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Investigation of certain nutritional properties of noodle enriched with raw flaxseed

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RESEARCH ARTICLE

Abstract

In this study, traditional homemade noodles were enriched with raw flaxseed and some nutritional properties such as resistant starch (RS), total starch, total dietary fibre (TDF), estimated glycaemic index (eGI) and major mineral composition of final products were investigated. Flaxseed was supplemented into the noodle mixture at three different concentrations (10, 15 and 20 g/100 g). RS content of the samples was in the range of 0.61-2.14 g/100 g and the highest RS was found for the sample having 10% flaxseed. Maximum TDF value was determined to be 8.28% for the noodle sample enriched with 20% of flaxseed while that of control was 1.68%. Estimated eGI of the samples was not significantly affected by the flaxseed fortification while mineral composition of noodle samples was significantly affected by the flaxseed addition ($P<0.05$). The major mineral compounds present in the samples were sodium, potassium, magnesium and phosphorus. It could be concluded that the noodle enriched with 10% of flaxseed would be a healthier alternative product for consumption.

Keywords: noodle, raw flaxseed, resistant starch, glycaemic index, minerals

1. Introduction

Noodles are traditional cereal products commonly consumed in Turkey and many Asian countries (Yüksel *et al.,* 2018). The main ingredients of these traditional products are flour, salt and water. Noodles provide considerable amount of calories when consumed due to their high level of carbohydrate and protein content (Eyidemir and Hayta, 2009). Different fibre, flour (oat, barley, corn, soy flour, etc.), hydrocolloid and gum sources can be used in the noodle formulation in order to enrich them nutritionally and to provide better digestion for the human body (Choo and Aziz, 2010; Fu, 2008; Li *et al.*, 2012).

In recent years, food industry aims to enrich foods with new ingredients such as dietary fibre, protein, omega 3 fatty acids and other bioactive compounds including phenolics and antioxidants due to their positive health effects (Kayacier *et al.,* 2014). The new products called as functional foods providing positive effects on human body are commonly consumed to prevent some diseases such as cardiovascular problems, obesity, diverticulosis, diabetes and suboptimal health problems (Anderson *et al.*, 1994; Gorinstein *et al.*, 2001; Villanueva-Suarez *et al.*, 2003). Glycaemic index of foods is a very important issue for diabetic patients, and the food industry makes an effort to formulate the foods having low glycaemic index values and rich in functional components such as resistant starch (RS), dietary fibres and omega fatty acids (Brasil *et al.,* 2011; Cavallero *et al.*, 2002; Marco *et al.*, 2013). Flaxseed can be a potential source for the production of foods with low glycaemic index and high dietary fibre, protein and omega 3 contents due to its high level of functionality.

Flaxseed belongs to flax family and is known as *Linum usitatissimum*. Flaxseed contains high amount of fibre (30%), protein (22.5%), oil (40-45%, especially unsaturated), carbohydrate (28%) and bioactive compounds which make flaxseed as a good source of bioactive substances (Cameron and Hosseinian, 2013; Ibrügger *et al.*, 2012; Marpalle *et al.*, 2014; Yuksel *et al.*, 2014). In this regard, flaxseed can be used in the food industry for the production of enriched foods having functional properties (Austria *et al.*, 2016; Edel *et al.*, 2015; Marpalle *et al.*, 2014; Yüksel *et al.,* 2018). There are a lot of studies in the literature concerning the enrichment of foods with the flaxseed (Aliani *et al.,* 2011;

Kayacier *et al.,* 2014; Khouryieh and Aramouni, 2012; Yüksel *et al.,* 2018), but there is no published study regarding to the nutritional properties of noodle enriched with flaxseed.

The main aim of the present study was to produce a new noodle formulation with the addition of raw flaxseed to improve nutritional quality of final product. The nutritional characteristics of noodle samples enriched with flaxseed including RS, non-resistant starch (NRS), total starch (TS) and total dietary fibre (TDF) contents were determined in addition to hydrolysis index (HI), estimated glycaemic index (eGI) and mineral analysis.

2. Material and methods

Materials

Wheat flour (12.9 g/100 g moisture, 11.1 g/100 g protein, 2.86 g/100 g crude fat, 2.5 g/100 g dietary fibre, 70 g/100 g carbohydrate in dry matter) was obtained from Sinangil Flour Co. (Gumushane, Turkey). Raw flaxseed (6.1 g/100 g moisture, 36.6 g/100 g crude fat, 2.5 g/100 g sugar, 2.8 g/100 g carbohydrate, 32.5 g/100 g TDF, 17.2 g/100 g protein in dry matter) and salt (Kristal, Izmir, Turkey) were purchased from a local market in Gumushane (Turkey).

Methods

Preparation of traditional homemade noodle enriched with flaxseed

The production of noodle was conducted according to the procedure described by Yüksel *et al.* (2018) and the process flow chart is illustrated in Figure 1. Wheat flour and raw flaxseed at different concentrations (100:0, 90:10, 85:15 and 80:20 wheat flour:raw flaxseed) were mixed according to the levels in Table 1. Salt (1.5 g/100 g) and water (50±2 ml) were added to the mixture to form a dough using dough mixer (Kitchen Aid Professional 600, Benton Harbor, MI, USA). Afterwards, the thickness of dough was adjusted to 1.5 mm using a dough roller. Then, the dough covered with stretch film was held for 30 min at room conditions (25±5 °C and 35% relative humidity) for uniform hydration. Then, the shape of sample (20 cm) was given using a household type noodle machine (Ampia 150, Marcato, Campodarsego, Italy) and dried at room temperature. Finally, the traditional homemade noodles enriched with the flaxseed were kept at room conditions (25±5 °C and 30 days) and subjected to further analysis.

Determination of resistant starch, non-resistant starch and total starch

Determination TS, RS and NRS contents of the noodle samples were determined according to the method described by Goni *et al.* (1997) with some minor modifications. A 100±5 mg of sample was weighed into a 50 ml screw capped test tube and then 4 ml of pancreatic α-amylase solution (50 ml of sodium maleate buffer + 0.5 g of pancreatic α-amylase (3 Ceralpha units/mg) + 0.5 of diluted amyloglucosidase; AMG) was added and the tubes were placed in a shaking water bath (100 rpm) and kept at 37 °C for 16 h. Afterwards, 4 ml of ethanol was added to the samples and then the supernatants were collected. After that, 8 ml of ethanol was added and mixed again and then the tubes were centrifuged (1,600×*g*, 10 min). The last stage was once again repeated and the supernatants were collected into the same volumetric flask. They were combined with sodium acetate buffer (pH: 4.5) up to 100 ml and 100 µl sample was taken from each volumetric flasks and then 10 µl of dilute AMG was added to them. The samples were incubated at 50 °C for 20 min. and 3 ml of GOPOD (glucose determination reagent) was added to test tubes and they were again incubated. The glucose

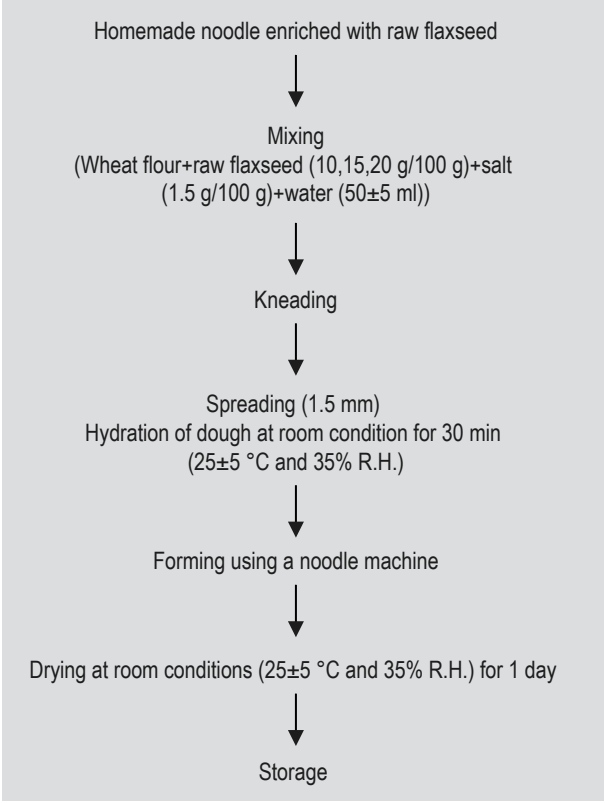

Figure 1. Process flow chart for the production of noodle.

Table 1. Experimental study design.

Sample	Wheat flour (g/100 g)	Raw flaxseed (g/100 g)
1	100	0
2	90	10
3	85	15
4	80	20

level was determined using the GOPOD and NRS values and was calculated using the Equation 1 described in the megazyme assay kit handbook (Megazyme Int. Ireland Ltd., Wicklow, Ireland):

$$NRS\ (g/100\ g) = \Delta E \times F \times \frac{100}{0.1} \times \frac{1}{1000} \times \frac{100}{W} \times \frac{162}{180} \quad (1)$$

where ΔE is absorbance read against to reagent blank, F is conversion factor of D-glucose and the W is sample weight. 100/0.1 is volume correction, 1/1000 is conversion from micrograms to milligrams and 162/180 is the factor to convert from free D-glucose to an hydro-D-glucose as occurs in starch.

The RS was determined by using the solid phase in the test tubes. For this purpose, 2 ml of KOH was added and the test tubes were mixed at iced medium. 8 ml of sodium acetate buffer (pH: 3.8) was added to the test tubes and then 100 µl of concentrated AMG was added. Afterwards, the test tubes were placed into hot water bath (50 °C, 30 min) and centrifuged (1,600×*g*, 10 min). The glucose was determined using the glucose oxidase assay kit (GOPOD) using a Shimadzu (Shimadzu, Kyoto, Japan) spectrophotometer (510 nm). The RS was calculated using the Equation 2 described by the Megazyme assay kit handbook (Megazyme Int. Ireland Ltd.):

$$RS\ (g/100\ g) = \Delta E \times F \times \frac{10.3}{0.1} \times \frac{1}{1000} \times \frac{100}{W} \times \frac{162}{180} \quad (2)$$

Where ΔE is absorbance read against the reagent blank, F is conversion factor of D-glucose and W is the sample weight. After the calculation of RS and NRS, TS was calculated by using Equation 3

$$TS\ (g/100\ g) = RS + NRS \quad (3)$$

Determination of total dietary fibre

TDF of the samples was determined using the method described in AOAC (1995). The digestible starch and protein were removed from the samples by using the sequential enzymatic digestion procedure (heat-stable enzymes). Before filtration, the enzyme digestate was treated with alcohol. Afterwards, the TDF residue was washed with alcohol and acetone and then dried, weighed and expressed as (g TDF/100 g dry sample). TDF capacity was calculated as follows (Equation 4):

$$TDF\ (\%) = \frac{\frac{R_1 + R_2}{2} - p - A - B}{\frac{m_1 + m_2}{2}} \times 100 \quad (4)$$

where R_1 is residue weight 1 from m_1, R_2 is residue weight 2 from m_2, p is protein weight from R_2. A is ash weight from R_1, B is blank and m_1 and m_2 are the sample weight 1 and 2, respectively.

Determination of total starch hydrolysis and estimated glycaemic index

The *in vitro* hydrolysis rate was determined using pancreatic α-amylase approach according to the method described by Goni *et al.* (1997). A 75 mg of noodle sample was weighed into a 50 ml screw capped test tube and 10 glass beads were placed. Then HCI buffer (2 ml, 0.05 M) and then 10 mg pepsin (P6887, Sigma, Aldrich, St. Louis, MO, USA) were added into the tubes and the samples were incubated in a shaking water bath at 37 °C for 30 min. At the end, sodium acetate buffer (4 ml, 0.5 M, pH 5.2) was incorporated into the each test tube. A 1 ml freshly prepared enzyme solution (0.9 g porcine pancreatin + 4 ml distilled water (centrifuged at 1,500×*g*, 10 min)=5.4 ml supernatant + 0.6 ml AMG + 0.4 ml distilled water=6.4 ml) was added to each tube after 1 min intervals and then the mixtures were incubated at 37 °C in a shaking water bath for 180 min. A 100 µl aliquot was taken from each glass tube into the Eppendorf including 1 ml ethanol during the incubation period (0, 10, 20, 30, 60, 90, 120 and 180 min intervals). Afterwards, these solutions were centrifuged at 800×*g* for 10 min. The supernatant content which contains hydrolysed glucose was measured by using GOPOD (glucose oxsidase/peroxsidase assay kit, Megazyme). Total starch hydrolysis (TSH) was calculated using Equation 5:

$$TSH\ (\%) = \frac{\text{released glucose weight} \times \frac{160}{182}}{\text{total starch weight in noodle sample}} \times 100 \quad (5)$$

A nonlinear model established by Goni *et al.* (1997) was used for the kinetic analysis of *in vitro* starch digestion. The first order equation is $C=C_\infty(1-e^{-kt})$, where C is the percentage of starch hydrolysed at the time t (min), C_∞ is the equilibrium percentage of starch hydrolysed after 180 min, and k is the kinetic constant. C_∞ and k were estimated for each treatment based on the data obtained from the *in vitro* starch digestion. HI was calculated by dividing the area under the hydrolysis curve of the noodle samples by the area obtained for the noodle sample (first sample). The eGI was calculated using the equation described by Goni *et al.* (1997) as follows (Equation 6):

$$eGI = 39.71 + 0.549(HI) \quad (6)$$

Mineral analysis

Mineral contents of noodles enriched with the flaxseed were determined using an inductively coupled plasma (ICP) spectrophotometer (Agilent 7500a series ICP/MS; Agilent Technologies Inc., Santa Clara, CA, USA). A microwave oven (Berghof speedwave; Berghof GmbH, Eningen, Germany) was used for decomposition of the samples. The noodle sample (about 500 mg) was weighed into the digestion vessels and 6 ml of HNO_3 (65%) and 2 ml

of H_2O_2 (30%) were added into the vessels. Afterwards, the mixture was carefully shaken and then the vessels were kept for 20 min with the lids closed. The noodle samples were held at 145 °C for 5 min using the ICP spectrophotometer. The pressure was to be 4.000 kPa and the microwave power was 80%. The temperature was increased at 2 °C/min to 170 °C and the samples were kept at this temperature for 10 min. Then, the samples were kept at 220 °C for 15 min. Then, the solution was transferred to a volumetric flask. The samples were diluted with distilled water and then filtered through a filter paper (Whatman no. 42, Whatman Ltd, Maidstone, UK). All diluted digested samples were analysed by using ICP-MS. For quality control, internal standards (9Be, 45Sc, 103Rh and 208Bi) and reference materials were run together with the samples.

Statistical analysis

The differences between the analysed results were expressed by the general linear model procedure with SAS statistical software (version 8.2 software package SAS 2002, SAS Institute Inc., Cary, NC, USA). Means were compared by ANOVA analysis and statistical significance was denoted at the 0.05 *P*-value.

3. Result and discussion

The nutrition analysis results of uncooked noodles enriched with raw flaxseed were tabulated in Table 2. The highest RS content (2.14 g/100 g) was determined in the samples containing 10 g/100 g flaxseed and the lowest RS value (0.61 g/100 g) was in the sample prepared with the addition of 20 g/100 g flaxseed ($P<0.05$, Table 2). The NRS level of samples decreased significantly with the increase in flaxseed concentration ($P<0.05$). The NRS values ranged from 64.23 to 74.47 g/100 g for the noodle samples containing 0 to 20 g/100 g flaxseed. (Table 2). The TS content of samples decreased significantly with increasing the flaxseed concentration ($P<0.05$). The maximum TS content (75.21 g/100 g) was determined in the control samples and the minimum value (64.84 g/100 g) was in the sample added with 20 g/100 g flaxseed (Table 2). It could be seen that the TS and NRS of noodle samples decreased with the increase of the flaxseed concentration.

As can be seen from the nutrition values, the RS content of the samples was affected significantly ($P<0.05$)by the flaxseed addition due to the decrease in TS content of the samples by increasing the flaxseed level. But the RS content increased with the addition of 10 g/100 g and 15 g/100 g flaxseed compared to control sample while it decreased for the sample having 20 g/100 g flaxseed. It could be speculated that the RS content of samples decreased since the protein (from 11 to 14 g/100 g), lipid (from 3 to 12 g/100 g) and moisture (from 11 g/100 g to 9 g/100 g) content of noodle samples changed. Also, the RS content decreased in the sample prepared with 20 g/100 g flaxseed since the TS content of samples decreased. The RS content of control sample was reported as 0.41 g/100 g by Srikaeo and Sangkhiaw (2014). Our results were similar to those of Srikaeo and Sangkhiaw (2014). The RS content of starches could be lower due to starch-protein and starch (amylose)-lipid interactions (Sajilata *et al.*, 2006). Seczyk *et al.* (2017) reported the RS and TS values of bread prepared with flaxseed hulls at different concentrations (0, 1, 2, 3, 4, 5 and 6%). The RS levels were determined to be 25.4, 27.7, 26.9, 26.2, 27.2 and 25.8% for the samples having 0, 1, 2, 3, 4, 5 and 6% flaxseed hulls, respectively. The contents of TS were determined to be ranged from 630.5 to 613.4 mg/g. It was observed that these results were similar to our results. However, the study of Rendón-Villalobos *et al.* (2009) shows that the addition of flaxseed flour (10-20%) into tortilla increased the RS content of the final products.

TDF contents of the noodles increased with the increase of raw flaxseed significantly ($P<0.05$, Table 2). This increase was expected because flaxseed contain considerably high amounts of dietary fibre. The TDF contents of sample were determined as in the range of 1.68-8.28 g TDF/100 g. Similar results were observed by Yuksel *et al.* (2014) as being 28 g/100 g and Seczyk *et al.* (2017) as being 30 g/100 g. The increment of TDF in the samples could be associated to the TDF content of flaxseed. Moraes *et al.* (2010) have reported a significant increase in the TDF for the cakes enriched

Table 2. Some nutritional properties of noodles.[1]

Sample no	Resistant starch g/100 g	Non-resistant starch g/100 g	Total starch g/100 g	Total dietary fibre g/100 g
1	0.76±0.01^{c}	74.47±1.21^{a}	75.23±1.20^{a}	1.68±0.27^{c}
2	2.14±0.02^{a}	71.14±0.85^{a}	73.28±0.83^{a}	5.13±1.08^{b}
3	1.60±0.03^{b}	64.70±1.68^{b}	66.30±1.65^{b}	7.04±1.36^{ab}
4	0.61±0.01^{d}	64.23±2.18^{b}	64.84±2.18^{b}	8.28±0.51^{a}
R^2	0.99	0.93	0.93	0.94

[1] a-d: The superscript small letters in same column indicate significant difference among the samples ($P<0.05$).

with whole flaxseed flour. Similar results were observed by Hussain *et al.* (2012) who reported the properties of flat bread prepared by using different concentrations of flaxseed. The TDF values of flat breads enriched with different flaxseed levels increased significantly ($P<0.05$). Marpalle *et al.* (2015) who reported some characteristics of bread enriched with roasted ground flaxseed found that the TDF values of sample increased with the increase of flaxseed from 1.33 g/100 g (control sample) to 5.56 g/100 g (including 15 g/100 g flaxseed). Dietary guidelines recommend a daily diet providing 25-30 g of dietary fibre per day (USDA, 2015). The developed noodles (enriched with flaxseed) may contribute to increased dietary fibre intake.

Table 3 shows the HI and eGI values of uncooked homemade noodles. The HI levels of the samples ranged between 99.85 and 103.44 with no significant statistical difference ($P>0.05$). The eGI levels of samples were similar to the HI levels. The TS hydrolysis slowly increased from beginning until 210 min and so it could be speculated that the noodles were slowly digested due to the starch degree of crystallinity (Figure 2). Choo and Aziz (2010) reported the characteristics of noodle enriched with beta glucan and banana flour and they found that the TS hydrolysis rate of samples (30% banana flour and 30% banana flour + beta glucan) was lower than that of the control sample due to the starch degree of crystallinity. As can be understood from the RS and eGI values, the lowest value in eGI (control) does not follow the highest RS (10 g/100 g) and eGI values were not statistically different ($P>0.05$). Similar results were observed by Seczyk *et al.* (2017) who reported the properties of wheat bread prepared by using different concentrations of flaxseed hull. The eGI values of wheat breads enriched with different flaxseed hull levels did not significantly changed ($P>0.05$). However, the study of Rendón-Villalobos *et al.* (2009) shows that the addition of flaxseed flour (10-20%) to tortilla significantly decreased the eGI ($P<0.05$).

Table 3. Hydrolysis and estimated glycaemic index values of noodles.

Sample no	Hydrolysis index	Estimated glycaemic index
1	99.85±0.2^{a}	94.53±0.1^{a}
2	101.90±8.2^{a}	95.65±4.5^{a}
3	103.44±4.5^{a}	96.50±2.5^{a}
4	101.38±1.4^{a}	95.37±0.8^{a}

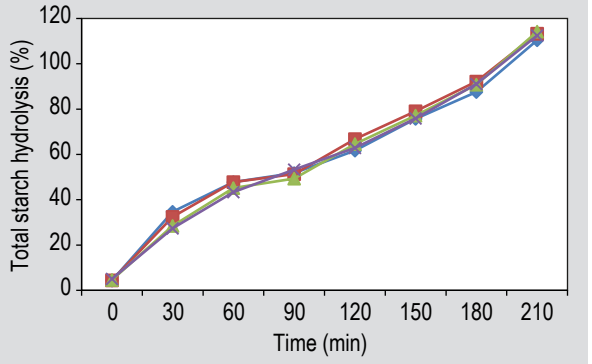

Figure 2. Total starch hydrolysis of noodle samples (◆: 1st sample; ■: 2nd sample; ▲: 3rd sample; ×: 4th sample).

The results of mineral matters of traditional homemade noodles enriched with raw flaxseed are presented in Table 4. As can be seen from the table, the major minerals were measured to be Na, K, P and Mg since salt was one of the ingredients used in the formulation of noodle; Among

Table 4. Some mineral matter levels of noodles (mg/kg).[1]

Minerals	Sample no.				R^2
	1	2	3	4	
Ca	469.5±0.5^{d}	971.5±16.3^{c}	1,193.0±6.1^{b}	1,480.5±3.1^{a}	0.99
Mg	567.5±10.1^{d}	1,180.5±0.5^{c}	1,522.0±17.8^{b}	1,838.5±2.1^{a}	0.99
Na	10,616.0±152.2^{b}	12,146.0±171.4^{a}	12,595.0±670.9^{a}	11,871.5±29.6^{a}	0.89
K	3,882.0±149.4^{d}	5,064.5±15.2^{c}	5,602.0±23.1^{b}	6,733.5±19.0^{a}	0.99
P	1,495.0±3.5^{d}	2,122.0±1.4^{c}	2,404.0±2.8^{b}	2,884.0±2.8^{a}	0.99
Fe	49.7±3.1^{c}	72.2±3.7^{a}	60.6±1.1^{b}	56.0±1.0^{bc}	0.95
Zn	15.2±0.7^{d}	26.0±2.0^{c}	29.3±0.2^{b}	34.8±0.5^{a}	0.98
Cu	3.8±0.1^{d}	6.5±0.1^{c}	7.2±0.2^{b}	8.2±0.1^{a}	0.99
Al	18.7±2.1b	30.4±1.0^{a}	29.9±2.0^{a}	39.3±6.9^{a}	0.88
Mn	18.0±0.3^{d}	26.5±0.2^{c}	31.5±0.1^{b}	33.8±0.7^{a}	0.99
Total	17,219.0	21,645.0	23,480.0	24,969.0	

[1] a-d: The superscript small letters in same row indicate significant difference among the samples ($P<0.05$).

the minerals, Na was determined to be the major mineral. Similar results were observed by Yuksel and Karaman (2015) who reported some properties of powder of pasta boiling water. The other mineral matters in the samples were Ca, Fe, Zn, Cu, Al and Mn. The mineral content of raw flaxseed was determined to be K, Na, Ca, Fe and Mg (Kajla *et al.*, 2017). The total mineral matters content of noodle samples were determined to be as 17,219, 21,645, 23,480 and 24,969 mg/kg for the samples containing the flaxseed at the concentration of 0, 10, 15 and 20%, respectively, and also the total mineral matter of the flaxseed was 61,557 mg/kg. Consequently, the total mineral matters of noodle sample increased with the enrichment of samples by the flaxseed in the formulation. Kumar *et al.* (2017) studied the mineral values of yogurt prepared with flaxseed concentrations and they reported that the mineral level of control yogurt and mixed yogurt with 2% flaxseed were 0.85 and 0.92%, respectively.

4. Conclusions

The results showed that the traditional homemade noodles could be enriched with the addition of raw flaxseed. The increment in the flaxseed level of the noodle samples increased the TDF and total mineral matter content levels of final products significantly ($P<0.05$). The developed noodle may contribute to the increased intake of certain minerals (Na, K, P, Mg). The RS values were significantly affected by the flaxseed addition in the formulation. The NRS and TS values of sample decreased with the flaxseed enrichment. As a result, traditional homemade noodles enriched with the flaxseed (up to 10 g/100 g) can be considered as a good alternative for food industry.

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