

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%), β -
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 (ΔE) 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^a

	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 ^aMeans 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 ΔE value of all lasagna noodles is higher than 1.5. The highest ΔE 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^a.

	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±0.13	26.67a±0.38	1.08e±0.06

^aMeans 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^a

	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 ^aMeans 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.

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^a.

	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 ^aMeans 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)^a.

	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 ^aMeans 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

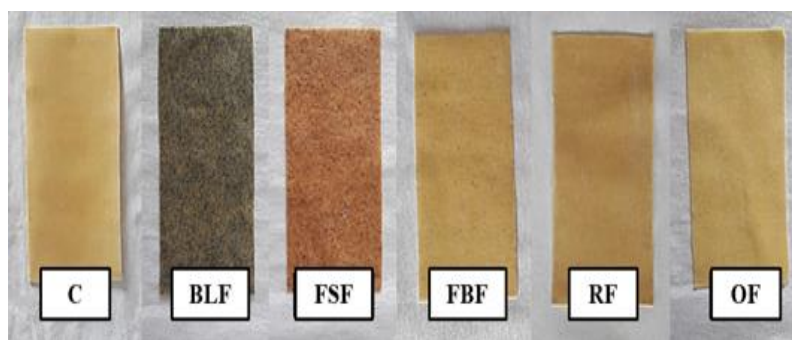
320 analysis results. Kaur et al. (2017) used flaxseed in the cookie formulation (0-30%) and reported
321 that beyond the 15% replacement level, the texture and taste of the cookies were negatively
322 affected.

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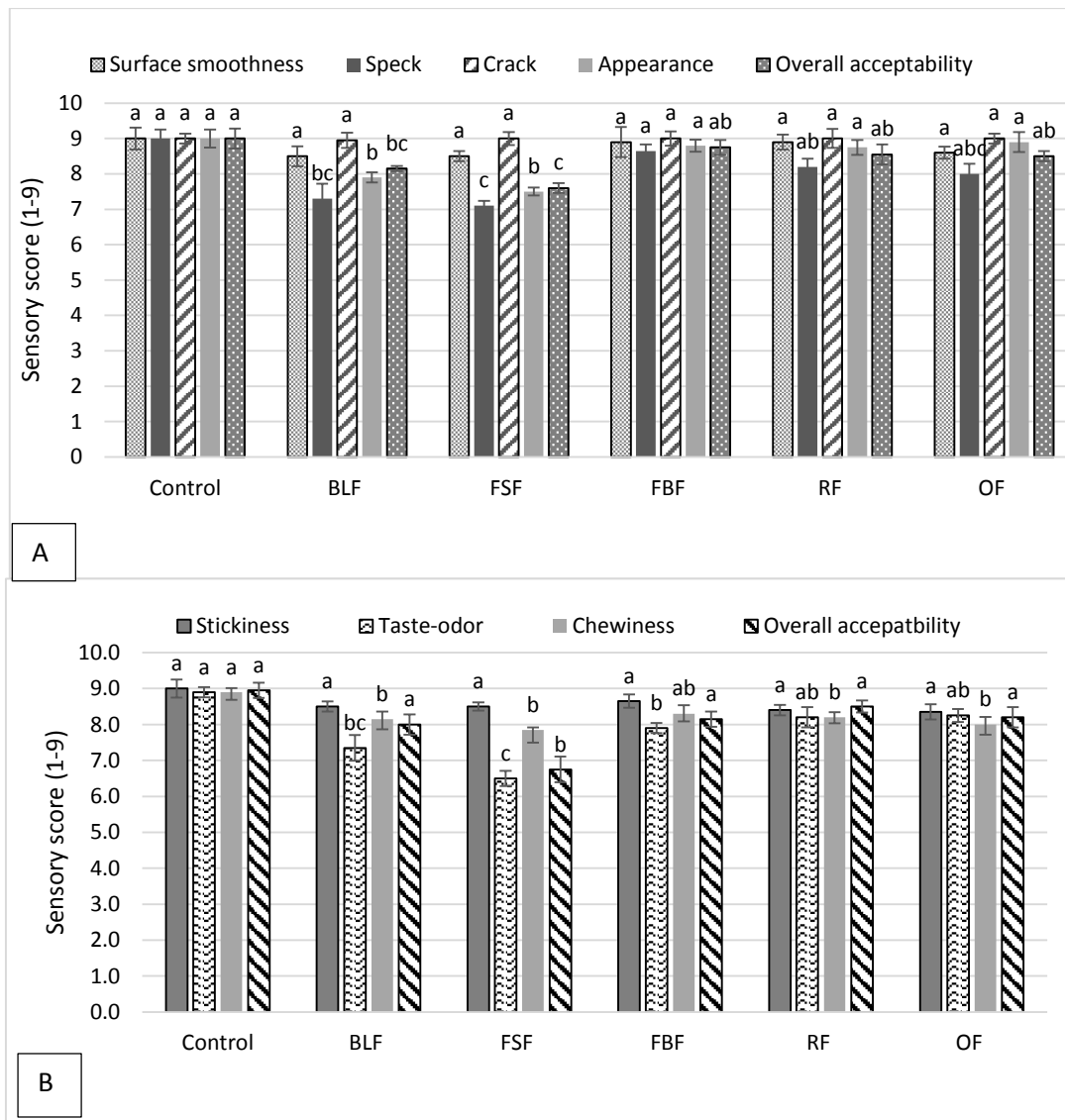
341 **Figure 1.** Control (C) and lasagna samples substituted with BLF (black lentil meal), FSF
342 (flaxseed flour), FBF (faba bean flour), RF (rye flour) and OF (oat flour)

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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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