ACCEPTED ARTICLE

Impact of black lentil, flaxseed, faba bean, rye and oat flours on physicochemical and textural properties of lasagna noodles

Hacer Levent[1*], and Elif Kurt[2]

[1] Karamanoğlu Mehmetbey University, Faculty of Health Sciences, Department of Nutrition and Dietetics, 70100, Karaman, Turkey.

[2] Karamanoğlu Mehmetbey University, School of Applied Sciences, Department of Gastronomy and Culinary Arts, 70100, Karaman, Turkey.

***Corresponding author;** e-mail: hacerlevent@hotmail.com

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 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, 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, due to their antioxidant activities, may reduce the risk of health disorders (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%), 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, 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, 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, salt, used in lasagna noodles making process 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 hr (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 control lasagna noodles.

Color measurements

The color parameters (L^*, a^* and b^*) of raw materials and lasagne 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 following formula,

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

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 the formula below (Beta et al, 2005).

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

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 min). 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 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 (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/sec, strain: 100%.

Sensory analyses

Uncooked and cooked lasagna noodles were evaluated in terms of appearance, speck, surface smoothness, crack 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 randomised 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 analyzes 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 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, 64.32% (FSF), 5638.10 mg GAE/kg, 78.65% (turmeric) and 5213.08 mg GAE/kg, 65.17% (grape seed), respectively. Millar et al. (2019) reported that FBF had significantly higher TPC (387.52 mg GAE/100g) and AA (250.81 mg ascorbic acid equivalents, AAE/100g) than green and yellow pea flours (121.93-129.85 mg GAE/100g, 57.66-60.97 AAE/100g). Paravanitana et al. (2021) determined that green and black lentils have abundant phenolic compounds with antioxidant capacity. It was reported that lentils are 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 (Paravanitana 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, respectively. It was determined that BLF, FSF, FBF, RF and OF had higher mineral content compared to wheat flour.

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

	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/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

[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, AA: Antioxidant activity.

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 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 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 is 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.

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±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; *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

[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.

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 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 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% indicate good quality products.

Firmness values of lasagna noodles containing BLF, FSF and OF were not statistically different from 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 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. In the samples containing BLF and FBF, the amount of crude protein 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 g/100 g to 18.8 g/100 g. Millar et al. (2019), reported that pulse flour is 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 that, 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 contents of lasagna noodles were found between 168.10 mg/100g and 436.62 mg/100g, and the lowest value was determined in the control sample. Lasagna noodles containing FSF presented the highest TPC (1127.15 mg GAE/g) and AA (24.65%), followed by pasta samples containing FBF and BLF. 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 mgGAE/100g, 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.

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

[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. 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.

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

[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. 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.

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 (Figure 1 and Figure 2). As with raw lasagna noodles, BLF and FSF caused a greater decrease in taste-odor scores in 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 ingredinets 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 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. 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 found to be the most different from the control, followed by 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 other samples. In sensory analysis, FSF caused a greater decrease in overall acceptability scores in cooked lasagna noodles than 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.

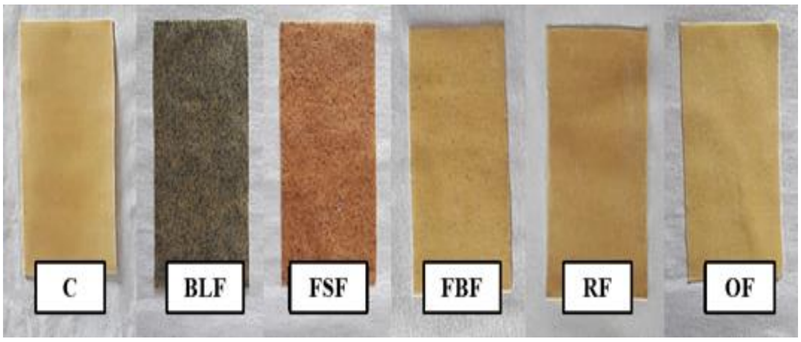

Figure 1. Control (C) and lasagna samples substituted with BLF (black lentil meal), FSF (flaxseed flour), FBF (faba bean flour), RF (rye flour) and OF (oat flour)

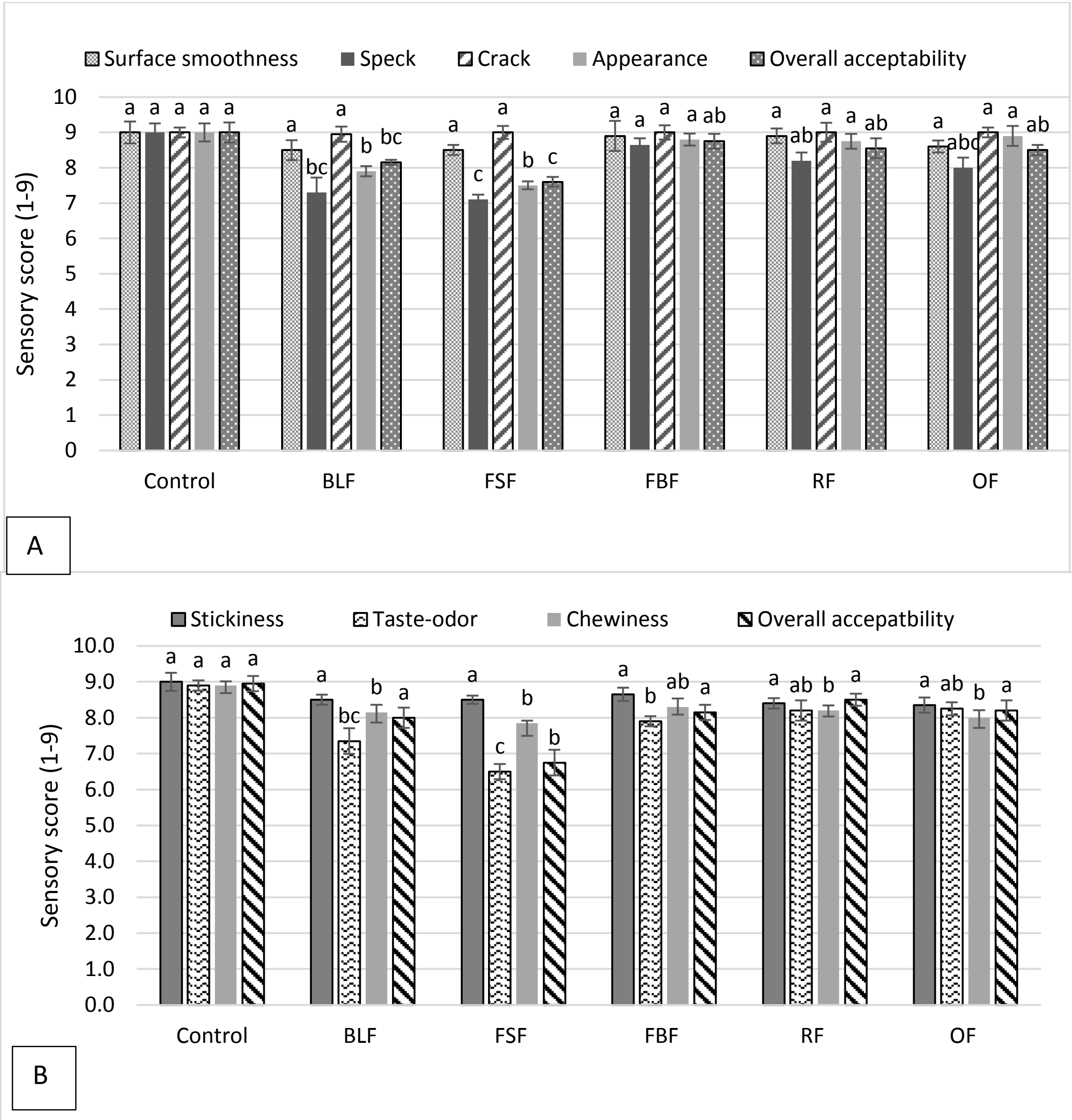

Figure 2. Sensory properties of raw (A) and cooked (B)lasagna samples (BLF: Black lentil flour, FSF:Flaxseed flour, FBF:Faba bean flour, RF:Rye flour, OF:Oat flour).

REFERENCES

AACC, 2000. Approved Methods of the American Association of Cereal Chemists, 10th ed. St. Paul/Minnesota, USA.

Bayrakçı, H. A. and Bilgiçli, N. 2015. Influence of resistant starches on chemical and functional properties of tarhana. *J Food Sci Tech.*, **52**: 5335-5340.

Beta, T., Nam, S., Dexter, J. E. and Sapirstein, H. D. 2005. Phenolic content and antioxidant activity of pearled wheat and roller-milled fractions. Cereal Chem., **82(4)**: 390-393.

Bilgiçli, N. 2002. Nutritional importance of phytic acid and food production methods with reduced phytic acid content. *Selcuk J. Agr. Food Sci.,* **16 (30)**: 79-83 (In Turkish).

Boskov Hansen, H., Andreasen, M., Nielsen, M., Larsen, L., Knudsen, B. K., Meyer, A., ... and Hansen, Å. 2002. Changes in dietary fibre, phenolic acids and activity of endogenous enzymes during rye bread-making. *Eur Food Res Technol.*, **214**: 33-42.

Bustos, M. C., Perez, G. T. and Leon, A. E. 2015. Structure and quality of pasta enriched with functional ingredients. *Rsc Advances*, **5(39)**: 30780-30792.

De Noni, I. and Pagani, M. A. 2010. Cooking properties and heat damage of dried pasta as influenced by raw material characteristics and processing conditions. *Crit Rev Food Sci*, **50(5):** 465-472.

Ertaş, N., Türker, S., Bilgiçli, N. and 2008. Effect of various processes on nutritional and antinutritional components of legumes. Türkiye 10th Food Congress, Erzurum, Türkiye

Fardet, A., Hoebler, C., Baldwin, P. M., Bouchet, B., Gallant, D. J. and Barry, J. L., 1998. Involvement of the protein network in the in vitro degradation of starch from spaghetti and lasagne: a microscopic and enzymic study. *J Cereal Sci.,* **27 (2)**: 133-145.

Gao, L., Wang, S., Oomah, B. D. and Mazza, G. 2002. Wheat quality: antioxidant activity of wheat millstreams, In: "Wheat Quality Elucidation", (Eds.): Ng, P., Wrigley, C.W. AACC International, St. Paul, MN, PP. 219-233.

Garros, L., Drouet, S., Corbin, C., Decourtil, C., Fidel, T., Lebas de Lacour, J., ... and Hano, C. (2018). Insight into the influence of cultivar type, cultivation year, and site on the lignans and related phenolic profiles, and the health-promoting antioxidant potential of flax (Linum usitatissimum L.) seeds. *Molecules*, **23(10)**: 2636.

Ghandehari Yazdi, A. P., Kamali Rousta, L., Azizi Tabrizzad, M. H., Amini, M., Tavakoli, M. and Yahyavi, M. 2020. A review: new approach to enrich pasta with fruits and vegetables. *Food Sci Technol*., **17 (103),** 129–149.

Gull, A., Prasad, K. and Kumar, P., 2015. Effect of millet flours and carrot pomace on cooking qualities, color and texture of developed pasta. *LWT-Food Sci Technol.*, **63 (1)**, 470-474.

Han, F., Moughan, P. J., Li, J., Stroebinger, N. and Pang, S. 2021. The complementarity of amino acids in cooked pulse/cereal blends and effects on DIAAS. *Plants*, **10(10)**: 1999.

Haug, W. and Lantzsch, H. J. 1983. Sensitive method for the rapid determination of phytate in cereals and cereal products. *J. Sci. Food Agric*., **34 (12)**: 1423–1426.

Herchi, W., Arráez-Román, D., Boukhchina, S., Kallel, H., Segura-Carretero, A. and Fernández-Gutierrez, A. 2012. A review of the methods used in the determination of flaxseed components. *Afr J Biotechnol.*, **11 (4)**: 724-731.

Kamali Rousta, L., Pouya Ghandehari Yazdi, A., Khorasani, S., Tavakoli, M., Ahmadi, Z. and Amini, M., 2021. Optimization of novel multigrain pasta and evaluation of physicochemical properties: using D-optimal mixture design. *Food Sci Nutr*. **9 (10)**: 5546-5556.

Kan, L., Nie, S., Hu, J., Wang, S., Bai, Z., Wang, J., ... and Song, K. 2018. Comparative study on the chemical composition, anthocyanins, tocopherols and carotenoids of selected legumes. *Food Chem.*, **260**, 317-326.

Kaur, G., Sharma, S., Nagi, H. P. S. and Ranote, P. S. 2013. Enrichment of pasta with different plant proteins. *J Food Sci Technol*., **50:** 1000-1005.

Kaur, M., Singh, V. and Kaur, R., 2017. Effect of partial replacement of wheat flour with varying levels of flaxseed flour on physicochemical, antioxidant and sensory characteristics of cookies. *Bioactive Carbohydrates and Dietary Fibre*, **9:** 14-20.

Krawęcka, A., Sobota, A., Ivanišová, E., Harangozo, Ľ., Valková, V., Zielińska, E., ... and Mildner-Szkudlarz, S. 2022. Effect of Black Cumin Cake Addition on the Chemical Composition, Glycemic Index, Antioxidant Activity, and Cooking Quality of Durum Wheat Pasta. *Molecules*, **27(19)**: 6342.

Krupa-Kozak, U., Bączek, N., Capriles, V. D. and Łopusiewicz, Ł. 2022. Novel Gluten-Free Bread with an Extract from Flaxseed By-Product: The Relationship between Water Replacement Level and Nutritional Value, Antioxidant Properties, and Sensory Quality. *Molecules*, **27(9)**: 2690.

Kömürcü, T. C. and Bilgiçli, N. 2023. Effect of germinated and heat-moisture treated ancient wheat on some quality attributes and bioactive components of noodles. *Food Chem.*, **404**, 134577.

Kumar, A., Singh, B., Raigond, P., Sahu, C., Mishra, U. N., Sharma, S. and Lal, M. K., 2021. Phytic acid: blessing in disguise, a prime compound required for both plant and human nutrition. *Food Res. Int.*, **142:** 110193.

Levent, H., Koyuncu, M., Bilgiçli, N., Adıgüzel, E. and Dedeoğlu, M. 2020. Effects of depyhtinized cereal brans and enzymes on physical and sensory quality of pasta. *Gıda*, **45 (2)**: 397-407.

Levent, H., Sayaslan, A. and Yeşil, S., 2021. Physicochemical and sensory quality of gluten-free cakes supplemented with grape seed, pomegranate seed, poppy seed, flaxseed, and turmeric. *J Food Process Pres*., **45 (2)**: e15148.

Liu, R., Yang, G., Guo, J., Wu, T., Sui, W. and Zhang, M., 2018. Effects of incorporation of black garlic on rheological, textural and sensory properties of rye (*Secale Cereale L*.) flour noodles. *CYTA-Journal of Food*, **16 (1):** 1102-1108.

Mel, R. and Malalgoda, M. 2022. Oat protein as a novel protein ingredient: Structure, functionality, and factors impacting utilization. *Cereal Chem.*, **99(1):** 21-36.

Man, S. M., Stan, L., Păucean, A., Chiş, M. S., Mureşan, V., Socaci, S. A., ... and Muste, S. 2021. Nutritional, sensory, texture properties and volatile compounds profile of biscuits with roasted flaxseed flour partially substituting for wheat flour. *Appl Sci*, **11(11**): 4791.

Marti, A. and Pagani, M. A. 2013. What can play the role of gluten in gluten free pasta?. *Trends Food Sci Technol.*, **31(1),** 63-71.

Millar, K. A., Gallagher, E., Burke, R., McCarthy, S. and Barry-Ryan, C. 2019. Proximate composition and anti-nutritional factors of fava-bean (*Vicia faba*), green-pea and yellow-pea (*Pisum sativum*) flour. *J Food Compos Anal*., **82**: 103233.

Moreno-Valdespino, C. A., Luna-Vital, D., Camacho-Ruiz, R. M., and Mojica, L. 2020. Bioactive proteins and phytochemicals from legumes: Mechanisms of action preventing obesity and type-2 diabetes. *Food Res Int.*, **130**: 108905.

Paranavitana, L., Oh, W.Y., Yeo, J., Shahidi, F., 2021. Determination of soluble and insoluble-bound phenolic compounds in dehulled, whole, and hulls of green and black lentils using electrospray ionization (ESI)-MS/MS and their inhibition in DNA strand scission. *Food Chem*., **361**: 130083.

Petitot, M., Boyer, L., Minier, C. and Micard, V., 2010. Fortification of pasta with split pea and faba bean flours: pasta processing and quality evaluation. *Food Res Int*., **43 (2)**: 634-641.

Poutanen, K., Katina, K. and Heiniö, R.L., 2014. Rye. Bakery Products Science and Technology, (Ed.): Weibiao Zhou, Y. H., Hui, I., De Leyn, M. A., Pagani, C. M., Rosell and J. D. Selman, Second Edition, N. Therdthai. PP. 75-87.

Rakhesh, N., Fellows, C.M. and Sissons, M., 2015. Evaluation of the technological and sensory properties of durum wheat spaghetti enriched with different dietary fibres. *J Sci Food and Agr*., **95 (1)**: 2-11.

Sabanis, D., Makri, E. and Doxastakis, G., 2006. Effect of durum flour enrichment with chickpea flour on the characteristics of dough and lasagne. *J Sci Food Agr*., **86 (12):** 1938-1944.

Sannino, A., Capone, S., Siciliano, P., Ficarella, A., Vasanelli, L. and Maffezzoli, A., 2005. Monitoring the drying process of lasagna pasta through a novel sensing device-based method. *J Food Eng*., **69 (1)**: 51-59.

Shahidi, F. and Ambigaipalan, P., 2015. Phenolics and polyphenolics in foods, beverages and spices: antioxidant activity and health effects–A review. J Func Foods, **18**: 820-897.

Singh, R., De, S. and Belkheir, A., 2013. Avena sativa (oat), a potential neutraceutical and therapeutic agent: an overview. *Crit Rev Food Sci*., **53 (2)**: 126-144.

Singh, B., Singh, J.P., Kaur, A. and Singh, N., 2017. Phenolic composition and antioxidant potential of grain legume seeds: a review. Food Res Int., **101**: 1-16.

Singh, J. P., Singh, B. And Kaur, A. 2021. Bioactive compounds of legume seeds. *Bioactive Compounds in Underutilized Vegetables and Legumes*, 645-665.

Sun, W., Shahrajabian, M. H., and Cheng, Q. 2022. Bioactive ingredients of legumes. In: "*Functional Foods and Nutraceuticals in Metabolic and Non-Communicable Diseases"* PP. 371-382, Academic Press.

Torres, A., Frias, J., Granito, M., Guerra, M., & Vidal-Valverde, C. 2007. Chemical, biological and sensory evaluation of pasta products supplemented with α-galactoside-free lupin flours. *J Sci Food Agr*, **87(1)**: 74-81.

Ugarčić-Hardi Ž., Jukić M., Koceva Komlenić D., Sabo M. and Hardi J. 2007: Quality parameters of noodles made with various supplements. *Czech J. Food Sci*., **25**: 151–157.

Wójtowicz, A. and Mościcki, L., 2014. Influence of legume type and addition level on quality characteristics, texture and microstructure of enriched precooked pasta. LWT-Food Sci Technol., **59 (2)**: 1175-1185.

Yaghtini, M., Feizy, J., Hoseini Taheri, S.E. and Jahani, M., 2021. Survey of physicochemical, nutritional and antioxidant properties of two cultivars of Iranian black and green lentil. *J Food Sci Technol.*, **17 (109)**: 55-64.

Zarzycki, P., Sykut-Domańska, E., Sobota, A., Teterycz, D., Krawęcka, A., Blicharz-Kania, A., ... and Zdybel, B., 2020. Flaxseed enriched pasta chemical composition and cooking quality. *Foods*. **9 (4)**: 404.

Zhao, Y. H., Manthey, F. A., Chang, S. K., Hou, H. J., Yuan, S. H., 2005. Quality characteristics of spaghetti as affected by green and yellow pea, lentil, and chickpea flours. *J. Food Sci*., **70 (6)**: 371-376.