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Impact of Black Lentil, Flaxseed, Faba Bean, Rye and Oat Flours on Physicochemical and Textural Properties of Lasagna Noodles

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ABSTRACT

This research was carried out to reveal the effect of black lentil flour (BLF), flaxseed flour (FSF), faba bean flour (FBF), rye flour (RF) and oat flour (OF) on the physical, chemical, textural, cooking and sensory properties of lasagna noodles. Wheat flour in the lasagna noodles formulation was replaced by 20% of BLF, FSF, FBF, RF and OF, separately. Enriched lasagna noodles had higher volume increase and cooking loss values than the control samples. The protein contents of lasagna noodles containing BLF and FBF were found to be 24.6 and 21.6% higher than the control sample. Lasagna noodles containing RF revealed the highest firmness value. In lasagna noodles, the highest Total phenolic content (TPC) and antioxidant activity (AA) were determined in the sample containing FSF, followed by the sample containing FBF and BLF, respectively. Among the lasagna noodles, the highest phytic acid content was determined in the sample containing FBF, while the control sample revealed the lowest amount of phytic acid. The use of FSF, BLF, FBF and OF in the formulation increased the Ca, Fe-Zn, Mg and Mn amounts of lasagna noodles by 1.98-, 1.5-1.7-, 1.8- and 1.8-fold, respectively. Lasagna noodles prepared using BLF had the highest total color difference value. In sensory analysis, FSF had the lowest overall acceptability value among the cooked lasagna noodle samples. The overall evaluation of all analyzed quality parameters indicates that FBF, RF, and OF can be successfully used in lasagna noodles production.

Keywords: Food functional properties, Legume flour, Pasta, Quality of lasagna noodles,

INTRODUCTION

Pasta is one of the most popular staple foods being consumed globally due to its nutritional value, comfortable preparation, low glycemic index, long shelf life, affordable price and variety (Kamali Rousta *et al*., 2021). Lasagna noodles, one of the traditional Italian dish, is a type of wide and flat pasta prepared with wheat flour, eggs, water and salt, shaped and dried in a certain width and length (Sannino *et al*., 2005).

The use of refined wheat flour/or semolina, which is the main ingredient in pasta production, makes the pasta rich in calories but poor in some nutritional components such as dietary fiber, vitamins, minerals, essential amino acids and phenolic compounds, which are necessary for a healthy diet. Pasta can be used as a suitable carrier for enrichment due to the simplicity of the pasta production process, its consumption by all segments of the society, and the limited number of raw materials in production (Ghandehari Yazdi *et al*., 2020; Kamali Rousta *et al*., 2021).

Legumes have an important place in the human diet with their high protein,

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carbohydrate, mineral, B group vitamins and dietary fiber content (Ertaş *et al*., 2008). When used with cereals, legumes are a natural complement to cereals in producing an overall balance of essential amino acids (Han *et al*., 2021). On the same note, legumes are a good source of phytochemicals such as phenolic acids, flavonols, proanthocyanidins and anthocyanins (Kan *et al*., 2018; Moreno-Valdespino *et al*., 2020). Most of the phenolic compounds are found in the legume seed coat. In legumes, within each species, the pigmented seeds have higher contents than their pale or white-coated counterparts (Singh *et al*., 2017). There is increasing evidence that the consumption of various phenolic compounds found in foods may reduce the risk of health disorders, due to their antioxidant activities (Shahidi and Ambigaipalan, 2015; Moreno-Valdespino *et al*., 2020; Singh *et al*., 2021; Sun *et al*., 2022).

Whole oat groats contain high amounts of valuable nutrients such as proteins (12-20%) and β-glucan (3-7%), which constitutes an important part of oat dietary fiber, unsaturated fatty acids, vitamins, minerals and phytochemicals (Singh *et al*., 2013; Mel and Malalgoda, 2022). Due to its rich composition, oats have different pharmacological activities such as antioxidant, antidiabetic, anti-inflammatory, anticholesterolemic, immunomodulator, and wound healing (Singh *et al*., 2013).

Flaxseed has advantages for human health due to its nutritional components, protein, fat, lignans, dietary fiber, vitamins, and phenolic compouds (Herchi *et al*., 2012; Garros *et al*., 2018). Flaxseed has gained importance in recent years due to its health benefits and its protective role in some diseases (Herchi *et al*., 2012).

Rye is a nutritionally interesting cereal due to its high fibre (19.3%) content (Boskov Hansen *et al*., 2002). Arabinoxylan is the major dietary fiber component of the rye grain. The main bioactive compounds in rye are lignans, alk(en)ylresorcinols, phenolic acids, folates, phytosterols, trace elements and minerals, tocotrienols and tocopherols and other vitamins. Consuming whole-wheat rye products has been associated with several health effects, including reducing the risk of prostate and colon cancer (Poutanen *et al*., 2014).

In the literature, studies on lasagna noodles are quite limited. At the same time, nutritionally and functionally valuable raw materials black lentil, faba bean, oat, flaxseed and rye flours have not yet been used in the production of lasagna noodles. The aim of this study were to: (1) Improve the nutritional and functional properties of lasagna noodles by using black lentil, faba bean, oat, flaxseed and rye flours, and (2) Investigate the effects of these ingredients on the quality (physical, chemical, textural and cooking properties) of lasagna noodles.

MATERIALS AND METHODS

Wheat flour (Type, 550), egg, and salt used in making lasagna noodles were obtained from the local markets in Karaman, Türkiye. Black lentil flour, flaxseed, rye flour, oat and faba bean flour were purchased from Ingro Gıda Bilişim Pazarlama, Karaman, Türkiye. Flaxseed and oat were milled with a lab grinder (MKM600, Bosch, BSH Home Appliances Industry and Trade Inc., Istanbul, Türkiye, < 500 μm) and used as whole flour.

Preparation of Lasagna Noodles

The production of the lasagna noodles was carried out by modifying the method given by Sannino *et al*. (2005). Control lasagna noodles were prepared with 100% wheat flour without any enrichment. For the production of the control lasagna noodles, 150 g wheat flour, 30 g egg, 2.5 g salt and water (45-50 mL) were kneaded in the mixer (Kitchen-aid, Artisan, USA) for 5 min. The amount of water used was determined by preliminary trials according to the optimum dough consistency. The dough obtained was divided into two equal parts (~114 g) and the dough pieces were pre-thinned on the wooden plate with the help of a rolling pin. The thinning process was continued until the thickness of these dough sheets was 0.8 mm in the noodle-cutting machine (Shule Pasta Machine, China). The thinned dough sheets were cut 7.9 mm wide and 17.8 mm long, and then dried in an oven (Nüve KD-200, Ankara, Türkiye) at 50°C for 3 hours (Fardet *et al*., 1998; Sabanis *et al*., 2006). Dried lasagna noodles were kept in an airtight glass container at 25-27°C until analysis. For the production of enriched lasagna noodles, 20% of wheat flour was replaced with BLF, FSF, FBF, RF and OF and the same procedure was used for the production of the control lasagna noodles.

Color Measurements

The color parameters ($L*$, $a*$ and $b*$) of the raw materials and lasagna noodle samples were measured using a Chroma-meter (Konica Minolta, Japan). Color measurements were made at three different points on the same product. Total color difference (ΔE) was calculated according to the Eq. 1:

$$\Delta E = ((L_c - L_i)^2 + (a_c - a_i)^2 + (b_c - b_i)^2)^{1/2} \quad (1)$$

Where, L_c, a_c and b_c are the color parameters of the control sample, L_i, a_i and b_i are the color parameters of the enriched lasagna samples (Zarzycki *et al*., 2020).

Chemical Analysis

The moisture, ash, crude protein and crude fat contents of the raw materials (wheat flour, BLF, FSF, FBF, RF and OF) and lasagna noodles were quantified according to the method 44-19, method 08-01, method 46-12 and method 30-25, respectively (AACC, 2000). Phytic acid in raw materials and lasagna noodles was analyzed with a colorimetric method (Haug and Lantzsch, 1983).

The Total Phenolic Content (TPC) was determined using the Folin-Ciocalteu method and was given as mg Gallic acid equivalents/100g (Beta *et al*., 2005; Gao *et al*., 2002). The Antioxidant Activity (AA) of the samples was assayed according to 2-2-diphenyl-2-picrylhydrazyl (DPPH) method. AA was calculated as percentage inhibition according to Eq.2 (Beta *et al*, 2005).

$$(Inhibition\ (\%) = \left(1 - \left[\frac{Abs_{sample}}{Abs_{control}}\right]\right) \times 100 \quad (2)$$

The mineral contents of the sample were determined using the ICP-OES (Agilent 720, USA) according to the method used by Levent *et al*. (2020).

Determination of Cooking Properties and Firmness of Lasagna Noodles

For volume increase determination, 10 g of lasagna noodles were cooked in 300 mL of boiling distilled water for optimum cooking time (18 minutes). The optimum cooking time for lasagna noodles was determined by squeezing the lasagna noodles taken from boiling water at different times between two glass slides until the white core in the middle disappeared. The volume increase values were determined from the differences between volume of the cooked and raw samples. Cooking loss, expressed as a percentage of the total weight of the residue, was measured by evaporating the cooking water at 135^{o}C overnight (Cankurtaran Kömürcü and Bilgiçli, 2023). Firmness was measured in cooked lasagna noodles using the TAXT Plus Texture Analyzer (Stable Microsystems, UK). A/LKB-F blade assembly was used for analysis. Test optimal conditions in this study were Test mode: Compression, Contact force: 40 g, Test speed: 1.50 mm s^{-1}, and Strain: 100%.

Sensory Aanalyses

Uncooked and cooked lasagna noodles were evaluated in terms of surface smoothness, speck, crack, appearance and overall acceptability (uncooked), stickiness, taste-odor, chewiness, and overall acceptability (cooked) by 15 semi-trained panelists (aged 22-52) from Karamanoğlu Mehmetbey University, Department of Nutrition and Dietetics. Panelists were selected based on the criteria of being healthy, not allergic to gluten/wheat products and not smoking. Lasagna noodles were served to the panelists on dishes labeled with randomized numbers. Panelists were given water to rinse their mouths between assessments. In the evaluation, a scale ranging from 1 to 9 points (1-dislike extremely, 9-like extremely) was used (Bayrakçı and Bilgiçli, 2015).

Statistical Analysis

All analyses were the average of triplicate measurements on the duplicate samples. The results were expressed as mean value±standard deviation. One-way Analysis Of Variance (ANOVA) was performed using JMP 10.0 (SAS Institute, USA). $P< 0.05$ was considered as statistically significant.

RESULTS AND DISCUSSION

Raw Material Properties

The values of color parameters and proximate compositions of wheat flour, BLF, FSF, FBF, RF and OF used in lasagna noodles formulation are given in Table 1. Among the raw materials, it was determined that FSF had the highest a^* value, FSF and BLF had the highest b^* value. BLF, FSF, FBF, RF, and OF had significantly higher amounts of ash, crude protein and crude fat than wheat flour ($P< 0.05$). Ash, crude protein and crude fat values of BLF, FSF, FBF, RF and OF were found in the ranges of 1.26-4.26, 11.31-26.79, and 1.30-39.50%. These values were determined as 0.68% (ash), 10.42% (crude protein) and 0.71% (crude fat) in wheat flour. Raw materials analyses results were complying with the previous studies carried out by Kaur *et al*. (2017), Liu *et al*. (2018) and Yaghtini *et al*. (2021). FSF gave the highest TPC value, followed by FBF, BLF, RF, OF, and the lowest TPC value was determined in wheat flour. The highest AA value was determined in FSF. Levent *et al*. (2021) reported that the TPC and AA of FSF, turmeric and grape seed were 4872.96 mg GAE kg^{-1}, 64.32% (FSF), 5638.10 mg GAE kg^{-1}, 78.65% (turmeric) and 5213.08 mg GAE kg^{-1}, 65.17% (grape seed), respectively. Millar *et al*. (2019) reported that FBF had significantly higher TPC (387.52 mg GAE 100 g^{-1}) and AA (250.81 mg Ascorbic Acid Equivalents, AAE 100 g^{-1}) than green and yellow pea flours (121.93-129.85 mg GAE 100 g^{-1}, and 57.66-60.97 AAE 100 g^{-1}). Paranavitana *et al*. (2021) determined that green and black lentils had abundant phenolic compounds with antioxidant capacity. It was reported that lentils were a rich source of phenolic compounds such as caffeic acid, protocatechuic acid, trans-p-coumaric acid derivative, quercetin and its derivatives, formononetin, myricetin, catechin and gallic acid (Paranavitana *et al*., 2021).

Legumes, cereal flours and FSF used in the production of lasagna noodles were a very good source of some notable minerals, e.g. calcium, iron, magnesium, manganese and zinc (Table 1). Ca, Fe, Mg, Mn and Zn contents of BLF, FSF, FBF, RF and OF were found in the range of 45.53-153.11, 3.79-7.43, 114.54-165.80, 1.32-2.30 and 2.86-5.98 mg100g^{-1}, respectively. It was determined that BLF, FSF, FBF, RF and OF had higher mineral content compared to wheat flour.

Color Values of Pasta Samples

One of the most important features that define quality pasta is its characteristic yellowness (Bustos *et al*., 2015). The values of L^* ranged from 74.55 to 49.83 (Table 2). After the control, the lightest color was

Table 1. Color values and proximate composition of raw materials.[a]

Parameter	Wheat flour	BLF	FSF	FBF	RF	OF
*L**	93.03a±0.25	54.54e±0.27	72.10d±0.42	88.52bc±0.45	88.16c±0.34	89.81b±0.30
*a**	-0.21d±0.08	-2.24f±0.06	7.18a±0.10	-0.74e±0.04	1.18b±0.08	0.86c±0.07
*b**	9.24c±0.27	19.03a±0.33	20.01a±0.20	15.93b±0.37	9.48c±0.18	9.67c±0.17
Moisture (g 100 g^{-1})	11.27a±0.41	9.46b±0.23	7.56c±0.34	10.28ab±0.18	9.40b±0.14	9.89b±0.10
Ash (g 100 g^{-1})	0.68f±0.07	4.26a±0.03	3.58b±0.04	2.86c±0.03	1.26e±0.08	1.66d±0.06
Crude protein (g 100 g^{-1})	10.42e±0.24	26.79a±0.31	20.48c±0.25	25.27b±0.27	11.31e±0.30	12.92d±0.16
Crude fat (g 100 g^{-1})	0.71e±0.13	1.88d±0.20	39.50a±0.17	2.51c±0.08	1.30d±0.11	6.71b±0.16
TPC (mg GAE 100 g^{-1})	38.05f±0.69	278.07c±0.85	323.62a±0.76	312.92b±0.58	145.02d±0.92	112.84e±0.82
AA (Inhibition%)	10.50d±0.42	32.68b±1.95	60.14a±0.31	34.20b±1.22	18.47c±0.61	14.95c±0.85
Phytic acid (mg 100 g^{-1})	141.70f±4.67	1415.36c±9.42	1477.50b±5.80	1579.17a±7.03	942.50e±6.65	1238.62d±9.64
Ca (mg 100 g^{-1})	25.80f±0.71	117.55b±0.42	153.11a±1.09	79.68c±0.37	64.11d±0.98	45.53e±0.47
Fe (mg 100 g^{-1})	2.16f±0.07	7.43a±0.11	5.98c±0.08	6.42b±0.16	3.79e±0.10	5.15d±0.04
Mg (mg 100 g^{-1})	51.16e±0.11	138.10b±0.35	114.54d±0.98	165.80a±0.71	137.50b±0.49	131.79c±0.18
Mn (mg 100 g^{-1})	0.96d±0.03	1.49c±0.11	1.95ab±0.07	1.32c±0.04	1.85b±0.08	2.30a±0.14
Zn (mg 100 g^{-1})	1.24d±0.06	5.98a±0.10	5.54a±0.07	3.59b±0.16	3.12bc±0.21	2.86c±0.08

[a] Means followed by the different letter within a raw are significantly different ($P < 0.05$). Values are the average of triplicate measurements on the duplicate samples. Chemical properties except moisture are based on dry matter. BLF: Black Lentil Flour, FSF: Flaxseed Flour, FBF: Faba Bean Flour, RF: Rye Flour, OF: Oat Flour, *L**: Lightness; *a**: Color in the red/green field; *b**: Color in the blue/yellow field, TPC: Total Phenolic Content, and AA: Antioxidant Sctivity.

Table 2. Color values of lasagna samples.[a]

Treatment	*L**	*a**	*b**	*ΔE*
Control	74.55a±0.42	1.28d±0.11	26.46a±0.30	-
LBLF	49.83e±0.25	-0.42e±0.08	13.74d±0.23	27.85a±0.18
LFSF	60.61d±0.30	5.21a±0.04	19.05c±0.11	16.27b±0.17
LFBF	69.76c±0.34	-0.14e±0.06	22.23b±0.27	6.55c±0.01
LRF	72.32b±0.40	2.51b±0.08	26.44a±0.20	2.55d±0.01
LOF	73.79ab±0.55	2.02c±013	26.67a±0.38	1.08e±0.06

[a] Means followed by the different letter within a column are significantly different (P< 0.05). Values are the average of triplicate measurements on the duplicate samples. LBLF: Lasagna noodles with black lentil flour, LFSF: Lasagna noodles with flaxseed flour, LFBF: Lasagna noodles with faba bean flour, LRF: Lasagna noodles with rye flour, LOF: Lasagna noodles with oat flour, *L**: Lightness; *a**: Color in the red/green field, and *b**: Color in the blue/yellow field.

observed in the samples made with OF, whereas the darkest color was detected in the lasagna noodles made with BLF. Samples containing FSF gave higher *a**, while samples containing RF, OF gave *b** equivalent to the control sample. Similarly, Zarzycki *et al*. (2020) reported that the use of flaxseed flour in pasta formulation increased the redness and reduced the yellowness values of the control pasta. The color modifications measured instrumentally can be considered noticeable when the total color difference values are 1.5-3.0 (Zarzycki *et al*. (2020). Except for LOF, the Δ*E* value of all lasagna noodles was higher than 1.5. The highest Δ*E* value was determined in LBLF, which means that the color of LBLF is the most different from the control.

Cooking Quality of Pasta Samples

Cooking properties and firmness values of lasagna noodles are shown in Table 3. The addition of BLF, FSF, FBF, RF, and OF caused an increase in VI values. Kaur *et al*. (2013) used plant proteins obtained from mushroom powder, defatted soy flour and Bengal gram flour at different levels in the pasta formulation and reported that supplementation increased the water absorption and volume expansion values of pasta samples compared to the control pasta. Wójtowicz and Mościcki (2014) evaluated the quality of pasta enriched with white beans, yellow peas and lentils and reported that the water holding capacity of pasta products enriched with legume flour was significantly higher than wheat pasta. They reported that pasta containing lentil flour (40%) had the highest water holding capacity (%), which may be due to the fact that lentils had the highest protein content and can easily absorb and retain water. The increase in water uptake and volume expansion of pasta was attributed to the fine particle size and high protein content of legume flour, which has a higher hydration capacity (Kaur *et al*., 2013).

Cooking loss, which is an important indicator of the quality of pasta, indicates the amount of solids lost to the cooking water. Total solid loss of the control lasagna noodles was 7.1%, which increased with the incorporation of BLF, FSF, FBF, RF, and OF. High cooking loss is undesirable and, according to Ugarčić-Hardi *et al*. (2007), it should not exceed 12%. The increase in cooking loss can be attributed to the absence of gluten protein in these flours. The starch-gluten network is responsible for the physical integrity of the pasta during cooking. The use of gluten-free flours in pasta formulation diluted the strength of gluten and weakened the starch-gluten network, resulting in an increase in the cooking loss value (Torres *et al*., 2007; Marti and Pagani, 2013). Krawęcka (2022) found that cooking loss values increased with the increasing level of black cumin cake (5-25%) in pasta formulation. In the same study, it was reported that the cooking loss value was determined as 6.0% in the

Table 3. Cooking properties and firmness values of lasagna noodles. [a]

Treatment	Volume increase (%)	Cooking loss (%)	Firmness (g)
Control	200.6e±3.72	7.1c±0.31	331.10bc±12.73
LBLF	350.0b±3.11	9.9a±0.26	279.19c±18.94
LFSF	277.8d±2.37	9.2ab±0.11	271.10c±15.22
LFBF	300.0c±2.83	8.7b±0.27	377.34ab±10.13
LRF	371.9a±4.53	8.3b±0.10	427.50a±16.83
LOF	371.4a±1.96	8.8b±0.30	268.87c±18.48

[a] Means followed by the different letter within a column are significantly different (P< 0.05). Values are the average of triplicate measurements on the duplicate samples. Treatment symbols as in Table 2.

control sample and 6.67-9.04% in the pasta samples containing black cumin cake. Wójtowicz and Mościcki (2014) reported that the highest cooking loss value (7.9-8.7%) was determined at the highest level (40%) of white bean, yellow pea and lentil in precooked pasta, and results below 10% indicated good quality products.

Firmness values of lasagna noodles containing BLF, FSF and OF were not statistically different from the control. However, firmness values increased in the lasagna noodles containing FBF and RF compared to the control. Differences in the texture of pasta products can be attributed to changes in gluten strength, which decreased due to the use of different flours (Gull *et al*., 2015). Zhao *et al*. (2005) found similar results in spaghetti. Petitot *et al*. (2010) reported that fortification of durum wheat pasta with 35% of faba bean or split pea flour significantly increased the hardness of pasta by 38 and 43%, respectively. Firmness in cooked pasta is closely related to wheat protein quantity and quality (De Noni and Pagani, 2010). Hence, the use of non-gluten ingredients in pasta causes a decrease in gluten content and a decrease in firmness value. It is also possible that interference of the starch–protein matrix, allows more starch swelling, and this softens the pasta. Besides, the main possibility leading to greater firmness can be explained as the competition of additives with starch for water. If the ingredients have the ability to absorb more water during pasta making, they will reduce the starch swelling and water absorption of the pasta, causing the pasta to become firmer (Rakhesh *et al*., 2015).

Chemical Characteristics of Lasagna Noodles

Compared to the control sample, significantly higher ash content was detected in the samples containing BLF and FSF, and significantly (P< 0.05) higher amount of crude fat was detected in the samples containing FSF and OF (Table 4). BLF had the highest ash content, followed by FSF. Besides, FSF and OF had higher fat content than the other flours (Table 1). Compared to the control, the amount of crude protein in samples containing BLF and FBF increased by 24.6 and 21.6%, respectively. Similarly, Petitot *et al*. (2010) reported that, with the use of 35% faba bean flour in the pasta formulation, the protein content of control pasta samples increased from 13.3 to 18.8 g 100 g^{-1}. Millar *et al*. (2019), reported that pulse flour was an extremely nutritious source of protein in the production of protein-enriched cereal-based foods.

Phytic acid forms a complex with minerals such as Ca, Cu, Fe, Mg and Zn, which are necessary for human nutrition, and reduces their bioavailability (Bilgiçli, 2002). Therefore, phytic acid is considered as an antinutrient. Besides, phytic acid has positive effects on health such as having an antioxidant, anti-cancerous effect, lowering serum cholesterol and triglyceride, reduction of apoptosis and preventive foodborne pathogen (Kumar *et al*., 2021). Phytic acid

Table 4. Chemical properties of lasagna noodles.[a]

Treatment	Moisture (g 100 g^{-1})	Ash (g 100 g^{-1})	Crude protein (g 100 g^{-1})	Crude fat (g 100 g^{-1})	Phytic acid (mg 100 g^{-1})	TPC (mg GAE 100 g^{-1})	AA (Inhibition %)
Control	9.26a±0.23	1.28b±0.10	12.02c±0.28	2.33c±0.07	168.10e±7.50	40.26f±0.60	11.80d±0.31
LBLF	8.59ab±0.24	1.85a±0.07	14.98a±0.18	2.41c±0.11	371.25c±4.03	82.89c±0.85	16.97b±0.57
LFSF	7.86b±0.37	1.78a±0.08	13.70b±0.21	8.85a±0.14	412.85b±5.87	112.72a±0.71	24.65a±0.42
LFBF	8.43ab±0.21	1.60ab±0.11	14.62ab±0.34	2.60c±0.08	436.62a±6.96	90.56b±0.63	17.51b±0.30
LRF	8.75ab±0.16	1.32b±0.06	12.05c±0.24	2.37c±0.10	319.40d±4.10	65.82d±0.97	14.90c±0.54
LOF	8.09b±0.28	1.40b±0.07	12.10c±0.31	3.28b±0.16	355.18c±3.45	51.04e±0.64	13.27cd±0.25

[a] Means followed by the different letter within a column are significantly different (P< 0.05). Values are the average of triplicate measurements on the duplicate samples. Chemical properties except moisture are based on dry matter. Treatment symbols as in Table 2.

Table 5. Mineral contents of lasagna noodles (mg 100 g^{-1}).[a]

Treatment	Ca	Fe	Mg	Mn	Zn
Control	40.10f±0.85	2.10d±0.13	36.50f±0.17	0.82d±0.06	1.41c±0.16
LBLF	68.05b±0.92	3.25a±0.10	50.36b±0.40	1.06bcd±0.11	2.40a±0.14
LFSF	79.55a±0.61	2.83ab±0.07	43.06d±0.23	1.35ab±0.07	2.16ab±0.08
LFBF	62.30c±0.78	3.16a±0.16	65.58a±0.34	0.83cd±0.13	1.75bc±0.06
LRF	58.33d±0.51	2.30cd±0.07	45.80c±0.25	1.19abc±0.10	1.52c±0.10
LOF	52.16e±1.10	2.58bc±0.11	41.56e±0.13	1.46a±0.06	1.38c±0.14

[a] Means followed by the different letter within a column are significantly different (P< 0.05). Values are the average of triplicate measurements on the duplicate samples. Chemical properties except moisture are based on dry matter. Treatment symbols as in Table 2.

contents of lasagna noodles were found between 168.10 and 436.62 mg 100 g^{-1}, and the lowest value was determined in the control sample. Lasagna noodles containing FSF presented the highest TPC (112.72 mg GAE 100g^{-1}) and AA (24.65%), followed by pasta samples containing BLF and FBF. According to the proximate composition of raw materials (Table 1), FSF had high TPC and AA values in the raw materials, followed by BLF and FBF.This result may also be reflected in the lasagna noodle example where FSF was used.In the study conducted by Man *et al.* (2021), it was reported that as the ratio of roasted flaxseed flour in the formulation increased, the TPC and AA values in biscuit samples increased, and at 40% roasted flaxseed ratio, the TPC value increased from 63.06 to 78.82 mg GAE 100 g^{-1}, and the DPPH value increased from 13.57 to 32.03%. Krupa-Kozak *et al*. (2022) used Flaxseed Oil Cake Extract (FOCE) in the production of gluten-free bread and reported that FOCE significantly improved the antioxidant potential of bread samples.

The mineral contents of lasagna noodles are given in Table 5. The Ca, Fe, Mg, Mn and Fe content of lasagna noodles improved by 1.30 to 1.98, 1.23 to 1.55, 1.14 to 1.80, 1.01 to 1.78 and 0.98 to 1.70 times, respectively, as compared to the control. It was observed that the use of FSF, FBF and BLF in the formulation resulted in significantly higher Ca, Fe, Mg and Zn contents in lasagna noodles. The unfavorable effect of phytic acid on minerals may be partially compensated by the rich mineral content of lasagna noodles prepared with functional ingredients.

Sensory Characteristics

Speck, appearance, and overall acceptability scores decreased significantly ($P< 0.05$) with the use of BLF and FSF in raw lasagna noodles. Raw samples containing FBF, RF and OF were found to be equivalent to the control sample in terms of surface smoothness, speck, crack, appearance and overall acceptability (Figures 1 and 2). As with raw lasagna noodles, BLF and FSF caused a greater decrease in taste-odor scores in the cooked samples compared to other ingredients. Despite the high mineral, TPC and AA content, lasagna noodles containing FSF had the lowest overall acceptability score. Although all ingredients reduced the chewiness score in cooked lasagna noodles compared to the control, all samples received a chewiness score of 7.9 (~like very much) or above. According to the texture analysis results, although lasagna noodles containing RF had a high hardness value, this was not reflected in the sensory analysis results. Kaur *et al*. (2017) used flaxseed in the cookie formulation (0-30%) and reported that beyond the 15% replacement level, the

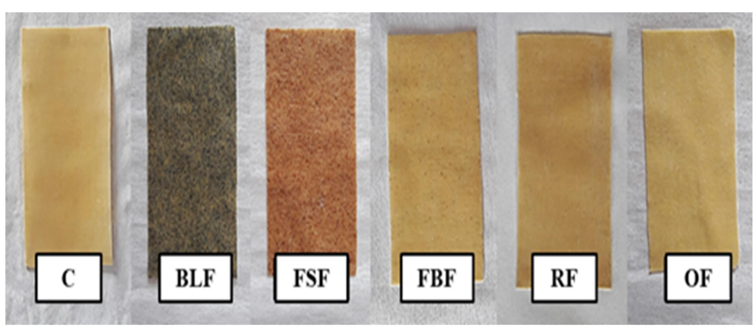
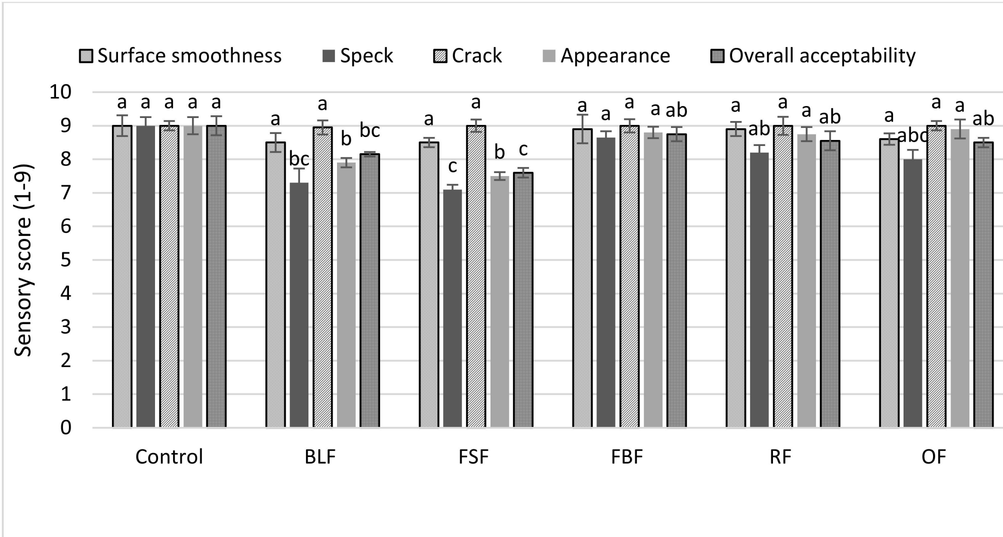
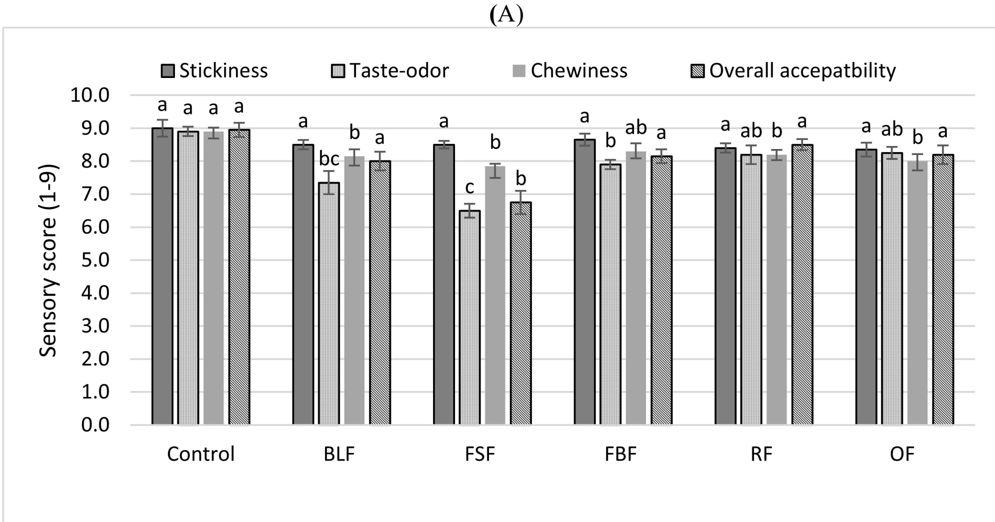


Figure 1. Control (C) and lasagna samples substituted with BLF (Black lentil meal), FSF (Flaxseed flour), FBF (Faba bean flour), RF (Rye flour) and OF (Oat flour).



(A)



(B)

Figure 2. Sensory properties of raw (A) and cooked (B) lasagna samples (BLF: Black Lentil Flour, FSF: Flaxseed Flour, FBF: Faba Bean Flour, RF: Rye Flour, OF: Oat Flour). Columns with different letters in the graph are significantly different (P< 0.05).

texture and taste of the cookies were negatively affected.

CONCLUSIONS

The use of BLF, FSF and FBF in the lasagna noodle formulation significantly improved the nutritional quality in terms of protein, Ca, Fe, and Mg contents. Generally, all ingredients used in the production of enriched lasagna noodles caused significant increases in TPC and AA values. The color of the lasagna noodle sample containing BLF was the most different from the control, followed by the sample containing FSF. In lasagna noodles, all the ingredients used caused an increase in the volume increase (%) and cooking loss (%) values. Higher firmness values were determined in lasagna noodles containing FBF and RF compared to the other samples. In sensory analysis, FSF caused a greater decrease in overall acceptability scores in cooked lasagna noodles than the other ingredients. When the nutritional, technological and sensory results were evaluated together, it was concluded that FBF, RF, and OF could be used successfully in lasagna formulation. It is recommended to use less than 20% of BLF and FSF in the lasagna noodles formulation, as they cause negative changes in the color and sensory properties of the product.

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تاثیر آردهای عدس سیاه، بذر کتان، باقلا، چاودار و جو دوسر بر خواص فیزیکوشیمیایی و بافتی رشته لازانیا

هاسر لونت، و ایلیف کورت

چکیده

این پژوهش به منظور بررسی تأثیر آرد عدس سیاه (BLF)، آرد بذر کتان (FSF)، آرد باقلا (FBF)، آرد چاودار (RF) و آرد جو دوسر (OF)بر روی خواص فیزیکی، شیمیایی، بافتی، پخت و پز و خواص حسی رشته لازانیا انجام شد آرد گندم در فرمول نودل لازانیا با ۲۰ درصد BLF، FSF، FBF، RF و OF به طور جداگانه جایگزین شد. نودل های لازانیا غنی شده نسبت به نمونه های شاهد افزایش حجم و از دست دادن ارزش پخت بیشتری داشتند. محتوای پروتئین نودل لازانیا حاوی BLFو FBF ٦. ٢٤٪ و ٢١.٦٪ بیشتر از نمونه شاهد بود. نودل لازانیا حاوی RF بالاترین ارزش سفتی را نشان داد. در نودل لازانیا، بیشترین محتوای فنلی کل (TPC) و فعالیت آنتی اکسیدانی (AA) در نمونه حاوی FSF و پس از آن نمونه حاوی FBF و BLF به ترتیب تعیین شد. در بین رشته های لازانیا، بیشترین میزان اسید فیتیک در نمونه حاوی FBF تعیین شد، در حالی که نمونه شاهد کمترین مقدار اسید فیتیک را نشان داد. استفاده از FSF، BLF، FBF و OF در فرمولاسیون، مقادیر Ca، Fe-Zn، Mg و Mn نودل لازانیا را به ترتیب ۱.۹۸-، ۱.۶-۱.۷-، ۱.۸- و ۱.۸ برابر افزایش داد. نودل لازانیا تهیه شده با استفاده از BLF بیشترین مقدار اختلاف رنگ کل را داشت. در تجزیه و تحلیل حسی، FSF کمترین مقدار پذیرش کلی را در بین نمونه‌های لازانیا پخته شده داشت. ارزیابی کلی تمام پارامترهای کیفیت تجزیه و تحلیل شده نشان می دهد که FBF، RF و OF می توانند با موفقیت در تولید رشته فرنگی لازانیا استفاده شوند.