
SFA (%)				
Lauric acid C 12:0	0.46 ^{c} ± 0.02	0.71 ^{a} ± 0.01	0.66 ^{b} ± 0.03	0.66 ^{b} ± 0.04
Tetradecanoic acid C 14:0	1.43 ^{a} ± 0.03	1.18 ^{b} ± 0.03	1.25 ^{b} ± 0.01	1.18 ^{b} ± 0.06
Pentadecanoic acid C 15:0	0.13 ± 0.02	0.11 ± 0.01	0.11 ± 0.01	0.11 ± 0.01
Hexadecanoic acid C 16:0	22.15 ^{a} ± 0.21	17.35 ^{b} ± 0.07	17.20 ^{b} ± 0.14	17.15 ^{b} ± 0.25
Heptadecanoic acid C 17:0	0.25 ^{a} ± 0.01	0.16 ^{b} ± 0.02	0.14 ^{b} ± 0.04	0.15 ^{b} ± 0.02
Octadecanoic acid C 18:0	9.00 ^{a} ± 0.14	6.25 ^{b} ± 0.07	6.35 ^{b} ± 0.21	6.30 ^{b} ± 0.11
Eicosanoic acid C 20:0	0.18 ^{c} ± 0.01	0.70 ^{a} ± 0.06	0.43 ^{b} ± 0.04	0.56 ^{b} ± 0.12
Heneicosanoic acid C 21:0	<0.1 ± 0.00	0.13 ± 0.01	0.10 ± 0.04	012 ± 0.03
Tricosanoic acid C 23:0	<0.1 ± 0.00	0.14 ± 0.01	0.11 ± 0.02	0.12 ± 0.04
Tetracosanoic acid C 24:0	<0.1 ± 0.00	0.11 ± 0.03	0.13 ± 0.06	0.11 ± 0.04
Σ saturated acids	33.60 ^{a} ± 0.14	26.80 ^{b} ± 0.10	26.35 ^{b} ± 0.07	26.42 ^{b} ± 0.34
MUFA (%)				
Oleomyristic acid C 14:1	0.15 ± 0.01	0.14 ± 0.01	0.14 ± 0.01	0.14 ± 0.01
Hexadecanoic acid C 16:1	3.60 ^{a} ± 0.14	3.00 ^{b} ± 0.10	2.88 ^{b} ± 0.20	2.90 ^{b} ± 0.15
Heptadecenoic acid C 17:1	0.17 ± 0.02	0.12 ± 0.01	0.12 ± 0.01	0.12 ± 0.01
Cis-9-octadecenoic acid C 18:1	35.55 ^{a} ± 0.07	28.10 ^{b} ± 0.14	28.20 ^{b} ± 0.28	28.07 ^{b} ± 0.21
Cis-11-octadecenoic acid C 18:1	2.10 ^{a} ± 0.02	1.50 ^{b} ± 0.04	1.50 ^{b} ± 0.06	1.50 ^{b} ± 0.03
Eicozenic acid C 20:1	0.46 ^{a} ± 0.01	0.34 ^{b} ± 0.04	0.32 ^{b} ± 0.02	0.33 ^{b} ± 0.01
Tetracosoic acid C 24:1	0.25 ± 0.03	0.27 ± 0.04	0.23 ± 0.01	0.24 ± 0.02
Σ monounsaturated fatty acids	42.65 ^{a} ± 0.40	33.75 ^{b} ± 0.56	33.60 ^{b} ± 0.14	33.55 ^{b} ± 0.31
PUFA (%)				
Octadecadienoic acid C 18:2	20.45 ^{b} ± 0.07	29.95 ^{a} ± 0.09	28.00 ^{a} ± 0.14	29.22 ^{a} ± 0.96
Alpha-octadecatrienoic acid C 18:3	1.85 ^{c} ± 0.07	8.20 ^{b} ± 0.10	10.70 ^{a} ± 0.14	9.80 ^{a} ± 0.91
Eicosadienoic acid C 20:2	0.31 ^{a} ± 0.02	0.15 ^{b} ± 0.01	0.16 ^{b} ± 0.02	0.15 ^{b} ± 0.02
Eicosatrienic acid C 20:3 n-3	0.94 ± 0.09	0.94 ± 0.01	0.97 ± 0.01	0.95 ± 0.02
Eicosatrienic acid C 20:3 n-6	0.16 ^{b} ± 0.01	0.23 ^{a} ± 0.04	0.22 ^{a} ± 0.01	0.23 ^{a} ± 0.01
Σ polyunsaturated fatty acids	23.70 ^{b} ± 0.58	39.50 ^{a} ± 0.90	40.05 ^{a} ± 0.72	40.10 ^{a} ± 0.60
Fatty acids N-3	2.80 ^{c} ± 0.14	9.15 ^{b} ± 0.07	11.70 ^{a} ± 0.14	10.50 ^{a} ± 1.06
Fatty acids N 6	20.95 ^{c} ± 0.07	30.35 ^{a} ± 0.07	28.40 ^{b} ± 0.14	29.62 ^{a} ± 0.96
TRANS (%)				
Trans-hexadecenoic acid C 16:1 trans	0.38 ^{a} ± 0.04	0.29 ^{b} ± 0.01	0.28 ^{b} ± 0.02	0.28 ^{b} ± 0.01
Σ trans fatty acids	0.40 ± 0.02	0.30 ± 0.04	0.30 ± 0.04	0.30 ± 0.02

Explanations: Group I—wheat roll 24%; group II—hemp seeds 8%, amaranth 10%, golden flaxseed 6%; group III—hemp seeds 8%, amaranth 6%, golden flax 10%; Group IV—hemp seeds, amaranth, golden flaxseed each in 8%; ^{a,b,c}—values in rows with different letters differ significantly, $p < 0.05$.

An important issue in the production of functional and enriched food is to maintain the appropriate sensory characteristics so that enriched meat products do not differ from traditional recipe products and are accepted by the consumer. The results of the sensory evaluation of poultry pâtés indicate that the plant additives used in research groups II, III and IV had a positive effect on the odour intensity and desirability, as well as juiciness, compared to the control group pâtés. However, the desirability of flavour and binding were rated highest for pâtés from group IV, with an 8% share of plant additives. According to Sharoba [33], juiciness, understood as the amount of juice released during chewing, is considered as a desirable sensory feature because it provides an excellent contrast for texture. In the case of ground meat products, the higher firmness of the products does not always reduce their quality. In the case of ground products, the consumer expects from such a product slicing characteristic, which results in better bonding and, at the same time, is characterised by greater firmness. In our own research, the spreadability and tenderness of pâtés with the addition of a mixture of hemp seeds, amaranth and golden flaxseed were assessed to be lower compared to the pâtés with the addition of wheat roll (Table 6). In studies by Zając et al. [13], the overall acceptability of pâtés with the addition of hemp ingredients (hemp flour, hemp protein and whole hemp seeds) was lower for the enriched products; only the taste of the product with the addition of hulled hemp seeds was comparable to the control product. As reported by Kostecka-Majchrzak et al. [15], the use of hemp pulp (a by-product of cold oil pressing) may have a positive effect on the sensory characteristics of meatballs but the share of the hemp product should not exceed 2.6%. As demonstrated by Longato et al. [17], natural ingredients (amaranth and pumpkin seeds) used in the production of poultry burgers had no significant effect on sensory characteristics; only burgers with 2% amaranth seeds were rated higher for juiciness and overall acceptability compared to the control burgers. In turn, Verma et al. [18] indicated that the addition of amaranth seeds in the range of 1.5% increased the acceptability of all sensory features of goat meatballs. In studies by Bilek and Turhan [32], it was noted that the addition of flaxseed flour obtained from flaxseeds had an impact on the assessment of sensory features (appearance, tenderness, juiciness and general acceptability); however, along with the increasing percentage of flaxseed, the sensory quality of beef cutlets worsened. The overall sensory quality of the products decreased significantly after the addition of 6% flaxseed flour.

Table 6. Effect of the addition of hemp seeds, amaranth and golden flaxseed on the sensory traits of poultry pâtés (points).

Parameter	Poultry Pâtés			
	Group I	Group II	Group III	Group IV
Odour intensity	$3.70^{b} \pm 0.48$	$4.67^{a} \pm 0.43$	$4.72^{a} \pm 0.26$	$4.72^{a} \pm 0.26$
Flavour intensity	4.20 ± 0.59	4.22 ± 0.44	4.28 ± 0.44	4.39 ± 0.42
Odour desirability	$3.80^{b} \pm 0.59$	$4.72^{a} \pm 0.44$	$4.72^{a} \pm 0.36$	$4.72^{a} \pm 0.36$
Flavour desirability	$3.90^{b} \pm 0.57$	3.94 ± 0.46	4.00 ± 0.50	$4.61^{a} \pm 0.49$
Juiciness	$4.00^{b} \pm 0.33$	$4.61^{a} \pm 0.38$	$4.72^{a} \pm 0.48$	$4.67^{a} \pm 0.43$
Tenderness	$4.60^{a} \pm 0.59$	$3.89^{b} \pm 0.42$	$3.61^{b} \pm 0.55$	$3.89^{b} \pm 0.49$
Connection	$3.90^{b} \pm 0.57$	$3.89^{b} \pm 0.49$	$4.00^{b} \pm 0.56$	$4.67^{a} \pm 0.50$
Consistenc/strukture	4.44 ± 0.30	4.33 ± 0.43	4.17 ± 0.43	4.44 ± 0.46
Spreadability	$4.83^{a} \pm 0.25$	$3.83^{b} \pm 0.50$	$3.89^{b} \pm 0.33$	$4.00^{b} \pm 0.35$
Total destrability	4.13 ± 0.58	4.23 ± 0.55	4.23 ± 0.57	4.46 ± 0.50

Explanations: Group I—wheat roll 24%; group II—hemp seeds 8%, amaranth 10%, golden flaxseed 6%; group III—hemp seeds 8%, amaranth 6%, golden flaxseed 10%; Group IV—hemp seeds, amaranth, golden flaxseed each in 8%; ^{a,b} values in rows with different letters differ significantly, $p < 0.05$.

5. Conclusions

The obtained results of the assessment of the colour of the cross-section of poultry pâtés showed that the products with the addition of hemp seeds, amaranth and golden flaxseed in all tested groups were characterised by a brighter colour, a higher degree of saturation towards yellow and greater hardness. Pâtés from group III, which contained 10% flaxseeds and 6% amaranth seeds, exhibited greater hardness in comparison with the other research groups.

The results of the study show that the addition of a mixture of hemp seeds, amaranth and golden flaxseed allows for obtaining pâtés with increased nutritional value without the use of any synthetic additives. Poultry pâtés prepared with the addition of a mixture of hemp seeds, amaranth and golden flaxseed have health-promoting properties. They are rich in protein, essential amino acids, fibre and vitamin E, have a favourable fatty acid profile and a healthy omega-6/omega-3 ratio (3:1). They are safe for the consumer.

In the sensory assessment, the connection and tenderness in pâtés with the addition of seeds were rated lower compared to the control pâtés; however, the flavour desirability and spreadability was rated the highest for pâtés with 8% plant additives.

The use of turkey leg as the raw meat allows the product to retain wholesome protein and favourable processing properties. The use of a mixture of flaxseed, hemp and amaranth seeds in appropriate proportions and the technology of their preparation allows the valuable properties of plant materials in the final product to be preserved.

6. Patents

Patent application marked with the number: P.439001 [WIPO ST 10/C PL439001].

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