academicresearchJournals

Vol. 6(7), pp. 433-443, September 2018
DOI: 10.14662/ARJASR2018.072

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

The Effect of Blending Ratio of Durum Wheat, Tef *[EragrostisTef (Zucc)Trotter]* and Chickpea on Nutritional Composition and Sensory Attributes of Macaroni

Tamirat Kore[1,2], Workineh Abebe[1] and Paulos Getachew[2]

[1]Debrezeit Agricultural Research Center, EIAR, P.O. Box 2003, Addis Ababa, Ethiopia.
[2]Center for Food Science and Nutrition, Addis Ababa University, Addis Ababa, Ethiopia
Correspondence should be addressed to: E-mail: tamiratkore9@gmail.com, +251920311237
E-mail: workineh09@gmail.com, +251983680300 E-mail: p_getachew@yahoo.com, +251989821171

Accepted 21 September 2018

Pasta products are commonly made with only durum wheat semolina, which has lower quality in nutrients such as protein, fiber and minerals as compared with other cereals and legumes. Besides, wheat is highly composed of gluten, which induces intolerance in significant part of the human population. Despite these facts, there are limited studies on formulating pasta products from composite flour with other cereals (tef) and legumes (chickpea) of higher nutritional quality. In this study, macaroni was formulated using composite flours of durum wheat semolina (60-100)%, tef (0-40)% and chickpea (0-15)% using Response Surface Methodology (RSM). Results indicated that an increasing proportion of tef and chickpea flour significantly improved the protein, fiber, fat, iron and zinc contents of the macaroni. Blending of chickpea flour only up to 15% with semolina produced macaroni with comparable sensory quality with semolina macaroni. Protein, fiber, iron, firmness and overall acceptability were deeming as common parameters for macaroni formula. The blend formulation with 74.19% semolina, 10.89% tef and 14.89% chickpea produced macaroni with improved nutrient content and sensory attributes. In general tef and chickpea flour blends with semolina showed good nutritional composition of macaroni.

Keywords: Macaroni, tef, chickpea, semolina, Response Surface Methodology, D-optimal.

Cite this article as: Tamirat, K., Workineh, A., Paulos, G. (2018). The Effect of Blending Ratio of Durum Wheat, Tef [*Eragrostis tef* (Zucc)Trotter] and Chickpea on Nutritional Composition and Sensory Attributes of Macaroni. Acad. Res. J. Agri. Sci. Res. 6(7): xxx-xx

INTRODUCTION

Pasta is the most widely consumed food item across the world due to its versatility, long shelf life and relatively low cost (Paola et al., 2015) and also it is a broad term which includes spaghetti, macaroni, vermeci, lasagna and so on. Among which, macaroni is an important starchy staple food product which is made from durum wheat semolina and water. Pasta products are poor in protein content (low lysine content); poor in dietary fiber and micronutrient contents due to the removal of the bran and germ of the wheat (rich in dietary fiber, vitamins and minerals) during durum wheat milling into semolina (Sissons, 2005, Petitot et al., 2010a). World Health Organization and US Food and Drug Administration recognize pasta products as a good vehicle for the incorporation of nutrients such as minerals, dietary fiber, proteins and vitamins (Marconi and Carcea , 2001;

Borneo and Aguirre, 2008; Chillo et al., 2009; De Pilli et al., 2013). In Sub-Saharan African diet, the main energy sources are cereals which are adequate in methionine and cysteine and B vitamins but limited in lysine. In contrast, most legumes are rich in lysine but low in sulfur containing amino acids. Hence, the blends of cereals and pulses can complement their limited nutrients (Mensa-Wilmot et al., 2004).The stable foods in Ethiopian are mostly carbohydrate based cereal products and for the majority of the population it is difficult to afford high protein foods. Hence, fortifying the durum wheat semolina with other nutritious cereal and legumes is important to improve the nutritional quality of macaroni products specifically the dietary fiber, protein and mineral contents can be improved. With this regard, tef and chickpea are an ideal candidate to replace durum wheat semolina partially for the mentioned purposes. Tef(*Eragrostis tef* (Zucc.)) Trotter is an indigenous and underutilized cereal stable crop; gluten free nature and attractive nutritional profile which used in the form of whole meal flour. Compared with other cereals such as wheat, barley and sorghum, tef has higher iron, calcium and zinc contents; higher content of insoluble polysaccharides and low allergenicity (Abebe et al., 2007; Hrušková et al., 2012).Tef is the principal ingredient of most Ethiopian population diet injera. Due to traditional and small scale tef processing techniques, the production of tef based products with industrial level are limited (Laike et al., 2010)and limited knowledge on nutritional profile parallels with the processing challenge (Baye, 2014). The other non-traditional potential substitute of durum wheat partially to enrich macaroni nutritionally is chickpea. Chickpea is the most widely consumed pulse type in the world and a rich source of high quality protein, vitamins (thiamine and niacin), minerals (calcium, phosphorous, iron, magnesium, and potassium), essential fatty acid (linoleic) and high dietary fiber(Zia-ul-haq et al., 2007; Fuad and Prabhasankar , 2010).

Therefore, the main objective of this study was to develop macaroni with improved protein, dietary fiber and mineral contents from tef-chickpea-durum wheat blends with modeling and optimization of the mixture using RSM. Accordingly, the physico-chemical and sensory characters-tics of the formulated macaroni was evaluated.

MATERIALSAND METHODS

Experimental materials

The grain samples: durum wheat (Utuba), tef (Magna) and chickpea (Habru) used for the experiment were collected from Debre Zeit Agricultural Research Center (DZARC) grown in the 2016/17 main crop production season. This 'Utuba' type durum wheat variety was selected for the formulation because of its higher yield per unit area, better quality for pasta making and well accepted by the local pasta processing industries (Legese, 2017).Because of its very white color and its acceptability by tef producing farmers and consumers, DZ-01-96 ('Magna') tef variety was selected for the formulation purpose (Assefa et al., 2013). Similarly, because of its seed coat color (white) and preference by farmers, Habru chickpea variety was selected (Kinfe et al., 2015).

Experimental process and macaroni formulation

The experimental process was conducted under laboratory condition. Under this study, mixture design was used to determine the ratio of blends cereals (durum wheat and tef) with pulse (chickpea). To determine the optimum formulation mix proportions of 60–100%, 0–40% and 0– 15% were considered for durum wheat semolina, tef flour and chickpea flour respectively were considered. Sixteen runs with 5 replications were obtained from the RSM mixture design with D-optimal mixture design. The upper and lower limits of the grains were selected based on preliminary trial and earlier reports. Durum wheat macaroni (100% semolina) was used as control which compares the other blend macaroni.

Sample preparation

The durum wheat, tef and chickpea grains were manually cleaned and removed the impurities and stored in food science laboratory for further analysis. During durum wheat milling process was done after tempering. In order to determine the amount of water, the initial moisture content in wheat grain sample was measured before tempering. Then the required amount of water to adjust 17.5% moisture level was added and mixed well for 15 min by using mixers (Chopin Technology, Type: MR 10L, France). Then the sample was conditioned in plastic containers and stored for 30 hr to facilitate tempering. After tempering, the wheat grain was milled into semolina using a Chopin laboratory mill (Moulin CD2 mill, Chopin technology, France).

Tef grain was ground into whole flour with a laboratory mill (Perten mill 120, Finland) fitted with a 750 µm opening screen size. Chickpea was milled by disc attrition mill after the seed coat/husk was removed. The flour was kept in moisture tight polyethylene plastic bags at refrigerator (5°C) for duration of analysis and macaroni processing.

Semolina, tef and chickpea flours were mixed by rotating drum mixer (Chopin MR 10L, France) for each blending proportion according to the result from the D-optimal mixture design.

Dough processing and macaroni extrusion

Macaroni containing semolina, tef and chickpea prepared using standard pasta recipes. The process included dough processing, extrusion, cutting and drying. Prior to extrusion 1 Kg of the blend flour (semolina, tef and chickpea flour) was mixed with 350 ml distilled water and then the dough was kneaded by manual mixer. The extrusion process was performed on laboratory scale single screw extruder (Lanuova Lampa, Model Minilab 305, Italy) fitted with an adjustable macaroni die. The dough was extruded using a single screw extruder fitted with macaroni die. The extruded macaroni was cut into pieces of uniform length and dried in oven at 60°C for about 4 hour to attain moisture content to about 11% (Mercier et al., 2016).

Proximate composition and mineral content of macaroni

Flour and macaroni proximate composition (moisture, crude ash, crude protein, crude fat, crude fiber, carbohydrate) and minerals (phosphorus, iron and zinc) content were analyzed with standard methods (AOAC, 2010). Macaroni was ground with laboratory mill (Perten mill 120, Finland) to pass through a sieve 750 µm. Then the milled macaroni products were kept in air tight polyethylene plastic bags at room temperature until further analysis.

Sensory Evaluation

The sensory evaluation was done to compare the acceptability of blend macaroni with the control macaroni. The sensory analysis was carried out by twenty semi-trained judges of Food Science and Nutrition Department staff members and post graduate students from Hawassa University. All the samples were cooked in boiling water (97-100°C).Then the samples were drained and immediately immersed in cool water. Then, they were dried in circulating air for 10 min before distributing into the containers and closing the lids. The sensory attributes of the cooked macaroni were evaluated using a nine point hedonic scale, where "1" extremely dislike, "5" neither like nor dislike and "9" extremely like. The panelists were asked to score for sensory attributes like color, flavor, firmness and overall acceptability.

Statistical analysis

The experiment was conducted in randomized complete block design (RCD) with three replications in nutritional composition and sensory analysis. All measurements were done in triplicate and the results were recorded as mean standard error. The results were analyzed by one-way analysis of variance (ANOVA) using SPSS version 20.0 (SPSS Inc. Chicago, IL, USA). Multiple comparisons between the product analysis on proximate composition, mineral content and sensory score were done. A polynomial equation from D-optimal mixture design was fitted to the data to obtain a regression equation. ANOVA was used to check the presence of significant difference at 95% confidence level between mean levels. The contour plots were drawn to develop the optimum blending ratio for the mixture of durum wheat semolina, tef flour and chickpea flour used.

RESULTS AND DISCUSSION

Characterization of raw materials is the primary concern in predicting macaroni quality. Accordingly, proximate and mineral composition of semolina extracted from the durum wheat and whole tef and chickpea flours are presented in Table 1. The nutritional composition of utilized raw materials and there is a significant difference ($p<0.05$) in protein, ash, fat, total carbohydrate and mineral contents between semolina, tef and chickpea flour. Protein contributes significantly to texture and flavor of food products; thus it gets priority in flour quality for pasta product formulation (Hager et al., 2012). Among raw materials, chickpea flour had highest amount of protein followed by tef flour and lower amount in semolina flour. This implies chickpea as means to improve protein content to enrich conventional macaroni.

Similarly, carbohydrate composition of ingredients plays an important role in determining pasta quality. Semolina has the highest carbohydrate content followed by tef and chickpea flour respectively. This could be due to semolina extraction that removed the germ in the durum wheat and lowered the fiber content by removing the bran. This helps such lower carbohydrate in the flours selected for blending (tef and chickpea) with durum wheat semolina underlines their potential for decreasing glycemic response of the pasta to be obtained. In contrast, semolina has lowest fat content than in tef and chickpea flours. Tef was whole milled and retained the lipid content in the germ; hence it has higher fat content than semolina. Among all the raw materials, semolina had the lowest ash content. The ash content of tef in this study is in agreement with the finding of Bultosa (2007) and Hager et al. (2012).

Proximate and mineral composition of macaroni

The moisture content of formulated macaroni was ranged from 9.64 - 10.43% (Table 2). The lowest and highest moisture content was observed with Run-9 (85%-semolina, 0%-tef and 15%-chickpea) and Run-13 (60%-semolina, 40%-tef and 0%-chickpea), respectively. This could be due to higher water absorption capacity of tef and chickpea flour (Table 1) (Farooq and Boye, 2011;

Abebe et al., 2015).

The ash content was varied between (0.96-1.78) g/100g (Table 2), the highest being in the greatest semolina replacement level: 1.78 g/100g for Run-15 (60.00%-semolina, 25.11%-tef, 14.89%- chickpea) and the lowest in the control sample- Run 2 (100% semolina). Chickpea and tef flour had high ash contents (2.94 and 2.33) g/100g, respectively (Table 1). Thus, ash content significantly increased (P<0.05) upon blending semolina with the two flours. Higher ash content in semolina or flour indirectly reveals the presence of higher amount of bran and mineral. High ash in flour can affect color, imparting a darker color to pasta products. Similarly, Sabanis et al.(2006) and Padalino et al.(2014) reported increased amount ash content in the spaghetti through the addition of chickpea. Also, the ash content of tef based pasta doubled as high as when compared with oat and wheat based pasta (Hager et al., 2012).

The mean protein content of the macaroni was ranged from 11.11- 14.84 g/100g (Table 2). The lowest protein content was obtained in 100% semolina sample (Run 11) while the highest protein levels were obtained at the maximum chickpea replacement levels: 14.84 g/100g for Run-9 (85%- semolina, 0%-tef and 15%-chickpea). All the macaroni formulations had higher protein content than the 100% semolina macaroni. This is because of high amount of protein in chickpea and tef flour compared to durum wheat semolina (Table 1). Therefore, increased proportion of chickpea and tef in the composite flour improved the protein content of the macaroni significantly (p<0.05) (Table 2). Sabanis et al.(2006) and Padalino et al.(2014) reported also similar finding upon enrichment of durum wheat semolina with chickpea flour. Addition of soy improved both quality and quantity of protein in pasta (Taha et al., 1992). Let alone the leguminous supplements, higher crude protein content of tef pasta than oat and wheat based pasta was reported by Hager et al.(2012).

The crude protein exhibit all quadratic model of blending ratio showed significant (p< 0.01) effect on the protein content of the macaroni and R^2 = 0.97 which demonstrating the adequacy of the model and shown in Figure 1. The fitted model for protein value is shown as Equation 1 indicating quadratic effects with all three variables. The following model was developed to predict the protein content.

$$Protein = 11.21S + 12.68T + 17.16C + 3.76ST + 4.84SC - 2.83TC \quad \text{(Equation 1)}$$

Where: S=semolina, T=tef and C= chickpea

The fat content of the formulated macaroni was varied significantly (p< 0.05) with the range value from 0.51 - 2.12 g/100g (Table 2) depending on the blending proportion. Control macaroni (Run 2-100% semolina) had the lowest fat content; while highest fat content was observed on macaroni obtained from a blend with maximum chickpea and lowest semolina substitution: in Run-15 (60.00% semolina, 25.11% tef, 14.89% chickpea). This could be due to significantly higher fat content in chickpea and tef flours than semolina (Table 1). Similarly, Flores-Silva et al.(2014) and Padalino et al.(2014) reported high fat content in pasta formulated with increased levels of chickpea.

The mean carbohydrate content of the macaroni samples were varied between (73.18 -76.60) g/100g. The highest carbohydrate content was found in control samples (Run 2), while the lowest carbohydrate levels were observed from maximum chickpea replacement levels: Run-9 (85%-semolina, 0%-tef and 15%-chickpea) (Table 2). The amount of carbohydrate in the formulated macaroni decreased when the proportion of tef and chickpea in composite flour increased. The reason for such trend could be the low level of carbohydrate in the chickpea flour followed by tef flour as compared to the durum wheat semolina (Table 1).In fact, the carbohydrate content of all the formulations significantly varied (p<0.05) compared with semolina based pasta. This is due to higher carbohydrate composition of semolina than tef and chickpea flours.

The fiber content of macaroni was also significantly (P<0.05) influenced with the incorporation level of tef and chickpea flours (Table 2). The crude fiber content of the macaroni formulations was between (0.98 to 2.17)g/100g. Run-13 (60%-semolina, 40%-tef and 0%-chickpea) and Run2 (100% semolina) had the highest and lowest crude fiber amount respectively. Blending ratio had positively influenced on the fiber content of macaroni. Supplementation of the control macaroni with chickpea and tef fiber significantly increased the fiber content of the formulated macaroni. This is due to the fiber content of tef (2.6-3.8 g/100g), which is higher compared with compared with wheat, sorghum, rice and maize (Bultosa, 2007; Baye, 2014)due to its small size and whole milled flour. Table 2 showed the estimates of coefficients and adjusted regression coefficients (R adjusted) for the effects of fiber content, the analysis of variance (ANOVA) for the fiber content was showed that the full quadratic model was significant in predicting the crude fiber of the macaroni. The model which explained the relationship between the fiber content of the macaroni and the independent factors (S, T. and C) is shown in Equation 2:

$$Fiber = 0.99S + 2.16T + 0.75C - 0.63ST + 2.14SC + 0.83TC \quad \text{(Equation 2)}$$

Where: S=semolina, T=tef and C= chickpea

Blending ratio had a significant (p < 0.05) effect on the gross energy content of the macaroni(Table 2). The energy of the blended macaroni was ranged between (357.28 -365.99) kcal. The lowest energy value was

Table 1. Proximate and mineral compositions of durum wheat, tef and chickpea

Composition (g/100g)	Durum wheat semolina	Tef flour	Chickpea flour
Crude protein	10.67 ± 0.11^{c}	11.63 ± 0.12^{b}	20.04 ± 0.22^{a}
Crude fat	0.58 ± 0.03^{c}	2.67 ± 0.07^{b}	7.66 ± 0.01^{a}
Crude ash	0.84 ± 0.03^{c}	2.36 ± 0.02^{b}	2.94 ± 0.02^{a}
Carbohydrate	77.36 ± 0.16^{a}	73.46 ± 0.10^{b}	58.99 ± 0.25^{c}
Crude fiber	1.00 ± 0.01^{b}	3.35 ± 0.04^{a}	3.30 ± 0.10^{a}
Mineral (mg/100g)			
Iron	0.45 ± 0.09^{c}	8.75 ± 0.38^{a}	$1.80\ \ 0.00^{b}$
Zinc	1.00 ± 0.00^{c}	2.83 ± 0.17^{a}	$2.00\ \ 0.00^{b}$
Phosphorus	163.27 ± 0.03^{c}	206.7 ± 1.27^{a}	$192.85\ \ 0.94^{b}$

Values followed by different letters with in a horizontal row indicate significant difference ($p<0.05$). All values are expressed as mean ± SE in triplicate

Table 2. Nutritional composition of Macaroni from blend proportion of semolina, tef and chickpea

Run	Blend proportion (%)			Proximate composition(g/100g)						Energy	Mineral content (mg/100g)		
	Semolina	Tef	Chickpea	Moisture	Ash	Protein	Fat	Fiber	Carbohyd rate	(kcal)	Iron	Zinc	Phosphorus
1	80.00	20.00	0.00	10.14^{c}	1.25^{fg}	12.83^{fg}	0.90^{g}	1.44^{d}	75.88^{bc}	358.95^{fg}	2.47^{c}	1.42^{def}	171.10^{cde}
2	100.00	0.00	0.00	9.86^{f}	0.96^{j}	11.17^{h}	0.51^{i}	0.98^{g}	76.60^{a}	357.28^{h}	0.90^{g}	1.08^{g}	161.48^{f}
3	72.76	12.76	14.48	9.96^{e}	1.60^{b}	14.10^{bc}	1.75^{b}	1.62^{c}	73.60^{g}	362.55^{c}	2.20^{cd}	1.50^{bcde}	173.38^{c}
4	60.00	32.58	7.42	10.28^{b}	1.56^{bc}	13.01^{efg}	1.42^{cd}	1.98^{ab}	74.74^{ef}	359.76^{f}	3.20^{b}	1.75^{ab}	183.90^{ab}
5	60.00	40.00	0.00	10.42^{a}	1.47^{de}	12.32^{gh}	1.01^{fg}	2.12^{a}	75.91^{bc}	359.52^{fg}	4.40^{a}	1.73^{ab}	188.13^{a}
6	60.00	25.11	14.89	10.26^{b}	1.78^{a}	13.90^{cd}	1.79^{b}	1.98^{ab}	73.28^{g}	360.79^{e}	3.27^{b}	1.47^{cde}	178.19^{b}
7	92.50	0.00	7.50	9.76^{g}	1.21^{hi}	13.25^{def}	1.16^{ef}	1.28^{e}	74.62^{f}	361.89^{cd}	1.07^{cde}	1.27^{efg}	164.09^{def}
8	80.00	20.00	0.00	10.12^{c}	1.28^{f}	13.19^{ef}	0.87^{g}	1.36^{de}	75.54^{cd}	358.78^{g}	2.03^{cde}	1.50^{bcde}	170.72^{cde}
9	85.00	0.00	15.00	9.64^{h}	1.42^{de}	14.84^{a}	1.54^{c}	1.37^{de}	73.55^{g}	363.45^{b}	1.35^{ef}	1.72^{abc}	166.08^{de}
10	68.44	28.08	3.48	10.23^{b}	1.50^{cd}	13.14^{ef}	1.19^{e}	1.44^{d}	74.95^{ef}	357.04^{h}	2.30^{c}	1.65^{abcd}	179.69^{b}
11	100.00	0.00	0.00	9.84^{f}	0.98^{j}	11.11^{h}	0.62^{hi}	1.05^{g}	76.09^{b}	359.82^{f}	0.70^{g}	1.08^{g}	158.51^{f}
12	82.15	9.11	8.74	9.89^{ef}	1.31^{f}	13.75^{d}	1.28^{de}	1.64^{c}	74.77^{ef}	361.62^{d}	1.47^{f}	1.22^{fg}	168.48^{d}
13	60.00	40.00	0.00	10.43^{a}	1.55^{bc}	12.71^{g}	1.14^{ef}	2.17^{a}	75.17^{de}	357.78^{h}	4.17^{a}	1.75^{ab}	184.77^{a}
14	89.61	10.39	0.00	10.05^{d}	1.17^{i}	13.24^{e}	0.72^{h}	1.12^{f}	75.82^{bc}	358.75^{g}	3.17^{b}	1.15^{g}	165.46^{de}
15	60.00	25.11	14.89	10.24^{b}	1.74^{a}	13.72^{d}	2.12^{a}	2.07^{a}	73.18^{g}	362.71^{bc}	2.90^{b}	1.86^{a}	176.46^{bc}
16	85.00	0.00	15.00	9.66^{h}	1.38^{e}	14.37^{b}	2.02^{a}	1.43^{d}	73.57^{g}	365.99^{a}	1.47^{def}	1.73^{ab}	167.11^{d}

Mean values in the same column followed by different superscript letters were showed differ significantly based on Duncan's multiple range test ($p<0.05$). Values are expressed as mean in triplicate.

obtained in 100% semolina sample (Run2) while the highest energy value was obtained at the maximum chickpea replacement levels: 366 kcal for Run-9 (85%-semolina,0%-tef and 15%-chickpea). All the macaroni formulations had higher energy value than the 100% semolina macaroni. This is due to a fortification of the control macaroni with chickpea and tef fiber significantly increased the protein and fat content of the formulated macaroni.

Mineral content of macaroni

The mineral content such as total iron, zinc and phosphorus levels in the macaroni with in blending proportions were showed significant differences ($p< 0.05$) are presented in Table 2. The highest iron, zinc and phosphorus content was obtained for the macaroni with the maximum tef proportion which scored: 4.4 mg/100g, 1.75 mg/100g and188.13 mg/100g for Run-13 (60%-semolina, 40%-tef and 0%-chickpea), respectively.

Meanwhile 100% semolina (Run-11) based macaroni had the lowest iron zinc and phosphorus content 0.7 mg/100g, 1.05 mg/100g and 58.51 mg/100g, respectively. Similarly, Hager et al. (2012) finding showed pasta formulated from tef flour scored significantly higher mineral content than wheat and oat pasta. This could be due to the availability of high mineral content in tef flour than the wheat flour (Abebe et al., 2015).The model developed that predict the macaroni iron for varying durum wheat semolina-tef flour-chickpea flour mix level is depicted in Equation below

$$Iron = 0.85S + 8.63T + 4.21C - 1.55ST - 9.61SC - 11.98TC \quad \text{(Equation 3)}$$

Where: S=semolina, T=tef and C= chickpea

Antinutritional factor of Macaroni

The tannin and phytate content of macaroni were below detection limit. The reason for this might be occurrence of complete tannin and phytate reduction and formation of insoluble complexes due to thermal degradation and denaturation during macaroni extrusion and drying processes (Kataria et al., 1989).

Sensory Evaluation of formulated Macaroni

The mean sensory score of produced macaroni are summarized in Table 3 and Figure 2. Blend ratio had a significant impact ($p<0.05$) on the color, flavor, firmness and overall acceptability of the macaroni among the 16 experimental formulations based on panelist preference.

Color is essential parameter for assessing pasta product quality. The color of the macaroni varied from 3.74 to 7.89. The lowest color score (3.74) was obtained for Run 13 (with maximum tef proportion levels, i.e., 60%-semolina, 40%-tef and 0%-chickpea) blend while highest color scores (7.89) was obtained for Run 16 (with the maximum chickpea proportion levels, i.e., 85%-semolina, 0%-tef and 15%-chickpea). Formulations with 100% semolina and high chickpea in the formulated macaroni had exhibited relatively maximum color value. Addition of tef flour had detrimental effect of on macaroni color and the effect progressively increased with tef addition level. This is due to high ash content of tef and use a form of whole floured (Bultosa, 2007).

Similarly, blending caused a significant ($p < 0.05$) difference on the flavor scores of the macaroni which ranged between 4.47 (Run-4: 60%-semolina, 32.58%-tef and 7.42%-chickpea) and 7.21 (Control-100% semolina). The incorporation of tef and chickpea increased in the formulations had shown relatively lower flavor score while the control samples (100% semolina) in the recipe had exhibited higher flavor score. Increased incorporation of tef and chickpea reduced the flavor score as compared with the 100% semolina macaroni.

The firmness score was varied from4.74 to7.11 (Table 3) and showed significant difference ($p < 0.05$) within all macaroni formulations. The 100% semolina macaroni (Run 2) gave the maximum (7.11) firmness score, followed by Run 16 (highest chickpea) (85%-semolina, 0%-tef and 15%-chickpea) with score of 7.00. The minimum score (4.74) was obtained with the highest tef Run-4 (60%-semolina, 32.58%-tef and 7.42%-chickpea) and Run-5 (60%-semolina, 40%-tef and 0%-chickpea).

At higher substitution level of chickpea led to macaroni with firmness more or less close to the control, while higher tef flour incorporation decreased the macaroni firmness. The results obtained were also had similar trend with report by Sabanis et al.(2006) where the incorporation of chickpea up to 10% to 15% gave lasagna optimum firmness. This could be attributed to the dilution of protein due to the added tef flour with gluten free nature and the increase of the same because of the addition of chickpea flour. The inclusion of dietary fiber (pea fiber and inulin) interfered with the structure of pasta, disruption in the protein matrix, lowered the continuity of the protein-starch matrix and lowers the firmness.

Blending ratio had a significant ($p<0.05$) effect on the overall acceptability of the blend macaroni (Table 3). The overall acceptability score of the blended macaroni ranged from 4.42to 7.53. The highest sensory score was recorded from control Run-2 (100% semolina) (7.53)and maximum chickpea incorporated macaroni samples Run-16 (85%-semolina, 0%-tef flour and 15%-chickpea flour) (7.37), respectively. Run-4 (60%-semolina, 32.58%-tef and 7.42%-chickpea) and Run-10 (68.4%-semolina,28.1%-tef and 7.00%-chickpea), were the least accepted macaroni products with respective scores of 4.42 and 5.10. Addition of more proportion of semolina exclusively or semolina with only chickpea flour produced a macaroni with the highest overall acceptability. In contrast, tef based macaroni had less overall acceptability. Most studies on the sensorial evaluation of fortified pasta focused on the overall product acceptability. No significant difference observed between the control macaroni and semolina-chickpea macaroni blend. These results were in line with the trend of pasta fortified up to a 10-15% substitution with chickpea flour were generally well accepted (Wood, 2009 and Petitot et al., 2010a).

Optimization

A numerical multi-response optimization technique of RSM was applied to determine the optimum combination of semolina, tef and chickpea for the production of nutrient rich and functional pasta. The criteria for optimization were nutritional content (crude protein, crude fiber and iron were maximum target) and sensory score (color, firmness and overall acceptability).

Based on macaroni nutritional composition (protein, crude fiber and iron) and sensory score (color, firmness and overall acceptability) the formula that could be selected as optimum blend is 74.18 g/100g semolina, 10.89 g/100g tef and 14.89 g/100g chickpea flour with desirability of 0.682. The white region in contour ovelay plot (Figure 3) showed the optimum option for producing macaroni with maximum nutrient and better sensory acceptance.

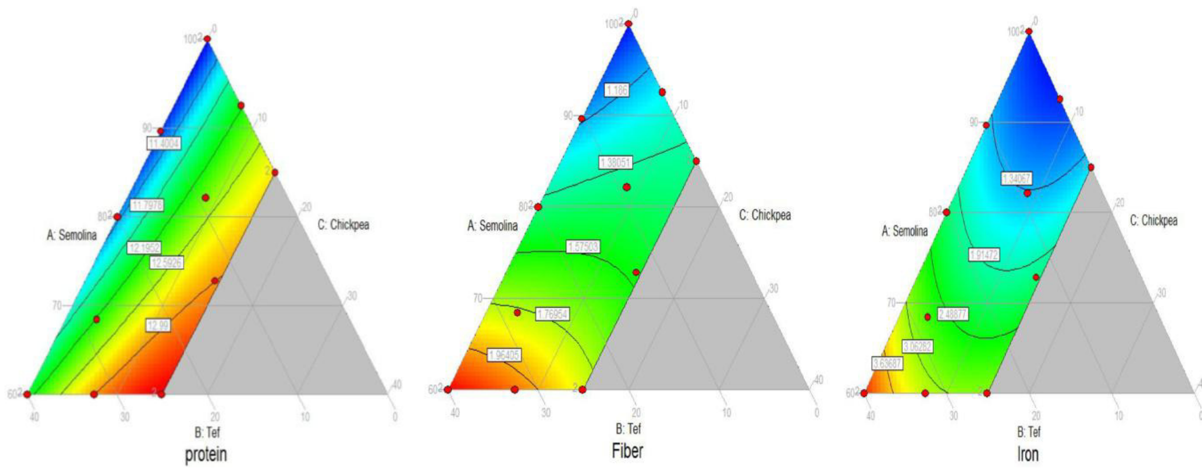

Figure 1: Model graph showing the nutritional composition of macaroni produced from composite blends of semolina, tef and chickpea flour.

Table 3. Sensory evaluation of macaroni formulated with semolina, chickpea and tef flours

Run	Color	Flavor	Firmness	Overall acceptability
1	5.74 ± 0.29^{cdef}	5.95 ± 0.44^{abcd}	6.00 ± 0.42^{abc}	5.74 ± 0.42^{cdef}
2	7.84 ± 0.23^{a}	7.21 ± 0.27^{a}	7.11 ± 0.32^{a}	7.53 ± 0.33^{a}
3	5.53 ± 0.42^{cdef}	4.84 ± 0.44^{ef}	5.42 ± 0.49^{cde}	5.16 ± 0.42^{efg}
4	3.97 ± 0.44^{hi}	4.47 ± 0.44^{f}	4.74 ± 0.46^{e}	4.72 ± 0.41^{g}
5	4.79 ± 0.31^{fgh}	5.32 ± 0.40^{cdef}	5.00 ± 0.42^{de}	5.11 ± 0.25^{efg}
6	5.11 ± 0.36^{defg}	4.89 ± 0.46^{ef}	5.11 ± 0.47^{cde}	5.47 ± 0.37^{defg}
7	6.47 ± 0.44^{bc}	6.63 ± 0.36^{ab}	5.84 ± 0.39^{bcd}	6.82 ± 0.41^{ab}
8	6.00 ± 0.33^{bcdef}	5.63 ± 0.34^{bcde}	6.05 ± 0.35^{abc}	6.25 ± 0.36^{bcde}
9	7.79 ± 0.24^{a}	6.53 ± 0.47^{abc}	6.68 ± 0.38^{ab}	6.84 ± 0.25^{ab}
10	4.00 ± 0.48^{ghi}	4.63 ± 0.40^{ef}	4.79 ± 0.43^{de}	4.63 ± 0.36^{fg}
11	7.26 ± 0.37^{ab}	6.84 ± 0.43^{ab}	6.84 ± 0.33^{a}	7.26 ± 0.3^{ab}
12	6.37 ± 0.43^{bcd}	6.26 ± 0.42^{abcd}	6.21 ± 0.41^{abc}	6.58 ± 0.43^{abcd}
13	3.74 ± 0.46^{hi}	5.16 ± 0.43^{def}	4.79 ± 0.39^{e}	5.37 ± 0.38^{efg}
14	6.16 ± 0.43^{bcde}	6.42 ± 0.44^{abcd}	6.50 ± 0.43^{ab}	6.81 ± 0.43^{abcd}
15	5.00 ± 0.53^{efgh}	5.21 ± 0.40^{def}	5.42 ± 0.35^{cde}	5.67 ± 0.46^{defg}
16	7.89 ± 0.32^{a}	7.16 ± 0.34^{a}	7.00 ± 0.29^{a}	7.37 ± 0.29^{a}

Mean values in the same column followed by different superscript letters were showed differ significantly based on Duncan's multiple range test ($p < 0.05$). All values are expressed in mean ± SE in triplicate.

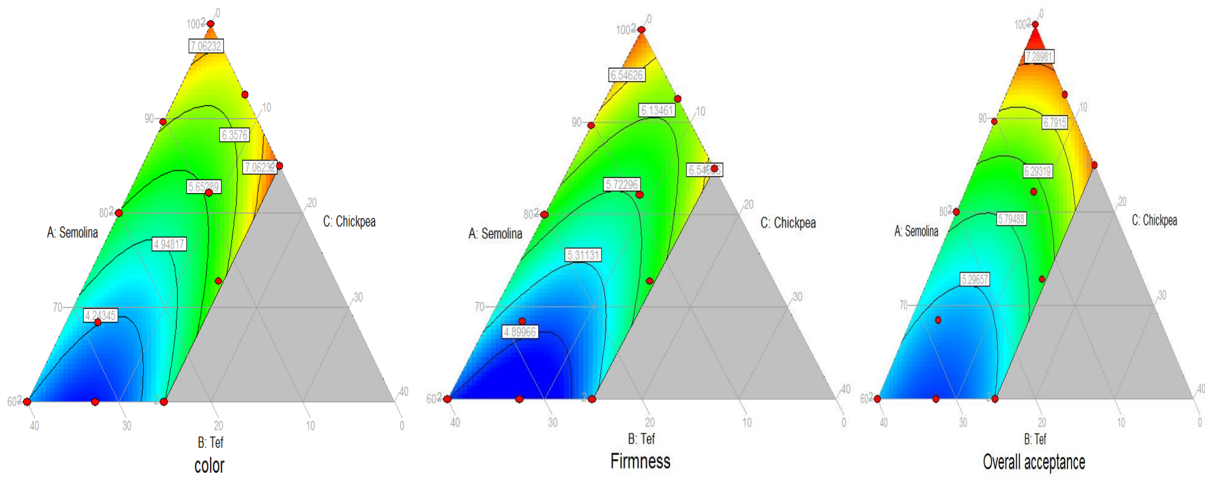

Figure 2: Model graph showing the sensorial properties of macaroni produced from composite blends of semolina, tef and chickpea flour.

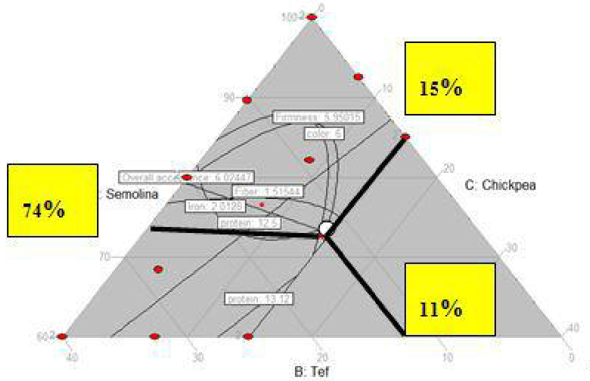

Figure 3: Mixture contour plot of nutritional and sensory

CONCLUSION

The study was conducted to enhance the nutritional contents of macaroni from durum wheat semolina through incorporation of non-conventional raw materials (tef and chickpea flours). Accordingly, fortification of durum wheat semolina with tef and chickpea flours considerably increased the level of protein, ash, fat, fiber, iron and zinc contents in the macaroni formulated. Exclusively chickpea fortified with incorporation level up to 15% with semolina produced a macaroni comparable sensory quality with durum wheat semolina macaroni. Though the addition of tef flour considerably increased the fiber and mineral content of the macaroni, higher level of tef flour incorporation had deleterious effect on macaroni textural and sensorial qualities. The optimization done indicated that macaroni produced from 74.18% durum wheat semolina, 10.89% tef and 14.94% chickpea had enhanced protein (13.30 g/100g),fiber (1.55 g/100g) and iron (2.15mg/100g) contents and without significantly affecting the color, firmness and overall acceptability of the macaroni. This could ultimately help to avail nutritionally improved and sensorially acceptable macaroni to the consumer.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Ethiopia Institute Agricultural Research for giving Mr. Tamirat full sponsorship for attending his MSc program. I would like to express my greatest appreciation goes to Addis Ababa University center for food science and nutrition and Debre Zeit Agricultural research center tef improvement program, durum wheat and chickpea Research team.

ABBREVIATION

RSM= Response surface methodology, ANOVA= Analysis of variance, SPSS= Statistical Product and Service Solutions, DZARC=DebreZeit agricultural research center

REFERENCES

Abebe W, Collar C and Ronda F (2015). Impact of variety type and particle size distribution on starch enzymatic hydrolysis and functional properties of tef flours. Carbohydrate Polymers 115: 260–268.

Abebe Y, Bogale A, Hambidge M, Stoecker J, Bailey K and Gibson (2007). Phytate, zinc, iron and calcium content of selected raw and prepared foods consumed in rural Sidama, Southern Ethiopia, and implications for bioavailability. Journal of Food Composition Analysis 20: 161-168

AOAC (2010). American official methods of analysis, 20th edition. AOAC International Association of Official Analytical Chemists, Washington, DC, USA, Official Methods 925.09,923.03, 979.09, 962.09, 4.5.01.

Assefa K, Solomon C and Gizaw M (2013). Conventional and Molecular Tef Breeding: Germplasm, Breeding & Tissue Culture. In: Assefa K, Chanyalew S and Zerihun T (ed.) Achievements and prospects of tef improvement: Proceedings of the Second International Workshop, November 7-9, 2011, DebreZeit, Ethiopia. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia; Institute of Plant Sciences, University of Bern, Switzerland.

Baye K (2014). Tef: nutrient composition and health benefits. review. International Food Policy Research Institute. ESSP, EDRI. Working paper 67.

Borneo R and Aguirre A (2008). Chemical composition, cooking quality, and consumer acceptance of pasta made with dried amaranth leaves flour. LWT - Food Science and Technology 41: 1748–1751.

Bultosa G (2007). Physicochemical Characteristics of Grain and Flour in 13 Tef [Eragrostis tef (Zucc.)Trotter] Grain Varieties. Journal of Applied Science Research 3 : 2042-2051.

Chillo S, Suriano N, Lamacchia C and Del Nobile MA (2009). Effects of additives on the rheological and mechanical properties of non-conventional fresh handmade tagliatelle. Journal of Cereal Science 49:163–170.

De Pilli T, Derossi A and Severini C (2013). Cooking quality characterization of ‘spaghetti’ based on soft wheat flour enriched with oat flour. International Journal of Food Science and Technology 48: 2348–2355.

Farooq Z and Boye JI (2011). Novel food and industrial applications of pulse flours and fractions. Pulse foods.11.6.3.

Flores-Silva PC, Berrios JJ, Pan J, Osorio-Dıaz P. and Bello-Perez LA(2014). Gluten free spaghetti made with chickpea, unripe plantain and maize flours: functional and chemical properties and starch digestibility. International Journal of Food Science and Technology 49: 1985–1991.

Fuad T and Prabhasankar P (2010). Role of Ingredients in Pasta Product Quality: A Review on Recent Developments, Critical Reviews in Food Science and Nutrition 50 (8): 787-798.

Hager A, Lauck F, Zannin E and Arendt E (2012b). Development of gluten-free fresh egg pasta based on oat and tef flour. European Journal of Food Research Technology.

Hrušková M and Jurinová I (2012).Composite flours-characteristics of wheat/hemp and wheat/teff Models. Food and Nutrition Sciences 3: 1484-1490

Kataria A, Chauhan BM and Punia D (1989).Antinutrients and protein digestibility (in vitro) of mungbean as affected by domestic processing and cooking. Food Chemistry 3: 9-17.

Kinfe E, Pragya S and Tigist F (2015).Physicochemical and Functional Characteristics of Desi and Kabuli Chickpea (Cicerarietinum L.) Cultivars Grown in Bodity, Ethiopia and Sensory Evaluation of Boiled and Roasted Products Prepared Using Chickpea Varieties. International Journal of Current Research Bioscience Plant Biology 2: 21 -29.

Laike K, Solomon W, Geremew B and Senayit Y (2010). Effect of extrusion operating conditions on the physical and sensory properties of tef (Eragrostis tef [Zucc.]Trotter) flour extrudates. Ethiopian Journal of Applied Science Technology 1: 27-38.

Legese W (2017).Fast truck variety development and participatory variety selection approach for climate smart agriculture in shebel berenta district, Eastern Gojam, Ethiopia. International Journal of Current Research 9: 50179-50183.

Marconi E and Carcea M (2001). Pasta from nontraditional materials. Cereal Food World 46: 522–530.

Mensa-Wilmot, Phillips RD, Lee J and Eitenmiller RR (2004). Formulation and evaluation of cereal/ legume-based weaning food supplements. Plant Foods for Human Nutrition 58: 1–14.

Mercier S, Moresoli C, Mondor M, Villeneuve S and Marcos B(2016). A Meta-analysis of enriched pasta: What are the effects of enrichment and process specifications on the 103 quality attributes of pasta? Comprehensive Reviews in Food Science and Food Safety 15: 685-704.

Paola F, Roberto R and Silvia F (2015). Raw materials for the production of functional pasta. Open Fields.

Padalino L, Mastromatteo M, Lecce L, Spinelli S, Conto F and Del Nobile MA (2014). Chemical composition, sensory and cooking quality evaluation of durum wheat spaghetti enriched with pea flour. International Journal of Food Science and Technology 49: 1544–1556.

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

Sabanis D, Makri E and Doxastakis G (2006). Effect of Durum flour enrichment with chickpea flour on the characteristics of dough and lasagna. Journal of the Science of Food and Agriculture 86: 1938–1944.

Sissons MJ, Egan NE and Gianibelli MC (2005). New insights into the role of gluten on durum pasta quality using reconstitution method. Journal of Cereal Chemistry 82(5): 601– 608.

Taha SA, Acs E and Sagi F (1992). Evaluation of economical pasta products prepared from durum semolina/yellow corn flour/soy flour mixture. 1. Mixing properties, chemical composition and color components. Acta Almentaria 21: 153-162.

Wood J (2009). Texture, processing and organoleptic properties of chickpea fortified spaghetti with insights to the underlying mechanisms of traditional durum pasta quality. Journal of cereal science 49: 128-133.

Zia-Ul-Haq M, Iqbal S, Ahmad S, Imran M, Niaz A and Bhanger MI (2007). Nutritional and compositional study of desi chickpea (Cicerarietinum L.) cultivars grown in Punjab, Pakitan. Food Chemistry 105: 1357–1363.