

# 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 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 sample containing FSF, followed by 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 1.98-, 1.6-1.7-, 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:** Lasagna, flaxseed, legume, rye, oat.

## INTRODUCTION

Pasta is one of the most popular staple foods being consumed globally due to its sensory and 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

37 a type of wide and flat pasta prepared with wheat flour, eggs, water and salt, shaped and dried  
38 in a certain width and length (Sannino et al. 2005).

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

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

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

62 Flaxseed has advantages for human health due to its nutritional components, protein, fat,  
63 lignans, dietary fiber, vitamins, and phenolic compounds (Herchi et al., 2012; Garros et al.,  
64 2018). Flaxseed has gained importance in recent years due to its health benefits and its  
65 protective role in some diseases (Herchi et al., 2012).

66 Rye is a nutritionally interesting cereal due to its high fibre (19.3%) content (Boskov Hansen  
67 et al., 2002). Arabinoxylan is the major dietary fiber component of the rye grain. The main  
68 bioactive compounds in rye are lignans, alk(en)ylresorcinols, phenolic acids, folates,  
69 phytosterols, trace elements and minerals, tocotrienols and tocopherols and other vitamins.

70 Consuming whole-wheat rye products has been associated with several health effects, including  
71 reducing the risk of prostate and colon cancer (Poutanen et al., 2014).

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

78

## 79 **MATERIALS AND METHODS**

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

85

### 86 **Preparation of lasagna **noodles****

87 The production of the lasagna **noodles** was carried out by modifying the method given by  
88 Sannino et al. (2005). Control lasagna noodles were prepared with 100% wheat flour without  
89 any enrichment. For the production of the control lasagna **noodles**; 150 g wheat flour, 30 g egg,  
90 2.5 g salt and water (45-50 ml) were kneaded in the mixer (Kitchen-aid, Artisan, USA) for 5  
91 min. The amount of water used was determined by preliminary trials according to the optimum  
92 dough consistency. The dough obtained was divided into two equal parts (~114 g) and the  
93 dough pieces were pre-thinned on the wooden plate with the help of a rolling pin. The thinning  
94 process was continued until the thickness of these **dough sheets** was 0.8 mm in the noodle  
95 cutting machine (Shule Pasta Machine, China). The thinned dough sheets were cut 7.9 mm wide  
96 and 17.8 mm long, and then dried in an oven (Nüve KD-200, Ankara, Türkiye) at 50 °C for 3  
97 hr (Fardet et al., 1998; Sabanis et al., 2006). Dried lasagna **noodles** were kept in an airtight  
98 glass container at 25-27°C until analysis. For the production of enriched lasagna **noodles**, 20%  
99 of wheat flour was replaced with BLF, FSF, FBF, RF and OF and the same procedure was used  
100 for the production of control lasagna **noodles**.

101

### 102 **Color measurements**

103 The color parameters ( $L^*$ ,  $a^*$  and  $b^*$ ) of raw materials and lasagne **noodle** samples were  
104 measured using a Chroma-meter (Konica Minolta, Japan). Color measurements were made at

105 three different points on the same product. Total color difference ( $\Delta E$ ) was calculated according  
106 to the following formula,

$$107 \Delta E = ((L_c - L_i)^2 + (a_c - a_i)^2 + (b_c - b_i)^2)^{1/2}$$

108 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  
109 parameters of the enriched lasagna samples (Zarzycki et al., 2020).

## 110 Chemical analysis

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

116 The total phenolic content (TPC) was determined using the Folin-Ciocalteu method and was  
117 given as mg Gallic acid equivalents/100g (Beta et al., 2005; Gao et al., 2002). The antioxidant  
118 activity (AA) of the samples was assayed according to 2-2-diphenyl-2-picrylhydrazyl (DPPH)  
119 method. AA was calculated as percentage inhibition according to the formula below (Beta et  
120 al, 2005).

$$121 (\text{Inhibition } (\%)) = \left(1 - \frac{Abs_{\text{sample}}}{Abs_{\text{control}}}\right) * 100$$

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

124

## 125 Determination of Cooking Properties and Firmness of Lasagna Noodles

126 For volume increase determination, 10 g of lasagna noodles were cooked in 300 ml of boiling  
127 distilled water for optimum cooking time (18 min). The optimum cooking time for lasagna  
128 noodles was determined by squeezing the lasagna noodles taken from boiling water at different  
129 times between two glass slides until the white core in the middle disappeared. The volume  
130 increase values were determined from the differences between volume of cooked and raw  
131 samples. Cooking loss, expressed as a percentage of the total weight of the residue, was  
132 measured by evaporating the cooking water at 135 °C overnight (Kömürcü and Bilgiçli, 2023).

133 Firmness was measured in cooked lasagna noodles using the TAXT Plus Texture Analyzer  
134 (Stable Microsystems, UK). A/LKB-F blade assembly was used for analysis. Test optimal  
135 conditions in this study were: Test mode: compression, contact force: 40 g, test speed: 1.50  
136 mm/sec, strain: 100%.

137

## 138 Sensory analyses

139 Uncooked and cooked lasagna **noodles** were evaluated in terms of appearance, speck, surface  
140 smoothness, crack and overall acceptability (uncooked), stickiness, taste-odor, chewiness, and  
141 overall acceptability (cooked) by 15 semi-trained panelists (aged 22-52) from Karamanoğlu  
142 Mehmetbey University, Department of Nutrition and Dietetics. Panelists were selected based  
143 on the criteria of being healthy, not allergic to gluten/wheat products and not smoking. Lasagna  
144 noodles were served to the panelists on dishes labeled with randomised numbers. Panelists were  
145 given water to rinse their mouths between assessments. In the evaluation, a scale ranging from  
146 1 to 9 points (1-dislike extremely, 9-like extremely) was used (Bayrakçı and Bilgiçli, 2015).

147

### 148 **Statistical analysis**

149 All analyzes were the average of triplicate measurements on the duplicate samples. The results  
150 were expressed as mean value±standard deviation. One-way analysis of variance (ANOVA)  
151 was performed using JMP 10.0 (SAS Institute, USA). P<0.05 was considered as statistically  
152 significant.

153

## 154 **RESULTS AND DISCUSSION**

### 155 **Raw material properties**

156 The values of color parameters and proximate compositions of wheat flour, BLF, FSF, FBF,  
157 RF and OF used in lasagna **noodles** formulation are given in Table 1. Among the raw materials,  
158 it was determined that FSF had the highest  $a^*$  value, FSF and BLF had the highest  $b^*$  value.  
159 BLF, FSF, FBF, RF and OF had significantly higher amounts of ash, crude protein and crude  
160 fat than wheat flour ( $p<0.05$ ). Ash, crude protein and crude fat values of BLF, FSF, FBF, RF  
161 and OF were found in the ranges of 1.26-4.26%, 11.31-26.79% and 1.30-39.50%. These values  
162 were determined as 0.68% (ash), 10.42% (crude protein) and 0.71% (crude fat) in wheat flour.

163 Raw materials analyses results complying with the previous studies carried out by Kaur et al.  
164 (2017), Liu et al. (2018) and Yaghtini et al. (2021). FSF gave the highest TPC value, followed  
165 by FBF, BLF, RF, OF, and the lowest TPC value was determined in wheat flour. The highest  
166 AA value was determined in FSF. Levent et al. (2021) reported that the TPC and AA of FSF,  
167 turmeric and grape seed were 4872.96 mg GAE/kg, 64.32% (FSF), 5638.10 mg GAE/kg,  
168 78.65% (turmeric) and 5213.08 mg GAE/kg, 65.17% (grape seed), respectively. Millar et al.  
169 (2019) reported that FBF had significantly higher TPC (387.52 mg GAE/100g) and AA (250.81  
170 mg ascorbic acid equivalents, AAE/100g) than green and yellow pea flours (121.93-129.85 mg  
171 GAE/100g, 57.66-60.97 AAE/100g). Paravanitana et al. (2021) determined that green and black  
172 lentils have abundant phenolic compounds with antioxidant capacity. It was reported that lentils

173 are a rich source of phenolic compounds such as caffeic acid, protocatechuic acid, trans-p-  
 174 coumaric acid derivative, quercetin and its derivatives, formononetin, myricetin, catechin and  
 175 gallic acid (Paravanitana et al., 2021).

176 Legumes, cereal flours and FSF used in the production of lasagna noodles were a very good  
 177 source of some notable minerals e.g. calcium, iron, magnesium, manganese and zinc (Table 1).  
 178 Ca, Fe, Mg, Mn and Zn contents of BLF, FSF, FBF, RF and OF were found in the range of  
 179 45.53-153.11, 3.79-7.43, 114.54-165.80, 1.32-2.30 and 2.86-5.98, respectively. It was  
 180 determined that BLF, FSF, FBF, RF and OF had higher mineral content compared to wheat  
 181 flour.

182 **Table 1.** Color values and proximate composition of raw materials<sup>a</sup>

	Wheat flour	BLF	FSF	FBF	RF	OF
<i>L</i> *	93.03a±0.25	54.54e±0.27	72.10d±0.42	88.52bc±0.45	88.16c±0.34	89.81b±0.30
<i>a</i> *	-0.21d±0.08	-2.24f±0.06	7.18a±0.10	-0.74e±0.04	1.18b±0.08	0.86c±0.07
<i>b</i> *	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/100g)	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/100g)	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/100g)	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/100g)	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/100g)	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/100g)	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/100g)	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/100g)	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/100g)	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/100g)	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/100g)	1.24d±0.06	5.98a±0.10	5.54a±0.07	3.59b±0.16	3.12bc±0.21	2.86c±0.08

183 <sup>a</sup>Means followed by the different letter within a row are significantly different (P<0.05). Values are the average of  
 184 triplicate measurements on the duplicate samples. Chemical properties except moisture are based on dry matter.  
 185 BLF: Black lentil flour, FSF:Flaxseed flour, FBF:Faba bean flour, RF:Rye flour, OF:Oat flour, *L*\*, lightness; *a*\*,  
 186 color in the red/green field; *b*\*, color in the blue/yellow field, TPC: Total phenolic content, AA: Antioxidant  
 187 activity.

### 189 Color values of pasta samples

190 One of the most important features that define quality pasta is its characteristic yellowness  
 191 (Bustos et al., 2015). The values of *L*\* ranged from 74.55 to 49.83 (Table 2). After the control,  
 192 the lightest color was observed in the samples made with OF whereas the darkest color was  
 193 detected in the lasagna noodles made with BLF. Samples containing FSF gave higher *a*\*, while  
 194 samples containing RF, OF gave *b*\* equivalent to the control sample. Similarly, Zarzycki et al.  
 195 (2020) reported that the use of flaxseed flour in pasta formulation increased the redness and



reduced the yellowness values of 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  $\Delta E$  value of all lasagna noodles is higher than 1.5. The highest  $\Delta E$  value was determined in LBLF, which means that the color of LBLF is the most different from the control.

**Table 2.** Color values of lasagna samples<sup>a</sup>.

	$L^*$	$a^*$	$b^*$	$\Delta E$
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±0.13	26.67a±0.38	1.08e±0.06

<sup>a</sup>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;  $b^*$ , color in the blue/yellow field.

### 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 it was reported that supplementation increased the water absorption and volume expansion values of pasta samples compared to 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 is significantly higher than wheat pasta. They reported that pasta containing lentil flour (40%) had the highest water holding capacity (330 g/100g), which may be due to the fact that lentils have the highest protein content, which 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).

**Table 3.** Cooking properties and firmness values of lasagna noodles<sup>a</sup>

	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

225 <sup>a</sup>Means followed by the different letter within a column are significantly different (P<0.05). Values are the average  
 226 of triplicate measurements on the duplicate samples. LBLF: Lasagna noodles with black lentil flour, LFSF:  
 227 Lasagna noodles with flaxseed flour, LFBF: Lasagna noodles with faba bean flour, LRF: Lasagna noodles with  
 228 rye flour, LOF: Lasagna noodles with oat flour.  
 229

230 Cooking loss, which is an important indicator of the quality of pasta, indicates the amount of  
 231 solids lost to the cooking water. Total solid loss of control lasagna noodles was 7.1% which  
 232 increased with the incorporation of BLF, FSF, FBF, RF and OF. High cooking loss is  
 233 undesirable and according to Ugarčić-Hardi et al. (2007), it should not exceed 12%. The  
 234 increase in cooking loss can be attributed to the absence of gluten protein in these flours. The  
 235 starch-gluten network is responsible for the physical integrity of the pasta during cooking. The  
 236 use of gluten-free flours in pasta formulation diluted the strength of gluten and weakened the  
 237 starch-gluten network, resulting in an increase in the cooking loss value (Torres et al., 2007;  
 238 Marti and Pagani, 2013). Krawęcka (2022) found that cooking loss values increased with the  
 239 increasing level of black cumin cake (5-25%) in pasta formulation. In the same study, it was  
 240 reported that the cooking loss value was determined as 6.0% in the control sample and 6.67-  
 241 9.04% in the pasta samples containing black cumin cake. Wójtowicz and Mościcki (2014)  
 242 reported that the highest cooking loss value (7.9-8.7%) was determined at the highest level  
 243 (40%) of white bean, yellow pea and lentil in precooked pasta, and results below 10% indicate  
 244 good quality products.

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



258 starch swelling and water absorption of the pasta, causing the pasta to become firmer (Rakesh  
259 et al., 2015).

## 260 261 **Chemical characteristics of lasagna noodles**

262 Compared to the control sample, significantly higher ash content was detected in the samples  
263 containing BLF and FSF, and significantly ( $p<0.05$ ) higher amount of crude fat was detected  
264 in the samples containing FSF and OF (Table 4). BLF had the highest ash content, followed by  
265 FSF. Besides, FSF and OF had higher fat content than other flours (Table 1). Compared to the  
266 control, the amount of crude protein in samples containing BLF and FBF increased by 24.6%  
267 and 21.6%, respectively. In the samples containing BLF and FBF, the amount of crude protein  
268 increased by 24.6% and 21.6%, respectively. Similarly, Petitot et al. (2010) reported that with  
269 the use of 35% faba bean flour in the pasta formulation, the protein content of control pasta  
270 samples increased from 13.3 g/100 g to 18.8 g/100 g. Millar et al. (2019), reported that pulse  
271 flour is an extremely nutritious source of protein in the production of protein-enriched cereal-  
272 based foods.

273 Phytic acid forms a complex with minerals such as Ca, Cu, Fe, Mg and Zn, which are necessary  
274 for human nutrition, and reduces their bioavailability (Bilgiçli, 2002). Therefore, phytic acid is  
275 considered as an antinutrient. Besides that, phytic acid has positive effects on health such as  
276 having an antioxidant, anti-cancerous effect, lowering serum cholesterol and triglyceride,  
277 reduction of apoptosis and preventive foodborne pathogen (Kumar et al., 2021). Phytic acid  
278 contents of lasagna noodles were found between 168.10 mg/100g and 436.62 mg/100g, and the  
279 lowest value was determined in the control sample. Lasagna noodles containing FSF presented  
280 the highest TPC (1127.15 mg GAE/g) and AA (24.65%), followed by pasta samples containing  
281 FBF and BLF. According to the proximate composition of raw materials (Table 1), FSF had  
282 high TPC and AA values in the raw materials, followed by BLF and FBF. This result may also  
283 be reflected in the lasagna noodle example where FSF was used. In the study conducted by Man  
284 et al (2021), it was reported that as the ratio of roasted flaxseed flour in the formulation  
285 increased, the TPC and AA values in biscuit samples increased, and at 40% roasted flaxseed  
286 ratio, the TPC value increased from 63.06 to 78.82 mgGAE/100g, and the DPPH value  
287 increased from 13.57 to 32.03%. Krupa-Kozak et al. (2022) used flaxseed oil cake extract  
288 (FOCE) in the production of gluten-free bread and reported that FOCE significantly improved  
289 the antioxidant potential of bread samples.

290 The mineral contents of lasagna noodles are given in Table 5. The Ca, Fe, Mg, Mn and Fe  
291 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

292 and 0.98 to 1.70 times respectively as compared to the control. It was observed that the use of  
 293 FSF, FBF and BLF in the formulation resulted in significantly higher Ca, Fe, Mg and Zn  
 294 contents in lasagna noodles. The unfavorable effect of phytic acid on minerals may be partially  
 295 compensated by the rich mineral content of lasagna noodles prepared with functional  
 296 ingredients.

297 **Table 4.** Chemical properties of lasagna noodles<sup>a</sup>.

	Moisture (g/100g)	Ash (g/100g)	Crude protein (g/100g)	Crude fat (g/100g)	Phytic acid (mg/100g)	TPC (mg GAE/100g)	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

298 <sup>a</sup>Means followed by the different letter within a column are significantly different (P<0.05). Values are the average  
 299 of triplicate measurements on the duplicate samples. Chemical properties except moisture are based on dry matter.  
 300 LBLF: Lasagna noodles with black lentil flour, LFSF: Lasagna noodles with flaxseed flour, LFBF: Lasagna  
 301 noodles with faba bean flour, LRF: Lasagna noodles with rye flour, LOF: Lasagna noodles with oat flour.

303 **Table 5.** Mineral contents of lasagna noodles (mg/100g)<sup>a</sup>.

	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

304 <sup>a</sup>Means followed by the different letter within a column are significantly different (P<0.05). Values are the average  
 305 of triplicate measurements on the duplicate samples. Chemical properties except moisture are based on dry matter.  
 306 LBLF: Lasagna noodles with black lentil flour, LFSF: Lasagna noodles with flaxseed flour, LFBF: Lasagna  
 307 noodles with faba bean flour, LRF: Lasagna noodles with rye flour, LOF: Lasagna noodles with oat flour.

### 309 Sensory characteristics

310 Speck, appearance and overall acceptability scores decreased significantly (p<0.05) with the  
 311 use of BLF and FSF in raw lasagna noodles. Raw samples containing FBF, RF and OF were  
 312 found to be equivalent to the control sample in terms of surface smoothness, speck, crack,  
 313 appearance and overall acceptability (Figure 1 and Figure 2). As with raw lasagna noodles,  
 314 BLF and FSF caused a greater decrease in taste-odor scores in cooked samples compared to  
 315 other ingredients. Despite the high mineral, TPC and AA content, lasagna noodles containing  
 316 FSF had the lowest overall acceptability score. Although all ingredients reduced the chewiness  
 317 score in cooked lasagna noodles compared to the control, all samples received a chewiness  
 318 score of 7.9 (~like very much) or above. According to the texture analysis results, although  
 319 lasagna noodles containing RF had a high hardness value, this was not reflected in the sensory

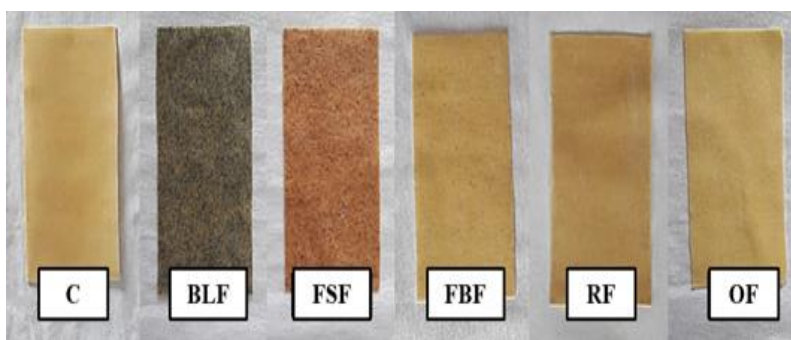
320 analysis results. Kaur et al. (2017) used flaxseed in the cookie formulation (0-30%) and reported  
321 that beyond the 15% replacement level, the texture and taste of the cookies were negatively  
322 affected.

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## 325 CONCLUSIONS

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

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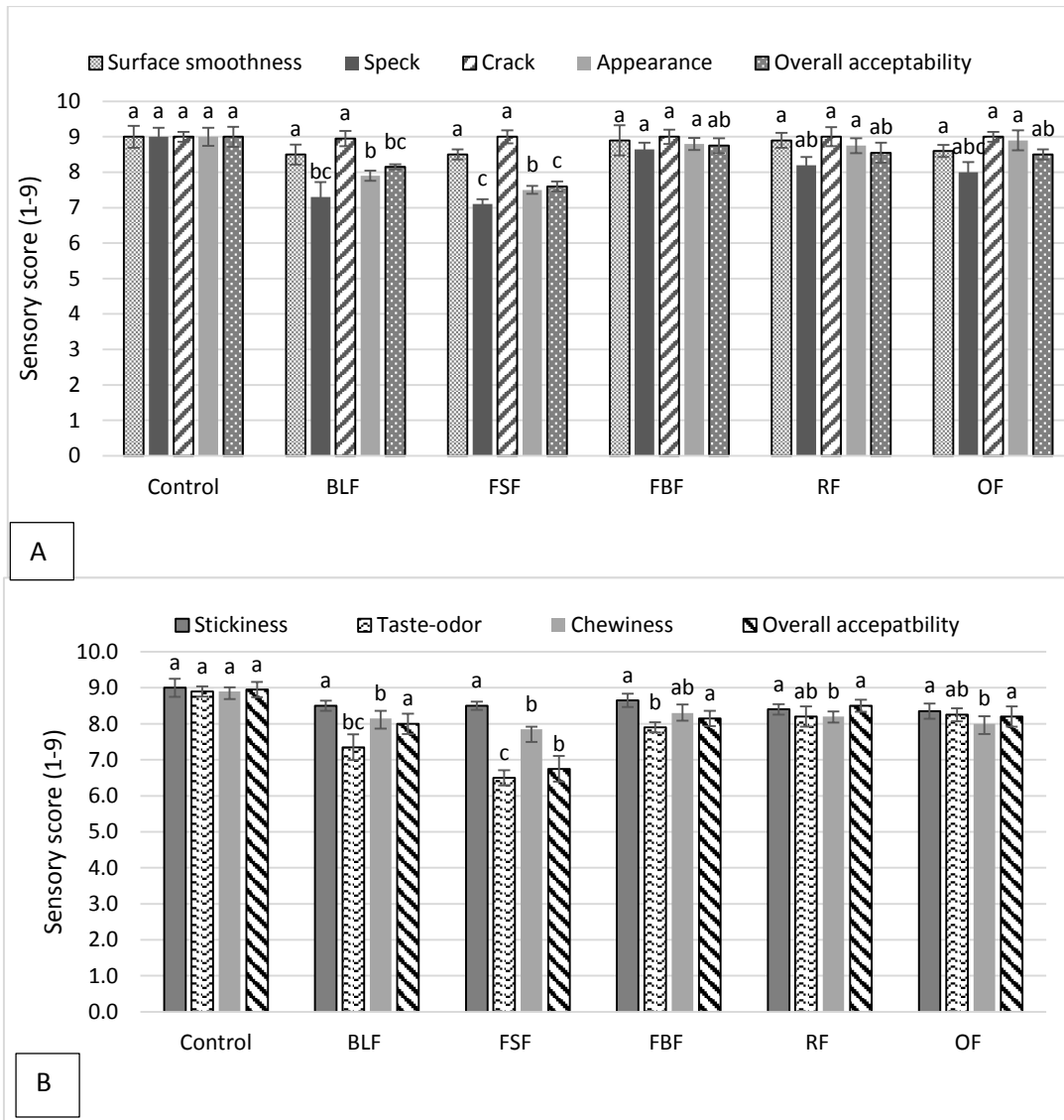
341 **Figure 1.** Control (C) and lasagna samples substituted with BLF (black lentil meal), FSF  
342 (flaxseed flour), FBF (faba bean flour), RF (rye flour) and OF (oat flour)

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349 **Figure 2.** Sensory properties of raw (A) and cooked (B) lasagna samples (BLF: Black lentil  
 350 flour, FSF: Flaxseed flour, FBF: Faba bean flour, RF: Rye flour, OF: Oat flour).

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