Food Biotechnology & Agricultural Sciences

Received: 21 Januaryr 2025 | Revised: 21 April 2025 | Accepted: 4 July 2025

RESEARCH ARTICLE

The Effect of Flax Seeds Addition on Selected Quality Features of Baked Liver Pâtés

Tomasz Florowski , Anna Florowska ,Magdalena Różalska, Marta Chmiel , Lech Adamczak , Dorota Pietrzak

Institute of Food Sciences, Department of Food Technology and Assessment, Warsaw University of Life Sciences - SGGW, Nowoursynowska 159C, 02-776, Warsaw, Poland

Correspondence

anna_florowska@sggw.edu.pl

Institute of Food Sciences, Department of Food Technology and Assessment, Warsaw University of Life Sciences - SGGW, Nowoursynowska 159C, 02-776, Warsaw, Poland

Abstract

The aim of the study was to determine the effect of flax seeds (FS) addition (2.5 - 15.0%), on selected quality parameters of baked liver pâtés. It was found that introducing only the smallest analyzed amount of flax seeds, i.e. 2.5%, into the batter had no significant effect ($p>0.05$) on any of analyzed quality parameters of pâtés (such an addition should be considered optimal). The addition of a larger amount of FS resulted in, among other things, significant ($p\leq0.05$) weakening of pâtés' structure, i.e. decrease in cutting force and penetration (with addition of FS ≥ 5.0%) and decrease in hardness (with addition of FS ≥ 7.5%), as well as an increase in brightness of color (with addition of FS ≥ 5.0%) and the value of the color parameter b* (with addition of FS ≥ 10.0%) of pâtés. The addition of FS also influenced the sensory quality of pâtés, causing, among other things, an increase in their juiciness (with addition of FS ≥ 7.5%) and weakening of the intensity of the meat aroma, and an increase in the intensity of the linseed aroma (with addition of FS ≥ 10.0%). The highest addition of FS, i.e. 15%, also resulted in the appearance of an off-flavor in the product. These changes, however, did not have a significant ($p>0.05$) impact on overall desirability of the pâtés. The positive effect of adding FS to the batter was the reduction of mass losses occurring during baking and cold storage of pâtés (with FS addition ≥ 7.5%).

KEYWORDS
flax seeds, baked liver pâté, quality

Introduction

The addition of flaxseed into food formulations is of interest to scientists due to its exceptional nutritional composition and functional properties. Flaxseed is a rich source of an omega-3 fatty acid, in particular alpha-linolenic acid (ALA), dietary fiber, proteins, and other bioactive compounds including lignans (secoisolariciresinol diglucoside) and phenolic compounds. These ingredients are associated with a range of health-promoting effects, such as cardiovascular protection, glycemic regulation, and anti-inflammatory, anti-cancer, and antioxidant activities [Giada, Lourdes 2010; Regnicoli, Marconi, Perretti 2012; Hussain, Anjum, Alamri, Mohamed,Nadeem 2013; Marpalle, Sonawane, Arya 2014; Ganguly, Panjagari, & Raman 2021]. Consequently, flaxseed has gained significant attention as a functional food ingredient capable of enhancing the nutritional value of various food matrices.

Beyond its nutritional benefits, flaxseed has a notable impact on the physicochemical properties of food. Its incorporation has been shown to modify textural attributes, enhance antioxidant capacity, and influence rheological behaviors in food applications [Turp 2016; Basiri, Haidary, Shekarforoush, Niakousari 2018; Cichońska, Pudło, Wojtczak, Ziarno 2021]. However, these functional improvements are often accompanied by alterations in sensory characteristics, including the development of distinctive grain or flaxseed flavors and bitterness, which may affect overall consumer acceptability [Juárez, Dugan, Aldai, Aalhus, Patience,

Zijlstra, Beaulieu 2011; Aliani, Ryland, Pierce 2011; Aliani, Ryland, Pierce 2012; Khouryieh, Aramouni 2012]. Strategies such as the use of flavor masking agents or complementary ingredient combinations have been proposed to address these challenges [Aliani et al. 2011; Aliani et al. 2012].

The application of flaxseed in pâtés presents a compelling opportunity to augment their nutritional and functional properties while addressing the dietary trends toward healthier food options. Pâtés, traditionally characterized by high fat and protein content, provide an ideal matrix for the incorporation of flaxseeds [Lorenzo, Pateiro, Fontán, Carballo 2014; Latoch, Glibowski, Libera 2016]. Their addition can elevate the levels of omega-3 fatty acids, dietary fiber, and bioactive compounds, thereby contributing to enhanced antioxidant activity and potential health benefits, on the other hand, it may lead to a deterioration of quality, especially in sensory evaluation [Hussainet al. 2013; Goyal, Sharma, Upadhyay, Gill, Sihag 2014]. Basing on the literature data a research hypothesis was formulated: The addition of flaxseed will have a negative effect on the quality features of liver pâtés, particularly influencing their physicochemical and sensory properties. This may be a limitation in the use of FS in the production of this type of products.

This study aims to evaluate the effects of flaxseed addition on the quality features of liver pâtés, with a focus on its impact on physicochemical attributes, and sensory properties.

MATERIALS AND METHODS

Research material

Six variants of pates were produced, with different amounts of flax seeds (FS) added i.e. 2.5; 5.0; 7.5; 10.0; 12.5 and 15.0% (in relation to the weight of the batter). The reference material was a control pâté produced without seeds addition (0% FS). The recipe composition of the control pâté included: meat raw materials, i.e. beef shoulder (29%) and beef flank (29%), beef liver (6%), egg mass (4%), salt (1.0%) and black pepper (0.1%). In the case of the experimental pâtés, flax seeds were also added to the basic batter (Golden Flax Bio; Bio Planet, Poland), previously ground (<0.2 mm) in a laboratory grinder WŻ-1 (Zakład Badawczy Przemysłu Piekarskiego Sp. z o.o., Poland). Before production, the meat raw materials were steamed in water at a temperature of 85°C for 1.5 hours, and the liver for 1 hour, and ground twice in a laboratory grinder (Ø 4.5 mm). The batter for the patés was prepared in a Kenwood Major mixer (Kenwood, Polska) in two stages. In the first stage, the beef shoulder and flank, liver, egg mass, broth and spices were mixed for 5 minutes. Then, grounded flax seeds were added to the experimental pâtés batter and mixed for another 5 minutes. The prepared batters (weighing 750 g) were filled into 7 x 20 cm aluminium moulds and the pâtés were baked (Mastercook type 7286, Wrozamet, Wrocław, Poland) at 180°C until the temperature in the thermal center reached 80°C (the temperature was measured using a thermometer Hanna HI 98804 (HANNA Instruments Sp. z o.o., Olsztyn, Poland). After heat treatment, the products were placed in a cold store for 24 hours, after which selected quality parameters were assessed. The tests were carried out in four replications (n=4).

Research methods

Determination of the amount of weight loss of pâtés during baking

The amount of weight loss during baking was determined on the basis of the difference in the weight of the pâté before and after thermal treatment (baking, 180°C until a temperature of 80°C was reached in the thermal center).

Determination of the amount of weight loss of pâtés during refrigerated storage

The pâté samples, weighing approximately 60 g, were weighed, vacuum-packed (<10 mbar) in polyethylene foil bags using a MULTIVAC C-200 vacuum packaging machine (Multivac, Natalin, Poland), and stored under refrigerated conditions (4-6°C) for two weeks. The amount of weight loss during refrigerated storage was determined on the basis of the difference in the weight of pâtés samples before and after storage.

Measurement of the color parameters of pâtés and determination of the total color difference index

The color of the pâtés was measured by the reflectance method, using a Minolta CR-200 (Minolta, Tokyo, Japan) colorimeter, with D65 light settings and a 2° observer. The color of the products was expressed on the CIEL*a*b* system. The color parameters were measured on a cross-section of the product. The measurement was performed in 6 repetitions for each sample. In order to comprehensively determine the differences between the color of the control product and the products with added flax seeds, the total color difference parameter ΔE was also calculated according to the formula:

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

where ΔL*, Δa*, Δb* meant differences in the values of the color parameters of the control pâtés and the compared variant of the pâtés with the addition of flax seeds. In the interpretation of the ΔE parameter value, it is assumed that if 0< ΔE < 1 – the difference in the color of the samples is invisible, 1< ΔE < 2 – the difference in the color of the samples is noticed only by an experienced observer, 2< ΔE < 3.5 – the difference in the color of the samples is also noticed by an inexperienced observer, 3.5 < ΔE < 5 – the inexperienced observer notices a clear difference in colors, 5< ΔE – the observer has the impression of two different colors [Mokrzycki, Tatol 2011].

Measurement of pâtés texture parameters

The texture tests of the pâtés included measuring the shear, penetration and compression forces. The samples for measuring the shear force were pâté slices 10 mm thick and 30 mm wide. During the study, the maximum force required to cut the pâté with a flat knife was measured using the Warner-Bratzler attachment. The samples used for measuring the penetration force were 20 mm thick slices of pâté. During the test, the maximum force required to insert a flat metal pin with a diameter of 14 mm into the pâté sample to a depth of 10 mm was measured. The samples for the compression force measurements were 20 mm cubes cut from the center of a block of pâté. During the test, the maximum force required to compress a pâté sample between two parallel plates by 25% of their original height was measured. All texture tests of the pâtés were performed using ZWICK 1120 texturometer (Zwick

GmbH & Co., Ulm, Germany). The measuring head movement speed during the test was 50 mm/min. Before measurement, the pâté samples were conditioned to a temperature of 18°C. The shear and compression force measurements were performed in 6 repetitions for each sample and the penetration force measurements were performed in 2 repetitions for each sample.

Determination of the content of basic proximate components in pâtés

The water content in the pâtés was determined by the drying method, in accordance with PN-ISO 1442:2000. The protein content in the pâtés was determined by the Kjeldahl method, in accordance with PN 75/ A-04018. The fat content in the pâtés was determined by the Soxhlet method, in accordance with PN-ISO 1444:2000.

pH measurement of pâtés

The pH of the pâtés was measured in accordance with PN-ISO 2917: 2001, using an ELMETRON CP-411 pH meter equipped with a glass-calomel electrode.

Sensory assessment of pâtés

The pâtés were tested for their sensory quality, assessing characteristics such as: surface moisture, smell and taste (meat, flaxseed and off), juiciness and overall desirability. Each time, the sensory evaluation of the pâtés was carried out by ten people. The team of panelists consisted of trained employees of the Institute where the research was conducted. The evaluation results were marked on a 10-centimetre, unstructured graphic scale with defined boundary terms (for surface moisture: 0 – dry surface, 10 – moist surface; for smell and taste: 0 – smell/taste barely perceptible, 10 – intense smell/taste; for juiciness: 0 – dry pâté, 10 – juicy pâté; for general desirability: 0 – unacceptable pâté, 10 – desirable pâté). The pâté samples intended for sensory evaluation had the shape of a slice, 1 cm thick and 5 cm long. Before starting the evaluation, the pâté samples were conditioned to reach room temperature (approximately 18°C).

Statistical analysis of results

The obtained results were statistically analyzed using Statistica 13.3 (StatSoft Inc., Tulsa, OK, USA), by performing one-way analysis of variance and detailed testing of the results using Tukey's test, assuming the significance level of α=0.05.

RESULTS AND DISCUSSION

Based on the obtained results, it was found that by introducing ground FS into the batters, it is possible to reduce the amount of weight loss occurring during baking of pâtés. Such a positive effect was observed when FS was added to the batter in the amount of 7.5% or more, and the higher the amount of FS was added to the batter, the smaller the weight loss of the pâtés during baking was (Figure 1a). The reduction in the amount of weight loss in pâtés during their heat treatment was probably the result of introducing, with flax seeds, soluble and insoluble fiber into the meat batter, and flax seeds are a good source of both kinds of fiber [Tarpila, Wennberg, Tarpila, 2005]. Fiber, characterized by its good ability to absorb and retain water, limits its loss during the heat treatment of meat products [Mishra, Mishra, Paital, Rath, Jena, Reddy, Pati, Panda, Sahoo 2023]. A similar effect was found by Han & Bertram [2017] whose tested the use of carboxymethylcellulose, chitosan and pectin at a level of 2% in a meat product model and by Li et al. [2019] who were examining pork meat batters formulated with various amounts of bamboo shoot dietary fiber (0 to 4%). The high capacity of the fiber contained in flax seeds to absorb and retain water also contributed to reducing the amount of storage leakage from the pâtés. Liquid released from meat products during refrigerated storage reduces their attractiveness among consumers and may contribute to the products spoiling more quickly. The meat industry therefore strives to limit its secretion. The conducted studies have shown that the reduction in the amount of the pâtés' weight losses during their storage was achieved by addition of FS to the pâtés' batter in the amount of 7.5% or more (Figure 1b). The significant effect of adding high-fiber seeds to the batters of meat products on the amount of weight loss occurring during chilled storage was also indicated by Xu et al. [2022] in studies on the addition of star anise dietary fiber on the quality of meat batter and Florowska et al. [2023] in studies on the addition of defatted flaxseeds on the selected quality features of liver pates.

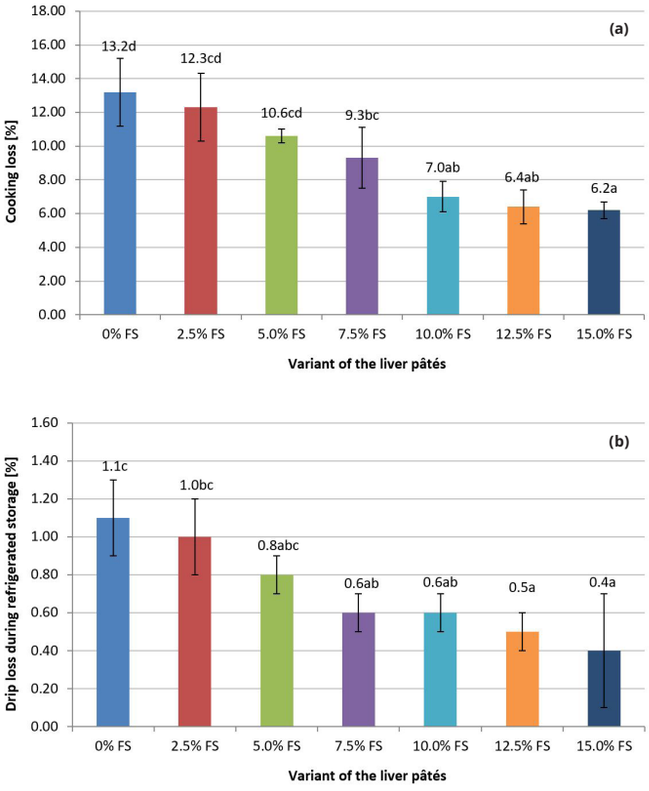


Figure 1. The effect of flax seed (FS) addition on the amount of weight loss occurring during baking (a) and cold storage (b) of baked pâtés

Mean values marked with different letter symbols differ significantly (p≤0.05)

One of the most important quality features of meat products, which determines their desirability by consumers, is color. Any deviations from the typical color of meat products may be perceived critically by consumers, resulting in a reduced willingness to purchase the products. Based on the conducted research, it was found that only the introduction of the smallest analyzed amount of FS, i.e. 2.5%, into the batter had no significant effect (p>0.05) on any of the measured color parameters of the pâtés (Figure 2a-c). For an inexperienced observer, the difference in color between such a pâté and the control pâté (i.e. without FS)

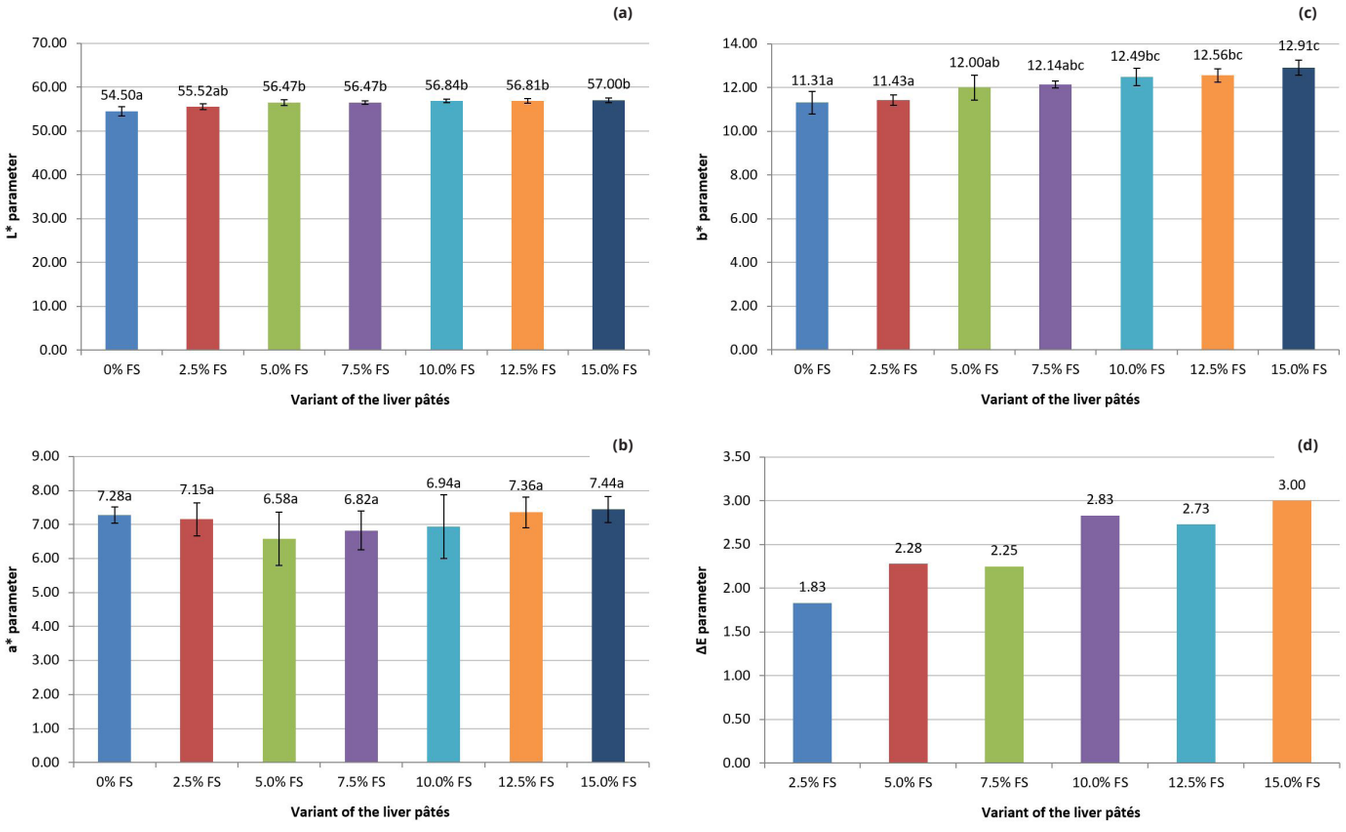


Figure 2. The effect of flax seed (FS) addition on the color parameters L* (a), a* (b), b* (c) and the total color difference parameter ΔE# (d) of baked pâtés

Mean values marked with different letter symbols are significantly different (p≤0.05); # in relation to the control product.

would be invisible, as indicated by the ΔE parameter values below 2 (Figure 2d). The addition of a larger amount of FS to the pâté batter, i.e. 5.0-15.0%, resulted in the obtaining of a pâté with a lighter color (higher values of the L* color parameter), and the addition of FS in the amount of 10.0-15.0% resulted in the obtaining of a product with a higher share of yellow color (i.e. higher values of the b* color parameter). As a result, the differences in the color of such pâtés, in comparison with the control pâté, were more pronounced and visible even to an inexperienced observer, as evidenced by the ΔE parameter values ranging from 2.25 to 3.00. The increase in the values of the L* and b* color parameters of pâté with the addition of a larger amount of FS was related to the characteristics of the flax seeds used in the experiment, which were characterized by a light yellow (golden) color. Moreover, based on the conducted research, it was found that the addition of FS to the batter, even in the largest amount analyzed, i.e. 15.0%, had no significant effect (p>0.05) on the share of red color of the pâté (i.e. the value of the color parameter a*). Studies on the effect of flax seed addition on the color of meat products were conducted, among others, by Novello et al. [2019]. The authors, similarly to this study, showed that the addition of flax seeds to cooked patties causes an increase in the color parameters L* and b*, but their influence on the value of the color parameter a* was insignificant (Figure 2.)

Apart from color, an important determinant of the quality of meat products is their texture. Meat products such as baked pâté should be characterized by both good cuttability and appropriate softness, allowing them to be spread on bread. Any deviations from the typical pâté structure, resulting from inappropriate selection of pâté recipe ingredients or errors in the production process, may contribute to their lack of acceptance by consumers. Based on the conducted research, it was found that the introduction of 2.5% FS into the batters did not cause significant (p>0.05) changes in the measured texture parameters of the pâtés (i.e. shear, penetration and compression forces; Figure 3a-c). However, adding a larger amount of FS to the batter, i.e. ≥5.0%, resulted in a weakening of the structure of the pâtés, which was manifested by a reduction in their shear and penetration force. With the addition of ≥7.5% FS to the batter, a reduction in the compression force of the pâtés was also observed. At the same time, it was found that further increasing the FS content in the pâtés, in the range from 7.5% to 15.0%, did not cause any further changes in the measured texture parameters of the products. The observed weakening of the pâté structure due to the addition of FS could have been the effect of the addition of mucous substances [Sharma, Sharma, Mendiratta, Talukder, Ramasamy, 2014] which form a gel-type matrix around unabsorbed protein in meat batters what can affect the binding and cohesiveness of the product [Ghafouri-Oskuei, Javadi, Saeidi-Asl, Azadmard-Damirchi, Armin, Riazi, Savadkoohi 2022].

Analyzing the effect of FS addition on the proximate composition of pâtés, it was found that the introduction of 7.5% or more seeds into the stuffing resulted in a reduction in their water content (Table 1). There was also a tendency to reduce the water content in the pâté with increasing the amount of added seeds. However, even the largest amount of flax seeds added to the stuffing did not cause any significant changes in their protein and fat content.

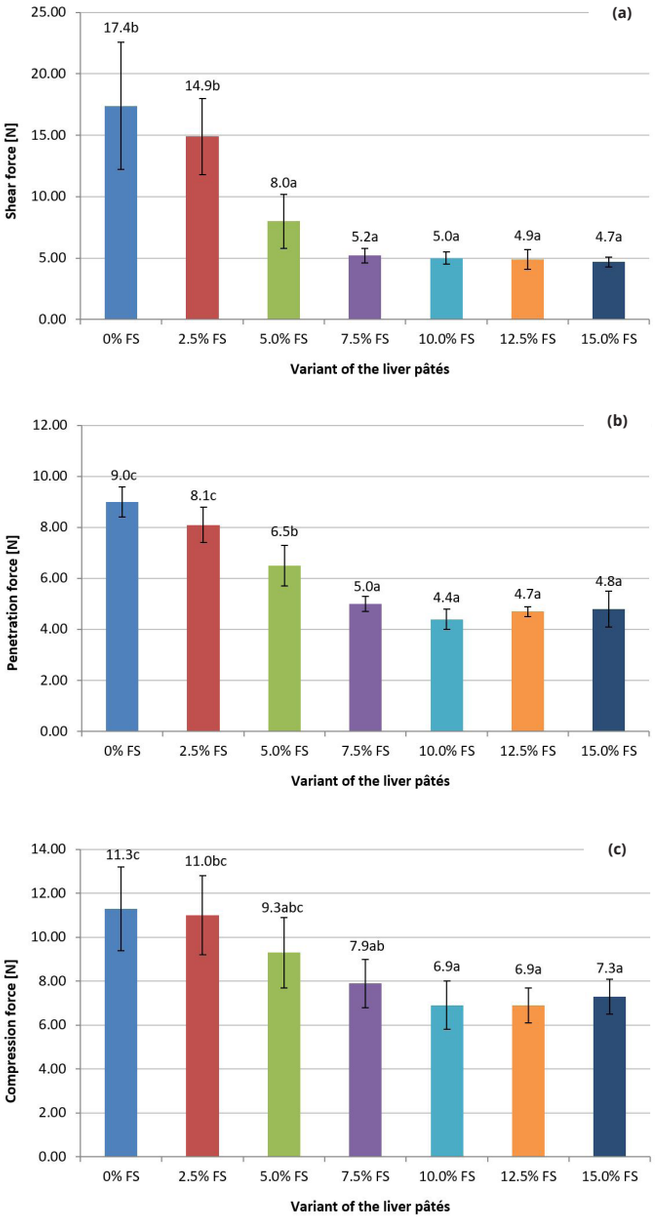


Figure 3. The effect of flax seed (FS) addition on the shear force (a), penetration force (b) and compression force (c) of baked pâtés

Mean values marked with different letter symbols differ significantly (p≤0.05)

Only a tendency was observed to slightly increase the fat content in the pâtés along with the increase in FS content, however, due to the differences in the proximate composition of the raw materials used to produce the pâtés in the individual research series, the differences in fat content between the individual variants of the pâté were not statistically significant (p>0.05). Researches on the effect of the additive flax seeds on the basic proximate composition of meat products were conducted also by Novello & Pollonio [2013] and Ghafouri-Oskueiet et al. [2020]. The authors concluded that flaxseed addition tends to increase the protein and fat content of beef patties produced with oil, flour or seed obtained from flaxseeds pâtés [Novello, Pollonio 2013]. The increase of this components was also noticed in sausages fortified with flaxseed powder [Ghafouri-Oskuei, Javadi, Asl, Azadmard-Damirchi & Armin 2020].

The pH value of meat products is an important factor influencing their shelf life. Based on the conducted research, it was found that even the highest amount of FS, i.e. 15.0%, introduced into the batters of pâtés did not cause any changes in the pH of the finished products. The lack of influence of the addition of flax seeds products on the pH of meat products was also indicated in beef patties [Novello et al. 2019] or mutton patties [Suleman et al. 2024].

Table 1. The effect of the amount of flax seed (FS) added on the of basic proximate composition and pH of baked pâtés

Variant	Water [g/100 g]	Protein [g/100 g]	Fat [g/100 g]	pH
Control	64.2^{d} ± 1.4	22.9^{ab} ± 0.6	9.3^{a} ± 1.3	6.17^{a} ± 0.10
FS 2.5%	63.0^{cd} ± 1.4	23.8^{b} ± 0.3	9.1^{a} ± 1.2	6.12^{a} ± 0.03
FS 5.0%	61.5^{bcd} ± 1.4	23.5^{ab} ± 0.8	10.3^{a} ± 1.3	6.16^{a} ± 0.10
FS 7.5%	61.0^{abc} ± 1.8	23.6^{ab} ± 0.4	10.7^{a} ± 1.7	6.16^{a} ± 0.12
FS 10.0%	60.5^{abc} ± 1.2	23.2^{ab} ± 0.6	11.2^{a} ± 1.2	6.17^{a} ± 0.11
FS 12.5%	59.5^{ab} ± 1.3	22.5^{ab} ± 0.5	11.7^{a} ± 1.5	6.15^{a} ± 0.10
FS 15.0%	58.3^{a} ± 0.9	22.3^{a} ± 0.5	12.4^{a} ± 1.7	6.13^{a} ± 0.12

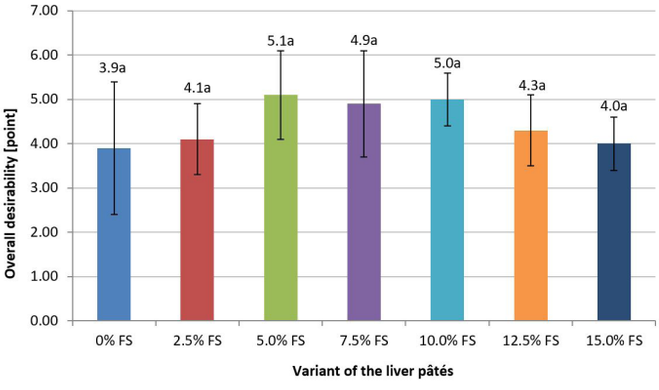
Mean values in columns marked with different letter symbols differ significantly (p≤0.05)

A important problem in the creation of health-promoting food through the addition of raw materials rich in bioactive compounds may be their adverse impact on the sensory quality of the products. Based on the conducted studies, it was found that the introduction of ≥7.5% FS into the batter resulted in the obtained products having significantly (p≤0.05) higher surface moisture than the control product (Table 2). This could be the result of water absorption and retention by mucous substances introduced into the product along with FS. It was also found that the addition of FS in the amount of ≥10.0% resulted in a significant (p≤0.05) decrease in the scores awarded in the evaluation of meat aroma and an increase in the scores awarded in the evaluation of flax seed aroma (the higher the FS content in the product, the less meaty its aroma was and the more noticeable was the characteristic aroma of flax seeds). Similar trends were also observed in the case of the taste of the pâtés, however, due to the large differences in the scores awarded in the assessment of the taste of the pâtés between the individual research series, these differences were not statistically significant (p>0.05). However, it was observed that the introduction of the largest amount of FS, i.e. 15.0%, into the stuffing resulted in a increase in the scores awarded for the product's off-taste. Analyzing the results of the sensory evaluation of the juiciness of the pâtés, it was found that the incorporation of up to 5.0% FS to the product did not have a significant effect (p>0.05) on this feature. However, a higher level of FS addition caused the obtained products to be rated as juicier than the control products. The observed changes in the individual components of the sensory quality of the pates, as a result of the addition of FS, did not, however, influence the overall desirability of the products. It was found that the introduction of even the largest amounts of this nutritionally valuable ingredient into the pâté batter did not have an adverse effect on the desirability of the pâtés as commercial products (Figure 4). The consumer acceptance of meat

products with the addition of flaxseed is reported to vary in the existing literature, with effects influenced by both the flaxseed dose and the specific product to which it is added. For instance, the addition of up to 5% flaxseed flour to beef patties generally resulted in good consumer acceptance, however, higher concentrations were associated with decreased acceptability [Novello et al. 2019]. Similarly, chicken burgers containing up to 10% golden flaxseed flour were well-received, but further increases in flaxseed concentration led to a decline in sensory scores [Cócaro, Laurindo, Alcantara, Martins, Junior, Deliza 2020]. In contrast, the inclusion of 1% flaxseed flour in restructured mutton chops has been shown to enhance sensory attributes such as appearance, binding, and texture [Sharma et al. 2014].

Figure 4. The influence of the amount of flax seeds (FS) added on the overall desirability of baked pâtés

Mean values marked with different letter symbols differ significantly (p≤0.05)



CONCLUSIONS

Flax seeds can be a valuable addition in the production of baked pâtés. The incorporation of these seeds allows to obtain technological benefits such as the reduction of the amount of weight loss occurring during baking and refrigerated storage. However, the limitation in the use of FS in the production of pâtés may be the negative impact of their addition on many quality characteristics of the products. The addition of ≥ 5.0% FS weakens the structure of the pâtés and increases the lightness of their color. With the addition of FS at a level of ≥ 7.5%, a reduction in the hardness of the pâtés is also observed, and with the addition of ≥ 10.0%, an increase in the share of yellow color in the product is observed, as well as a weakening of the intensity of the meat aroma and an increasing in the intensity of the linseed aroma. The addition of FS at the level of 15.0% causes the appearance of an off-taste. In order to obtain a baked pâté containing flax seeds of a quality similar to that of a traditional product, the addition of seeds should not exceed 2.5%.

REFERENCES

1. Aliani, M., Ryland, D., Pierce, G.N. Effect of flax addition on the flavor profile of muffins and snack bars. Food Research International. 2011, 44(8), 2489-2496.
2. Aliani, M., Ryland, D., Pierce, G.N. Effect of flax addition on the flavor profile and acceptability of bagels. Journal of Food Science. 2012, 77(1), S62-S70.
3. Basiri, S., Haidary, N., Shekarforoush, S.S., Niakousari, M. Flaxseed mucilage: A natural stabilizer in stirred yogurt. Carbohydrate Polymers. 2018, 187, 59-65.
4. Cichońska, P., Pudło, E., Wojtczak, A., Ziarno, M. Effect of the Addition of Whole and Milled Flaxseed on the Quality Characteristics of Yogurt. Foods. 2021, 10, 2140.
5. Cócaro, E.S., Laurindo, L.F., Alcantara, M., Martins, I.B.A., Junior, A.A.B., Deliza, R. The addition of golden flaxseed flour (*Linum usitatissimum L.*) in chicken burger: Effects on technological, sensory, and nutritional aspects. Food Science and Technology International. 2020, 26(2), 105-112.
6. Florowska, A., Florowski, T., Krajewska, M., Hilal, A. The Effect of Adding Degreased Flaxseeds on the Quality of Pates. In Biology and Life Sciences Forum. 2023, 26, 1, 32.
7. Ganguly, S., Panjagari, N.R., Raman, R.K. Flaxseed (*Linum usitatissimum*). In: Oilseeds: Health Attributes and Food Applications (eds. Tanwar B., Goyal A.; Springer Nature Singapore Pte Ltd.). 2021, 253-283.
8. Ghafouri-Oskuei, H., Javadi, A., Asl, M.S., Azadmard-Damirchi, S., Armin, M. Production of fortified sausages with flaxseed powder and study of their physical, chemical and microstructural properties. Iranian J. Nutr. Sci. Food. Technol. 2020, 15(3): 81-90.
9. Ghafouri-Oskuei, H., Javadi, A., Saeidi-Asl, M. R., Azadmard-Damirchi, S., Armin, M., Riazi, F., Savadkoohi, S. Mechanical attributes, colloidal interactions, and microstructure of

Table 2. The influence of the amount of flax seed (FS) added on the results of sensory evaluation of baked pâtés [points]

Variant	Moisture of the surface	Odor			Taste			Juiciness
		meat	flax seeds	off	meat	flax seeds	off	
Control	$2.7^{a} \pm 0.7$	$6.9^{c} \pm 0.7$	$2.7^{a} \pm 1.0$	$0.7^{a} \pm 0.6$	$6.4^{a} \pm 1.2$	$2.7^{a} \pm 1.1$	$0.4^{a} \pm 0.2$	$2.5^{a} \pm 0.6$
FS 2.5%	$2.6^{a} \pm 1.0$	$5.5^{abc} \pm 0.8$	$2.5^{a} \pm 1.0$	$0.8^{a} \pm 0.1$	$5.8^{a} \pm 1.2$	$3.2^{a} \pm 1.0$	$0.5^{ab} \pm 0.2$	$2.9^{a} \pm 0.5$
FS 5.0%	$3.1^{a} \pm 0.4$	$6.2^{bc} \pm 0.5$	$3.2^{ab} \pm 1.1$	$0.9^{a} \pm 0.3$	$5.8^{a} \pm 0.6$	$3.9^{a} \pm 1.0$	$0.9^{ab} \pm 0.4$	$2.9^{a} \pm 0.8$
FS 7.5%	$4.9^{b} \pm 0.9$	$5.6^{abc} \pm 0.2$	$3.8^{ab} \pm 0.7$	$0.8^{a} \pm 0.2$	$5.7^{a} \pm 1.0$	$3.5^{a} \pm 0.9$	$0.7^{ab} \pm 0.2$	$5.2^{b} \pm 0.9$
FS 10.0%	$5.6^{b} \pm 1.0$	$4.4^{ab} \pm 1.5$	$5.1^{b} \pm 0.7$	$0.8^{a} \pm 0.5$	$5.3^{a} \pm 0.7$	$4.6^{a} \pm 1.2$	$1.0^{ab} \pm 0.3$	$5.7^{b} \pm 0.5$
FS 12.5%	$6.2^{b} \pm 0.8$	$4.2^{a} \pm 0.9$	$5.1^{b} \pm 0.7$	$0.7^{a} \pm 0.3$	$4.8^{a} \pm 0.9$	$4.2^{a} \pm 1.2$	$0.6^{ab} \pm 0.3$	$5.6^{b} \pm 0.9$
FS 15.0%	$5.0^{b} \pm 0.4$	$4.1^{a} \pm 0.4$	$4.8^{b} \pm 0.7$	$1.0^{a} \pm 0.4$	$4.7^{a} \pm 0.9$	$4.9^{a} \pm 0.6$	$1.1^{b} \pm 0.2$	$4.9^{b} \pm 0.6$

Mean values in columns marked with different letter symbols differ significantly (p≤0.05)

meat batter influenced by flaxseed flour and tomato powder. Meat Science. 2022, 187, 108750.
10. Giada, M.de Lourdes R. Food applications for flaxseed and its components: Products and processing. Recent Patents on Food, Nutrition & Agriculture. 2010, 2(3), 181-186.
11. Goyal, A., Sharma, V., Upadhyay, N., Gill, S., Sihag, M. Flax and flaxseed oil: an ancient medicine & modern functional food. Journal of Food Science and Technology. 2014, 51, 1633-1653.
12. Han, M., Bertram, H. C. Designing healthier comminuted meat products: Effect of dietary fibers on water distribution and texture of a fat-reduced meat model system. Meat Science. 2017, 133, 159-165.
13. Hussain, S., Anjum, F.M., Alamri, M.S., Mohamed, A.A., Nadeem, M. Functional flaxseed in baking. Quality Assurance and Safety of Crops & Foods. 2013, 5(4), 375-385.
14. Juárez, M., Dugan, M.E.R., Aldai, N., Aalhus, J.L., Patience, J. F., Zijlstra, R.T., Beaulieu, A. D. Increasing omega-3 levels through dietary co-extruded flaxseed supplementation negatively affects pork palatability. Food Chemistry. 2011, 126(4), 1716-1723.
15. Khouryieh, H., Aramouni, F. Physical and sensory characteristics of cookies prepared with flaxseed flour. Journal of the Science of Food and Agriculture. 2012, 92(11), 2366-2372.
16. Latoch, A., Glibowski, P., Libera, J. The effect of replacing pork fat of inulin on the physicochemical and sensory quality of guinea fowl pate. Acta Scientiarum Polonorum Technologia Alimentaria. 2016, 15(3), 311-320.
17. Li, K., Liu, J.Y., Fu, L., Zhao, Y.Y., Zhu, H., Zhang, Y.Y., Zhang, H., Bai, Y.H. Effect of bamboo shoot dietary fiber on gel properties, microstructure and water distribution of pork meat batters. Asian-Australasian Journal of Animal Sciences. 2019, 33(7), 1180.
18. Lorenzo, J. M., Pateiro, M., Fontán, M.C.G., Carballo, J. Effect of fat content on physical, microbial, lipid and protein changes during chill storage of foal liver pâté. Food Chemistry. 2014, 155, 57-63.
19. Marpalle, P.N., Sonawane, S.K., Arya, S.S. Flaxseed: a nutrition booster and its role in quality of food. Agro Food Industry Hi-Tech. 2014, 25(1), 20-23.
20. Mishra, B.P., Mishra, J., Paital, B., Rath, P.K., Jena, M.K., Reddy, B.V., Pati, P.K. , Panda S.K. Sahoo, D.K. Properties and physiological effects of dietary fiber-enriched meat products: a review. Frontiers in Nutrition. 2023, 10, 1275341.
21. Mokrzycki, W.; Tatol, M. Colour Difference ΔE – A Survey. Mach. Graph. Vis., 2011, 20, 383–411.
22. Novello, D., Pollonio, M. A.R. Golden flaxseed and its by products in beef patties: physico-chemical evaluation and fatty acid profile. Ciência Rural. 2013, 43, 1707-17014.
23. Novello, D., Schiessel, D.L., Santos, E.F., Pollonio, M.A.R. The effect of golden flaxseed and by-product addition in beef patties: physicochemical properties and sensory acceptance. International Food Research Journal. 2019, 26(4), 1237-1248.
24. PN-ISO 1442: 2000. PCS, Polish Committee for Standardization. Polish Standard (2000). Meat and meat products. Determination of moisture content (reference method). Warsaw: PCS.
25. PN-ISO 1444: 2000. PCS, Polish Committee for Standardization. Polish Standard (2000). Meat and meat products. Determination of free fat content. Warsaw: PCS.
26. PN-A-04018: 1975. PCS, Polish Committee for Standardization. Polish Standard (1975). Agricultural food products. Determination of nitrogen by Kjeldahl method and expressing as protein. Warsaw: PCS.
27. PN-ISO 2917: 2001. PCS, Polish Committee for Standardization. Polish Standard (2001). Meat and meat products. pH measurement. Warsaw: PCS.
28. Regnicoli, G.F., Marconi, O., Perretti, G.I.F. Supercritical carbon dioxide and flaxseed oil like functional food. Progress in Nutrition. 2012, 14(1), 58-64
29. Sharma, H., Sharma, B.D., Mendiratta, S.K., Talukder, S., Ramasamy, G. Efficacy of flaxseed flour as bind enhancing agent on the quality of extended restructured mutton chops. Asian-Australasian Journal of Animal Sciences. 2014, 27(2), 247.
30. Suleman, R., Choudhary, H., Waseem, M., Alshammari, J.M., Muzamil, M., Liu, H., Ismail, T., Khan, M.A., Qamar, M., Tutu, C. O. Nutritional and antioxidative characterization, antimicrobial and sensorial stability of flaxseed powder supplemented mutton patties. Food Chemistry., 2024, X, 102098.
31. Tarpila, A., Wennberg, T., Tarpila S. Flaxseed as a functional food. Current Topics in Nutraceutical Research. 2005, 3, 167-188.
32. Turp, G.Y. Effects of four different cooking methods on some quality characteristics of low fat Inegol meatball enriched with flaxseed flour. Meat Science. 2016, 121, 40-46.
33. Xu, Y., Yan, H., Xu, W., Jia, C., Peng, Y., Zhuang, X., Qi, J., Xiong, G., Mei, L., Xu, X. The effect of water-insoluble dietary fiber from star anise on water retention of minced meat gels. Food Research International. 2022, 157, 111425.