SHORT COMMUNICATION

Some chemical and sensory properties of gluten-free noodle prepared with different legume, pseudocereal and cereal flour blends

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SUMMARY
In this research, some legume (chickpea and soya), pseudocereal (buckwheat and quinoa) and cereal (maize and rice) flour blends were used in gluten-free noodle formulations. All flour blends were gelatinized at a level of 25% in order to improve the dough forming ability. Noodle containing chickpea, soya, buckwheat and quinoa flours (flour blend 1) showed higher levels of protein (194.2 g·kg^{-1}), ash (27.8 g·kg^{-1}), lipids (81.2 g·kg^{-1}), calcium (1562.85 mg·kg^{-1}), copper (9.20 g·kg^{-1}), iron (56.29 mg·kg^{-1}), potassium (10295.21 mg·kg^{-1}), magnesium (1661.78 mg·kg^{-1}), manganese (24.07 g·kg^{-1}), phosphorus (5042.88 mg·kg^{-1}) and zinc (40.24 mg·kg^{-1}) contents than other gluten-free noodles and control noodle made with wheat flour. Phytic acid content increased up to 9.2 times in gluten-free noodle samples compared to control. Noodle containing buckwheat, quinoa, maize and rice flours (flour blend 3) was liked the most by the panellists in terms of overall acceptability score, though less than the control noodle.

Keywords
soya; chickpea; buckwheat; quinoa; noodle; minerals; phytic acid

Celiac disease is a chronic enteropathy caused by intake of gluten proteins [1]. Gluten-free noodle is a good choice for celiac patients with the advantages of having a long shelf-life and ease of transportation [2]. Maize, rice, millet, some pseudocereals such as buckwheat, amaranth, quinoa and legumes can be used in noodle formulation safely since they are gluten-free. Legumes are a good source of proteins, minerals, B vitamins and complex saccharides [3]. Although legume flours are lower in sulphur amino acids than cereal flour, the lysine content in legume flours is much higher than that in cereal flour. Buckwheat is an important raw material for functional food production with a balanced amino acid composition and high contents of several vitamins (B1, B2, B6 and E), minerals (P, Fe, Zn, K and Mg), polyunsaturated essential fatty acids, sterols, flavonoids (rutin, quercetin and quercitrin), and fagopyratol [4, 5]. Quinoa is a pseudocereal and is preferred in the formulation of gluten-free products due to its high content of nutritional components. The objective of this study was to develop gluten-free egg noodles with high nutritional value by using legume, pseudocereal and cereal flours.

MATERIALS AND METHODS

Materials

Wheat, maize and rice flours, whole egg and salt were purchased from a local market in Konya, Turkey. Xanthan gum was obtained from Vatan Gida (Istanbul, Turkey). Buckwheat groats were from Yar Gida (Antalya, Turkey), and quinoa, soya and chickpea grains were purchased from a local market in Istanbul, Turkey. Buckwheat, quinoa, soya and chickpea were ground in a hammer mill to whole flour.

Methods

In the preparation of control noodle, wheat flour (100.0 g), whole egg (20.0 g), salt (0.5 g) and water (40 ml) were used. In gluten-free noodle

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Tab. 1. Flour blends used for preparation of gluten-free noodles.

	Wheat flour [%]	Chickpea flour (CF) [%]	Soya flour (SF) [%]	Buckwheat flour (BF) [%]	Quinoa flour (QF) [%]	Maize flour (MF) [%]	Rice flour (RF) [%]
Control	100	–	–	–	–	–	
Flour blend 1	–	25	25	25	25	–	–
Flour blend 2	–	25	25	–	–	25	25
Flour blend 3	–	–	–	25	25	25	25
Flour blend 4	–	–	–	25	25	–	50
Flour blend 5	–	–	–	25	25	50	–

formulations, wheat flour was replaced with buckwheat flour (BF), quinoa flour (QF), chickpea flour (CF), soya flour (SF), maize flour (MF) and rice flour (RF) blends as given by Tab. 1. Xanthan gum (3%) was added in gluten-free noodle formulation. In order to improve the dough forming ability of flours, flour blends were gelatinized at a level of 25% using methods described by Yalçin [2]. Noodle making were performed according to Özkaya et al. [6].

AACC methods were followed for determinations of ash, protein and lipid content of noodle samples [7]. Mineral contents were determined by inductively-coupled plasma atomic-emission spectroscopy, ICP-AES (Varian Vista Model, Agilent Technologies, Melbourne, Australia) [8]. Phytic acid was measured by a colorimetric method according to Haugh and Lantzsch [9]. Phytic acid in the sample was extracted with a solution of HCl ($0.2\ mol{\cdot}l^{-1}$) and precipitated with solution of Fe III ammonium iron (III) sulphate.$12H_2O$. Colours of the samples were measured using Minolta CR-400 (Minolta Camera, Osaka, Japan). The numerical values of the colours were expressed by the lightness (L^*, light-dark), redness (a^*, ±red-green) and yellowness (b^*, ±yellow-blue). The hue angle, which describes the hue or colour of noodle sample, was calculated as arctan (b^*/a^*). Saturation index ($\sqrt{(a^{*2}+b^{*2})}$) describes the brightness or vividness of colour.

Water uptake was calculated by differences of dry (before cooking) and cooked (after draining) noodle weights.

For the volume increase determination, dry and cooked noodle were put into the water-full graduated cylinders. The volume increase was determined by the volume difference of water overflow.

Cooking loss as the weight of total solids expressed as a percentage, was measured by evaporating the noodle cooking water to dryness in an oven.

For sensory analysis, 100 g noodle were simmered in one liter unsalted water for 18 min and drained. Untrained panellists (n =10) evaluated sensory properties of raw and cooked noodles. The sensory parameters were surface smoothness, appearance and colour for raw noodle, and taste, chewiness, odour, colour and overall acceptability for cooked noodle. A 9-point hedonic scale was provided to the panellists as follows; like extremely (9), like very much (8), like moderately (7), like slightly (6), neither like nor dislike (5), dislike slightly (4), dislike moderately (3), dislike very much (2), dislike extremely (1).

The data were analysed by TARIST software (version 4.0, Ege University, Izmir, Turkey). Differences among the mean values were obtained by Duncan's multiple range test.

RESULTS AND DISCUSSION

Chemical composition of gluten-free noodles is given in Tab. 2. Gluten-free noodles made by using CF, SF, BF and QF (flour blend 1) had the highest protein, ash and lipid contents, and it was followed by noodles containing CF, SF, MF and RF (flour blend 2). The composition of finished product made by using flour blend 1 or 2 was directly affected by the rich chemical content of CF (18.2% protein, 2.4% ash and 5.5% fat) and SF (35.4% protein, 3.9% ash and 19.7% fat). Compared to control noodles made with wheat flour, increment ratios were found as 1.54 and 1.43 times for protein, 2.57 and 2.18 times for ash, 3.87 and 3.64 times for fat in gluten-free noodles containing flour blend 1 and 2, respectively. These increments are very important in terms of nutritional enrichment of gluten-free food products. Bilgiçli et al. [10] reported the protein and ash contents of 181.5–253.1 g·kg^{-1} and 21.5–27.4 g·kg^{-1}, respectively with 70% common bean/lentil flour usage in noodle formulation. In present study, utilization of flour blends of BF, QF, MF and RF (flour blend 3), BF, QF and RF (flour blend 4) and BF, QF and MF (flour blend 5) for noodle production gave lower protein contents compared to the control noodles. Phytic acid is considered an antinutrient due to its ability to bind minerals and proteins, either directly or indirectly, and thus change their solubility, functionality, absorption and digestibility [11]. The ranges of phytic acid content of the gluten-free noodles were found between 9640.25 mg.kg^{-1} and 7112.87 mg.kg^{-1}, while the control noodle had 1050.11 mg.kg^{-1} phytic acid content. Since BF, QF, CF, SF, MF and RF have a high phytic acid content (13120.12 mg.kg^{-1}, 15090.25 mg.kg^{-1}, 10020.13 mg.kg^{-1}, 17589.87 mg.kg^{-1}, 8970.12 mg.kg^{-1} and 8456.59 mg.kg^{-1}, respectively; data not shown), phytic acid content of the gluten-free noodles increased up to 9.2 times compared to the control noodle. The increase in phytic acid content in noodle with pseudocereal or legume flour was reported in the literature [12, 13].

Data on the mineral content of noodles are given in Tab. 3. All flour blends in gluten-free noodle formulations raised the mineral content of the finished product compared to the control except for Mn. The highest Ca, Cu, Fe, K, Mn, P and Zn contents in gluten-free noodles were obtained by using flour blend 1, followed by using flour blend 2. Legume flours (CF and SF) in gluten-free noodle formulation caused a significant increase in mineral content of finished product due to higher mineral contents compared to flours of cereals (MF and RF) and pseudocereals (BF and QF). Gluten-free noodles made by using flour blend 1 had higher Ca, Fe, K, Mg, P and Zn contents (3.93, 2.96, 4.57, 2.79, 2.46 and 2.87 times, respectively) than that of control noodles. The recommended dietary allowances (RDA) for adult males are 1.0 g of Ca, 10 mg of Fe, 1.6–2.0 g of K, 350 mg of Mg, 800 mg for P and 15 mg of Zn [14]. When an amount of 100 g (dry matter) of gluten-free noodles containing different flour blends was consumed, 4.0–15.6%, 20.5–56.3%, 19.2–57.2%, 25.5–47.5%, 38.9–63.0% and 16.0–26.8% of RDA for Ca, Fe, K, Mg, P and Zn, respectively, could be provided. For comparison, RDA percentage of 4.0% for Ca, 19.1% for Fe, 12.5% for K, 17.0% for Mg, 25.7% for P and 9.3% for Zn would be provided by control noodles made with wheat flour.

Gluten-free noodles showed lower lightness and higher yellowness values compared to control noodles (Tab. 4). While the flour blend containing BF reduced the lightness of the noodles to a higher extent, MF in the flour blend had a more enhancing effect on yellowness value of the noodles. Darker colour scores in spaghetti with the addition of BF were reported by Duarte et al. [15]. In Turkish noodles, yellow colour and bright appearance are preferred [6].

Gluten-free noodles containing legume flours had lower water uptake and volume increase values than the control and gluten-free noodles containing cereal or pseudocereal flour blends (flour blend 3, 4 or 5). Flour blend 5 gave the highest water uptake and volume increase values among the noodle samples.

As expected, cooking loss values of the gluten-free noodles were higher than those of the control. Noodles containing legume flours had the lowest cooking loss values among the gluten-free noodles.

Sensory properties of raw and cooked noodles are summarized in Tab. 5. Control noodles had the highest sensory scores except for the colour of cooked noodles. Among gluten-free noodles, noodles containing flour blend 3 was liked by the panellists in terms of overall acceptability. Colour of raw and cooked noodles was found best for gluten-free noodles made with flour blend 2.

Tab. 2. Chemical properties of gluten-free noodles.

	Protein [g·kg^{-1}]	Ash [g·kg^{-1}]	Lipids [g·kg^{-1}]	Phytic acid [mg·kg^{-1}]	Phytate phosphorus [mg·kg^{-1}]
Control	126.3 ± 1.8 c	10.8 ± 0.7 e	21.0 ± 1.4 c	1050.11 ± 24.0 e	296.14 ± 6.8 e
Flour blend 1	194.2 ± 1.7 a	27.8 ± 0.8 a	81.2 ± 1.1 a	9640.25 ± 84.9 a	2718.63 ± 13.3 a
Flour blend 2	181.0 ± 1.4 b	23.5 ± 0.7 b	76.5 ± 1.3 b	7112.87 ± 66.5 d	2005.89 ± 18.7 d
Flour blend 3	107.2 ± 1.7 de	16.8 ± 0.8 cd	34.1 ± 1.3 c	7354.21 ± 76.4 c	2073.95 ± 15.4 c
Flour blend 4	108.9 ± 1.3 de	15.5 ± 0.6 d	25.0 ± 1.4 c	7301.12 ± 69.3 c	2058.97 ± 19.5 c
Flour blend 5	104.8 ± 1.4 e	18.0 ± 0.8 c	45.5 ± 1.1 c	7552.75 ± 60.8 b	2129.94 ± 17.1 b

Means with the same letter within a column are not significantly different ($p < 0.05$). Values are based on dry matter.

Tab. 3. Mineral content of gluten-free noodle.

	Ca	Cu	Fe	K	Mg	Mn	P	Zn
	[mg·kg^{-1}]							
Control	398.12 ± 5.7^{d}	2.51 ± 0.7^{d}	19.03 ± 1.0^{e}	2255.09 ± 35.4^{f}	595.12 ± 14.1^{e}	7.10 ± 0.6^{c}	2054.09 ± 31.1^{f}	14.02 ± 1.4^{d}
Flour blend 1	1562.85 ± 18.4^{a}	9.20 ± 0.7^{a}	56.29 ± 1.0^{a}	10295.21 ± 49.5^{a}	1661.78 ± 28.3^{a}	24.07 ± 0.7^{a}	5042.88 ± 32.5^{a}	40.24 ± 1.7^{a}
Flour blend 2	1495.23 ± 14.1^{b}	6.51 ± 0.7^{b}	40.90 ± 1.3^{b}	8526.15 ± 33.9^{b}	945.02 ± 21.2^{cd}	17.35 ± 0.8^{b}	3755.15 ± 35.4^{b}	31.12 ± 1.4^{b}
Flour blend 3	398.19 ± 8.5^{bc}	4.98 ± 0.7^{bc}	23.66 ± 1.0^{d}	3754.00 ± 48.1^{d}	996.89 ± 24.0^{c}	8.17 ± 0.7^{c}	3215.45 ± 21.2^{d}	24.89 ± 1.7^{c}
Flour blend 4	411.54 ± 19.8^{bc}	5.29 ± 0.6^{bc}	20.53 ± 1.4^{e}	3452.21 ± 39.6^{e}	892.12 ± 25.5^{d}	8.22 ± 0.4^{c}	3114.97 ± 21.2^{e}	26.12 ± 1.8^{c}
Flour blend 5	400.09 ± 17.0^{c}	4.50 ± 0.8^{c}	27.60 ± 1.6^{c}	4025.89 ± 33.9^{c}	1108.02 ± 24.0^{b}	7.23 ± 0.4^{c}	3481.15 ± 29.7^{c}	23.95 ± 1.4^{c}

Means with the same letter within a column are not significantly different ($p < 0.05$). Values are based on dry matter.

Tab. 4. Colour values and cooking properties of gluten-free noodles.

	L^*	a^*	b^*	Saturation index	Hue	Water uptake [%]	Volume increase [%]	Cooking loss [%]
Control	88.20 ± 0.44^{a}	0.71 ± 0.25^{c}	13.55 ± 0.28^{f}	13.57 ± 0.35^{f}	87.00 ± 0.49^{b}	256.1 ± 2.83^{c}	268.0 ± 2.83^{c}	5.1 ± 0.14^{d}
Flour blend 1	81.44 ± 0.45^{c}	2.07 ± 0.28^{ab}	19.50 ± 0.37^{d}	19.61 ± 0.30^{d}	83.94 ± 0.41^{d}	194.8 ± 2.83^{e}	225.4 ± 2.83^{e}	8.9 ± 0.07^{c}
Flour blend 2	85.29 ± 0.41^{b}	0.2 ± 0.27^{c}	24.70 ± 0.25^{a}	24.70 ± 0.26^{a}	89.53 ± 0.59^{a}	212.2 ± 4.24^{d}	234.3 ± 4.24^{d}	9.2 ± 0.11^{b}
Flour blend 3	79.29 ± 0.41^{d}	2.23 ± 0.28^{ab}	20.70 ± 0.31^{c}	20.82 ± 0.28^{c}	83.85 ± 0.57^{d}	258.1 ± 2.83^{bc}	272.5 ± 4.24^{bc}	9.9 ± 0.07^{a}
Flour blend 4	79.71 ± 0.55^{d}	2.35 ± 0.31^{a}	16.17 ± 0.24^{e}	16.34 ± 0.25^{e}	81.73 ± 0.43^{e}	265.3 ± 4.24^{b}	277.8 ± 2.83^{b}	9.9 ± 0.14^{a}
Flour blend 5	81.59 ± 0.54^{c}	1.64 ± 0.25^{b}	21.80 ± 0.23^{b}	21.86 ± 0.29^{b}	85.69 ± 0.51^{c}	278.4 ± 4.24^{a}	295.4 ± 4.24^{a}	10.1 ± 0.07^{a}

Means with the same letter within a column are not significantly different ($p < 0.05$).

Tab. 5. Sensory properties of raw and cooked gluten-free noodles.

	Raw noodles			Cooked noodles				
	Surface smoothness	Appearance	Colour	Taste	Chewiness	Odour	Colour	Overall acceptability
Control	8.5 ± 0.14^{a}	8.0 ± 0.42^{a}	7.5 ± 0.28^{a}	7.5 ± 0.42^{a}	7.5 ± 0.28^{a}	7.6 ± 0.14^{a}	7.5 ± 0.14^{b}	7.7 ± 0.14^{a}
Flour blend 1	5.7 ± 0.14^{d}	5.7 ± 0.14^{cd}	5.7 ± 0.14^{c}	5.2 ± 0.28^{d}	5.7 ± 0.28^{b}	4.7 ± 0.28^{d}	5.2 ± 0.14^{d}	5.5 ± 0.14^{d}
Flour blend 2	6.5 ± 0.14^{c}	6.5 ± 0.14^{b}	8.0 ± 0.42^{a}	6.0 ± 0.42^{bc}	5.5 ± 0.14^{b}	5.5 ± 0.14^{c}	8.0 ± 0.14^{a}	6.1 ± 0.28^{c}
Flour blend 3	7.2 ± 0.28^{b}	6.1 ± 0.14^{bc}	6.5 ± 0.14^{b}	6.5 ± 0.28^{b}	7.0 ± 0.28^{a}	6.7 ± 0.14^{b}	6.5 ± 0.28^{c}	6.6 ± 0.14^{b}
Flour blend 4	5.2 ± 0.28^{e}	5.2 ± 0.28^{d}	6.5 ± 0.14^{b}	6.5 ± 0.14^{b}	5.5 ± 0.28^{b}	6.0 ± 0.28^{c}	6.5 ± 0.28^{c}	5.5 ± 0.14^{d}
Flour blend 5	5.5 ± 0.14^{de}	5.1 ± 0.28^{d}	6.7 ± 0.28^{b}	5.5 ± 0.14^{cd}	7.1 ± 0.14^{a}	5.5 ± 0.28^{c}	7.4 ± 0.14^{b}	6.0 ± 0.28^{c}

Means with the same letter within a column are not significantly different ($p < 0.05$).

CONCLUSION

Flour blends 1 and 2 containing legume flours (CF and SF) raised protein, ash, lipid and mineral as well as phytic acid contents of the gluten-free noodles. On the other hand, legume flours reduced water uptake and volume increase values of the samples. Gluten-free noodle containing flour blend 3 (containing BF, QF, MF and RF) was the most liked by the panellists in terms of overall acceptability, though less than the control noodle.

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