Effect of Replacement of Semolina with Tef and Chickpea Flour Blend on Cooking Quality and Textural Properties of Pasta

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Abstract

Pasta is unleavened extruded product which is mainly made from dough of durum wheat semolina. In this study, nutritionally enhanced macaroni was developed with partial substitution of semolina by tef flour (0 to 40%) and chickpea flour (0 to 15%) using D-optimal mixture design. The physical-chemical properties of the composite flours together with the cooking and textural characteristics of the developed macaroni were evaluated. Results indicated that the composite flour containing higher level of tef flour considerably improved the water absorption capacity/index and lowest wet gluten content, while pure semolina had highest gluten and lowest water absorption capacity.Macaroni containing maximum value of tef flour increased the cooking weight and darkened the color of macaroni. In addition, the cooking loss of macaroni increased with increasing level of tef and chickpea flours. The maximum value of chickpea flour (15%) had an optimum effect on macaroni firmness, while tef flour (40%) had a negative effect. Chickpea flour increased the stickiness of macaroni when compared to that of tef flour. However, the formula containing 67.08% semolina, 17.93% tef and 15% chickpea was selected as the best formulation to produce a rich macaroni product with desirable cooking loss, firmness and stickiness. Understanding the impact of the blending ratio to improve macaroni nutritional quality was considered useful to develop nutritionally enhanced pasta products.

Keywords: Macaroni, tef, chickpea, cooking and textural property, D-optimal design

Introduction

Macaroni is a well-liked and important starchy stable food product in many cultures and consumed by all age groups. It is unleavened extruded wheat dough, produced simply by mixing semolina and water. Durum wheat semolina is a preferable ingredient for making high quality pasta because of its excellent dough rheological properties, superior color, high protein/gluten content, excellent cooking quality and better consumer acceptance (Kneipp, 2008).

Pasta is a good source of complex carbohydrates, in contrary it is poor in protein (lysine, methionine), low in micronutrient composition and inadequate in dietary fiber content due to the removal of bran and germ during durum wheat milling into semolina (Sissons *et al.,* 2005, Petitot *et al.,* 2010). World Health

Organization and United States 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). Hence, fortification of the durum wheat semolina with other nutritious cereals and/or legumes is important to improve the nutritional quality of macaroni products specifically the dietary fiber, protein and mineral contents can be improved (Chillo *et al.,* 2008a & b).

Tef (*Eragrostis tef* (Zucc.)) Trotter is an indigenous popular cereal crop in Ethiopia which is getting cereal staple crop which is getting popular to the rest of the world. This is due to its gluten free nature, attractive nutritional profile (iron, calcium and zinc) and it is utilized in the form of whole flour (Abebe *et al.,* 2007; Hrušková *et al.,* 2012). In Ethiopia, tef is processed in traditional and small scale techniques since limited tef recipes at industrial level and limited technological processing aspects (Laike *et al.,* 2010 and Baye, 2014). On the other hand, chickpea is the most widely consumed pulse type in the world and a rich source of high quality protein, vitamins (thiamine and niacin), minerals, essential fatty acid (linoleic) and high dietary fiber (Zia-ul-haq*et al.,* 2007; Fuad and Prabhasankar, 2010). Hence, incorporation tef and chickpea flour in durum wheat semolina can be considered as good options to produce nutritious and healthy macaroni.

Pasta quality is highly related with excellent cooking quality and firmness, minimal stickiness and cooking loss, and less susceptibility to breakage f2(g)TJE( )-1lss,

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attrition mill. The milled chickpea flour was sieved through an 80-mesh screen to remove ground hulled pieces.

Formulations and experimental process

Design expert software was used to define the optimum proportions of the durum wheat semolina, tef flour and chickpea flour to get nutritionally enriched pasta formulation. In this study, mixture design was used to determine the optimum formulation of blends of durum wheat semolina (60–100%), tef (0–40%) and chickpea (0–15%). Eleven runs were obtained from the mixture Response surface methodology with D optimal design (Table 2). The upper and lower limits of the flours were selected based on preliminary trial and earlier reports (Wood, 2009; Giuberti *et al*., 2015). Macaroni made with 100% durum wheat semolina was used as the control (C). Semolina, tef and chickpea flours were mixed by rotating drum mixer (Chopin MR 10L, France) for each blending proportion according to design which ensures uniform mixing. The obtained composite flour was kept in polyethylene bags under refrigerated condition until their use.

Flour functional properties

Water Absorption Index

The Water Absorption Index (WAI) of composite flour was determined according to Anderson *et al*., (1969). Two grams of composite flour sample was suspended in 25 ml of distilled water in a tarred 50 ml centrifuge tube and shaked (Model AS130.1, IKA, USA) for 30 min. The sample was centrifuged for 10 min at 3000 rpm. The gel remaining in the centrifuge tube was weighed.

WAI (g/g) $=\frac{Wg}{Wds}$; Where: WAI = Water absorption Index;

Wg = Weight of the sediment;

Wds = Weight of dry sample

Water Absorption Capacity

Water Absorption Capacity (WAC) was determined by the difference the amount of distilled water before and after centrifuge (Beuchat, 1977). Two grams of composite flour sample was mixed with 20 ml of distilled water in 25 ml centrifuge tubes. The dispersed particles were vortexed for 30 sec at room temperature and centrifuged for 30 min at 3000 rpm.

$$\text{WAC} = \frac{\text{the volume of distilled water before and after centrifuge } (V2-V1)}{\text{Weight of sample } (W0)} * 100$$

Gluten content

Wet and dry gluten contents were performed mechanically with Glutomatic System (Perten Instruments, Sweden) to assess to the quantity of gluten. Gluten strength was estimated in flour/semolina samples by Gluten index (ICC Standard No. 158).

Chemical analysis

The composite flours were kept in air tight polyethylene plastic bags at room

Cooking time

Pasta was cooked in distilled water (2 L/100 g) containing 0.7% (w/v) of sodium chloride. Optimal cooking time was established by boiling the macaroni in distilled water until the time when the white strand core disappeared by squeezed between two glass plates (AACC (2000) method 16-50). Each 1 min., macaroni samples were removed from boiling water and squeezed between two pieces of Plexiglas.

Cooking loss

The cooking loss (%total solid weight) was determined by the percentage of solid particles present in the cooking water. Ten gram of pasta sample was cooked in pan which contained 300 ml of boiling water on water bath for optimal cooking point.Cooking water collected from each sample was evaporated to bone dry level in hot air oven at 105^{0}c to determine the solid loss in the gruel. The residue was weighed and the cooking loss was expressed as a percentage of the original weight of the sample

Cooking loss (%) = $\frac{Drymatterlossafterovendrying\ (g)}{Dryweightofuncookedpasta\ (g)}$ *100

Texture of cooked macaroni

The parameters firmness and stickiness of the cooked macaroni samples were analyzed using TA plus textural analyzer (LLOYD Instruments, UK 2007). This experiment was carried out in triplicate according to the method described by AACC 1995 method 16–50. The firmness and stickiness of samples were measured with the speed of 2.00 mm/s and strain 50. Pasta firmness is the work required to cut a defined amount of pasta while stickiness is the maximum peak force to separate the probe from the sample's surface upon probe retraction. The average value of force (N) required to shear the macaroni was reported after measuring five replicates for each composite sample. A higher shear value indicates a firmer product and the higher the force value, the stickier is the sample.

Overall acceptability

The sensory evaluation of the fresh pasta was carried out by twenty semi-trained judges of Food Science and Nutrition Department staff members and post graduate students from Hawassa University. Nine point Hedonic rating scale ranging (1=extremely dislike, 2 = dislike very much, 3= dislike slightly 4 = dislike, 5= neither like nor dislike, 6 = slightly like, 7= like, 8 = like very much and 9= Extremely like) was used for the sensory study. The panelists were asked to score for overall impression like color, texture and overall acceptability

Statistical analysis

One way analysis of variance (ANOVA) was used to check the presence of significant difference at 95% confidence level between mean levels. The effect of blending proportion of tef and chickpea with semolina were analyzed by Design expert®, version 7.0.1 (Stat-Ease Inc., Minneapolis, MN USA), used to perform data analysis. Duncan's Multiple Range test (SPSS version 20.0, USA) was carried out to determine level of significant ($p < 0.05$) differences among samples. All analyses were conducted in triplicate and the results were expressed as mean ± standard error.

Results and Discussion

Semolina and flour nutritional composition

Characterization of ingredients is the primary concern in predicting macaroni quality. The nutritional compositions of the durum wheat semolina, tef flour and chickpea flour utilized in this study are shown in Table 1. 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.,* 2012b). Among raw materials, chickpea flour had highest amount of protein and fat followed by tef flour and lower amount in semolina flour. This implies chickpea as means to improve protein and fat content to enrich conventional macaroni. Similarly, the starch of ingredients play important role in determining pasta quality (texture) because of its macromolecular structure (Hager *et al.,* 2012a). Semolina has the highest starch content (77.36%) followed by tef (73.46%) and chickpea (60.99%) 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 (Abebe *et al.,* 2015). This helps to lower carbohydrate content 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 fat content (2.67%) than semolina (0.58%). Among all the raw materials, semolina had the lowest ash content (0.84%). The ash content of tef in this study is in agreement with the findings of Bultosa (2007) and Hager et al. (2012). Similarly, tef was whole milled (contain bran & germ) and retained the lipid content in the germ, hence it has higher mineral, fat and fiber content (Bultosa, 2007; Hager *et al.* 2012).

Iron, zinc and phosphorus contents of the three raw materials significantly increased ($p<0.05$) as reported in Table 1. Among which, tef has the highest iron, zinc and phosphorus contents, while semolina has the least (USDA National nutrient data base, 2016). This helps to select tef as a substite in fortifying conventional pasta products with essential nutrients. The introduction of chickpea and tef flours could thus increase the nutritional quality of macaroni.

Table 1. Nutritional composition of semolina, tef and chickpea flours used to produce macaroni

RW	Proximate composition (g/100g)					Mineral (mg/100g)				
	Crude protein	Carbohydrate	Crude fat	Crude Fiber	Ash	Fe	Zn	P	WAC	WAI
DS	10.67 ± 0.11^{c}	77.36 ± 0.16^{a}	0.58 ± 0.03^{c}	1.00 ± 0.01^{b}	0.84 ± 0.03^{c}	0.45 ± 0.09^{c}	1.00 ± 0.00^{c}	163.27 ± 0.03^{c}	108.06^{b}	1.91^{c}
CF	19.04 ± 0.22^{a}	60.99 ± 0.25^{c}	7.66 ± 0.01^{a}	3.30 ± 0.10^{a}	2.94 ± 0.02^{a}	1.80 ± 0.00^{b}	2.00 ± 0.00^{b}	192.85 ± 0.94^{b}	172.05^{a}	2.12^{b}
TF	11.63 ± 0.12^{b}	73.46 ± 0.10^{b}	2.67 ± 0.07^{b}	3.32 ± 0.04^{a}	2.36 ± 0.02^{b}	8.75 ± 0.38^{a}	2.83 ± 0.17^{a}	206.70 ± 1.27^{a}	171.93^{a}	2.42^{a}

Values followed by different letters with in a column indicate significant difference ($p<0.05$). All attributes are expressed on dry matter basis. RW: Raw material, DS: Durum wheat semolina, CF: Chickpea flour, TF: Tef flour, WAC: Water absorption capacity, WAI: Water absorption index

Table 2: Functional properties of composite flour and blend proportion of semolina, tef and chickpea

Run	Blend proportion (%)			WAC (%)	WAI (g/g)	Amount of water added (%)	Gluten (%)	Protein (%)	Fiber (%)	Iron (%)
	Semolina	Tef	Chickpea							
1	80.00	20.00	0.00	111.91 ± 0.02^{f}	2.19 ± 0.02^{bc}	39.62 ± 0.27^{bc}	26.30 ± 0.48^{c}	11.06^{cd}	1.38^{bc}	2.11^{c}
2	100.00	0.00	0.00	88.91 ± 0.02^{h}	2.06 ± 0.03^{ef}	37.08 ± 0.21^{e}	35.70 ± 0.51^{a}	10.92^{de}	0.78^{e}	0.45^{g}
3	72.76	12.76	14.48	$128.05 \pm .04^{bcd}$	2.12 ± 0.03^{de}	38.36 ± 0.51^{d}	22.20 ± 0.81^{d}	12.20^{a}	1.57^{b}	1.70^{d}
4	60.00	32.58	7.42	122.11 ± 0.04^{cde}	2.20 ± 0.02^{b}	39.76 ± 0.27^{b}	16.20 ± 0.80^{g}	11.85^{ab}	1.87^{a}	3.25^{ab}
5	60.00	40.00	0.00	138.05 ± 0.02^{ab}	2.23 ± 0.01^{ab}	41.25 ± 0.14^{a}	14.88 ± 0.16^{h}	11.25^{c}	1.93^{a}	3.77^{a}
6	60.00	25.11	14.89	130.00 ± 0.01^{abc}	2.27 ± 0.02^{a}	39.67 ± 0.24^{b}	16.71 ± 0.69^{f}	12.41^{a}	1.87^{a}	2.74^{b}
7	92.50	0.00	7.50	115.02 ± 0.06^{ef}	2.18 ± 0.10^{bcd}	38.25 ± 0.64^{d}	28.75 ± 0.66^{b}	11.50^{b}	1.03^{de}	0.55^{fg}
8	85.00	0.00	15.00	118.65 ± 0.01^{def}	2.12 ± 0.01^{de}	38.45 ± 0.12^{d}	25.62 ± 1.21^{c}	12.18^{a}	1.19^{cd}	0.65^{f}
9	68.44	28.08	3.48	129.03 ± 0.01^{abc}	2.13 ± 0.01^{cde}	39.75 ± 0.04^{b}	20.89 ± 0.41^{e}	11.43^{c}	1.69^{ab}	2.83^{b}
10	82.15	9.11	8.74	125.05 ± 0.03^{bcde}	2.11 ± 0.01^{e}	38.11 ± 0.18^{d}	21.34 ± 0.29^{de}	11.74^{b}	1.27^{c}	1.32^{e}
11	89.61	10.39	0.00	117.98 ± 0.02^{ef}	2.11 ± 0.01^{e}	38.08 ± 0.07^{d}	30.11 ± 0.42^{b}	10.97^{d}	1.11^{d}	1.31^{e}

Values followed by different letters with in a column indicate significant difference ($p<0.05$); WAC: Water absorption capacity, WAI: Water absorption index

Functional properties of the composite flours

The blending of semolina with tef and chickpea flours significantly increased the WAI (from 2.04 to 2.27) g/g and WAC (88.91 to 172.05) % of the resulting composite flour values between the 11 runs (Table 2). Increasing the proportion of tef and chickpea flour had increased the WAI and WAC of composite flour. This trend could be due to the higher WAI and WAC scores of tef flours (i.e. tef flour > chickpea flour > semolina) and (i.e. tef flour ≥ chickpea flour>semolina), respectively (Table 1). The higher WAI in tef flour than the wheat flour could be due to its smaller starch granule size that led to increase in the bulk surface area (Bultossa *et al.,* 2007; Abebe *et al.,* 2015) can support this finding. Water absorption results in swelling, which is a required factor in determining quality of pasta products. Apparently, in this study also as the amount of water added in the processing of macaroni varied with the amount of tef and chickpea flour.

Wet gluten content in the composite flours significantly decreased ($p<0.05$) by 58.32% and 28.24% with increase in tef and chickpea flour levels from 0-40% and 0-15%, respectively. Control sample (100% semolina) had the highest gluten content (35.7%) while the lowest gluten levels (14.88%) were observed for the highest semolina substitution levels (40% tef) (Table 2). This could be due the gluten free nature of both tef and chickpea flour and decreasing proportion of durum wheat semolina in the composite flours leads to the dilution of available gluten account. Similarly, Sabanis et al. (2006) indicated the increase in the incorporation level of chickpea in durum wheat semolina from 0% to 50% improved protein content and reduced wet gluten content from 35% to 15%.

Furthermore, the incorporation of tef and chickpea flours in durum wheat semolina would induce structural changes in the produced macaroni. This is due to their high content of fibers and dilution of gluten proteins by albumins and globulins (Petitot *et al.,* 2010a, b). This could favor higher susceptibility of starch to digestive enzymes due to the disruption of the protein network entrapping starch granules (Tudorica *et al.,* 2002). This study helps enrich pasta with chickpea not only improve protein content but also increased digestibility of protein (Wesche-Ebeling *et al.,* 2001).

Protein, fiber and iron content of the composite flours increased with the increase in the content of the chickpea and tef flours (Table 2). Fortifying durum wheat semolina with tef flours would enhance the fiber and iron contents. Enhancing durum wheat semolina/spaghetti with chickpea flours would improve the protein content and nutritional value due to the complementation of amino acid profile from cereal and legume (Sabanis *et al.,* 2006; Padalino *et al.,* 2014). Let alone the leguminous supplements, higher crude protein content of tef pasta than oat and wheat based pasta was reported by Hager et al. (2012b).

Macaroni quality

Cooking quality

The pasta cooking quality showed that the formulations can make good macaroni in terms of reduced cooking losses, optimum cooking time, and weight increase and are greatest important quality parameters to consumers.

Cooking weight and Water absorption capacity (WAC)

Increase in weight of the cooked macaroni is related with water absorption capacity. The fortification of macaroni with 40% tef and 15% chickpea flour increased the cooking weight and WAC of the dry macaroni (from 271.58% and 166.53% for durum wheat macaroni to 347.67% and 215.07% for maximum semolina replacement levels, respectively) (Table 3). This could be due to the higher water absorption capacity and water absorption index of tef and chickpea flours and the high level of fiber in them. Additionally, tef starch has small granule size giving its larger surface area and the presence of high fiber in tef flour favoring water binding (Abebe *et al.*, 2015). Rosa *et al.*, 2015 reported that the pasta made from 100% buckwheat flour had the greatest weight gain (344%).The inherent proteins in raw chickpea flour may also have played some role in the higher water absorption capacity (Esmat *et al.*, 2010).

Cooking time

The variation of cooking time depended on the incorporation of the tef and chickpea flour. There was a significant decrease in the cooking time at 40% tef flour and interaction of both flour incorporation. Samples containing up to 15% chickpea flour did not demonstrate any significant change in cooking time. However, it is expected that the cooking time of tef fresh pasta is reduced when compared to that of durum wheat semolina pasta.

Cooking loss

The effects of the addition of tef flour and chickpea flour in durum wheat pasta on the cooking loss of the pastas can be seen in Table 3.The cooking loss of the formulated macaroni for individual and interaction effects of both flours and significantly varied from 1.47 to 4.03%. The lowest cooking loss was obtained in durum wheat macaroni and highest cooking loss of 4.03% was found from the maximum tef level formulation (40% tef). The cooking loss of chickpea incorporated pasta had significantly reduced as compared to tef based pasta (Figure 1). Cooking loss may be due to amylose leaching and solubilization of some salt-soluble proteins. Study by Hager et al, (2012) also indicated tef pasta exhibited higher cooking loss compared with wheat and oat pasta. Contrary to our study, El-Shatanovi et al. (2000) and Rasmay et al. (2000) reported that increasing the level of chickpea (5% to 15%) containing macaroni reduced cooking loss. The reason for such increase of the cooking loss upon the replacement of durum wheat semolina could be related to the dilution of the gluten which is unique to the durum wheat semolina that forms a gluten matrix and holds the starch in the pasta together. In addition, fibrous components in the tef flour could have interrupted and weakened the overall structure of the spaghetti. This may allow leaching of more solids from the spaghetti into the cooking water.

Textural characteristics

Texture is a prime concern of consumers, with a firm and non-sticky pasta being generally acceptable. Textural properties of pasta may be affected by the fortification of tef and chickpea inclusion.

Firmness

The result presented in Table 3 on the various blending ratio of tef and chickpea flour had a significant impact ($p<0.05$) on firmness of macaroni. Among all products containing tef and chickpea flours, the macaroni containing maximum chickpea had higher firmness (7.03N) while the progressive reduction in pasta firmness (4.42 N) with increasing tef flour (Figure 2). Fortification of durum wheat pasta with 15% of chickpea flour significantly increased pasta firmness by 14.68%. This implies the increased firmness of the cooked macaroni with higher chickpea amount (increased protein content). This could be attributed to a significant increase of protein level in obtained from the pea flour (Padalino *et al.,* 2014) while the amount tef increased in the formulations had shown lower firmness value compared with wheat and oat pasta (Hager *et al.*, 2012).

Table 3. Cooking, textural quality and color score of formulated macaroni

Run	Cooking quality (%)			Cooking time (min)	Texture analysis (N)		Color	OAA
	Cooking weight	WAC	Cooking loss		Firmness	Stickiness		
1	299.92 ± 0.02[bcd]	185.62 ± 1.29[g]	2.05 ± 0.12[f]	10.00 ± 0.50[ab]	4.95 ± 0.03[gh]	42.92 ± 0.29[cde]	6.18 ± 0.04[h]	6.00 ± 0.23[c]
2	271.58 ± 1.12[d]	166.53±3.07[h]	1.50 ± 0.06[g]	10.50 ± 0.75[a]	6.13 ± 0.08[c]	41.71 ± 0.23[e]	10.66 ± 0.09[c]	7.39 ± 0.30[a]
3	314.08 ± 1.91[abc]	212.55 ± 4.65[ab]	2.90 ± 0.02[c]	9.50 ± 0.50[b]	5.96 ± 0.04[d]	42.69 ± 0.18[cde]	6.21 ± 0.05[h]	5.16 ± 0.42[e]
4	307.75 ± 2.21[abcd]	195.65 ± 1.55[ef]	3.66 ± 0.01[b]	9.50 ± 0.50[b]	4.80 ± 0.04[i]	44.24 ± 0.15[bc]	5.64 ± 0.04[i]	4.72 ± 0.41[f]
5	321.00 ± 0.80[ab]	196.88 ± 2.57[de]	4.03 ± 0.18[a]	9.50 ± 0.50[b]	4.36 ± 0.10[j]	43.72 ± 0.20[cde]	4.26 ± 0.08[k]	5.24 ± 0.25[de]
6	327.92 ± 1.37[abc]	203.12 ± 1.50[cde]	2.80 ± 0.12[cd]	9.50 ± 0.75[b]	5.31 ± 0.04[efg]	43.64 ± 0.41[cd]	7.56 ± 0.05[f]	5.57 ± 0.42[d]
7	319.42 ± 1.80[ab]	204.23 ± 2.26[cd]	1.62 ± 0.02[g]	10.00 ± 0.50[ab]	6.62 ± 0.06[b]	44.15 ± 0.46[bc]	10.95 ± 0.04[b]	6.82 ± 0.41[b]
8	301.50 ± 0.55[bcd]	205.31 ± 1.86[bc]	2.57 ± 0.06[e]	10.00 ± 0.50[ab]	7.03 ± 0.02[a]	46.42 ± 0.18[a]	11.29 ± 0.04[ab]	7.18 ± 0.27[a]
9	347.67 ± 1.80[a]	215.07 ± 1.81[a]	2.51 ± 0.10[e]	9.00 ± 0.50[bc]	4.68 ± 0.05[i]	45.36 ± 1.60[ab]	5.13 ± 0.05[j]	4.63 ± 0.30[f]
10	303.58 ± 1.29[bcd]	189.01 ± 1.87[fg]	2.47 ± 0.06[e]	9.00 ± 0.70[bc]	5.39 ± 0.05[e]	42.28 ± 0.23[de]	6.66 ± 0.05[g]	6.58 ± 0.43[bc]
11	305.83 ± 0.50[bc]	200.36 ± 1.55[cde]	1.68 ± 0.01[fg]	10.00 ± 0.50[ab]	5.50 ± 0.06[de]	41.95 ± 0.45[de]	8.15 ± 0.08[d]	6.81 ± 0.43[b]

Values followed by different letters with in a column indicate significant difference based on Duncan multiple range test ($p<0.05$).WAC: Water Absorption Capacity; OAA: Overall acceptability

Stickiness

The stickiness of all formulated macaroni demonstrated a substantial change with the tef and chickpea flours incorporation. The addition of chickpea flour to the formulation of pasta led to increase the stickiness (46.42N) of the samples (Figure 3).The tef pasta stickiness was significantly reduced as compared to chickpea pasta. Compared with the value of control (41.71N), the respective stickiness of pasta samples containing 15% chickpea flour and 40% tef at 11.29% and 4.82% level were significantly decreased, respectively. This might be due to the effect of change in surface structure of macaroni strand and starch quality on strand surface during cooking. Moreover, the protein matrix gradually disintegrates releasing extrudes during starch gelatinization, which in turn contributes to an increase in stickiness on the cooked pasta surface (Jayasena and Nasar-Abbas, 2011). A significant decrease in stickiness was observed in spaghetti samples prepared by adding quinoa, broad bean or chickpea flour (Chillo *et al*. 2008a). Hence, the highest stickiness of the chickpea -fortified spaghetti in this study might be related with higher protein and higher amylose contents (Sissons *et al.*, 2005).

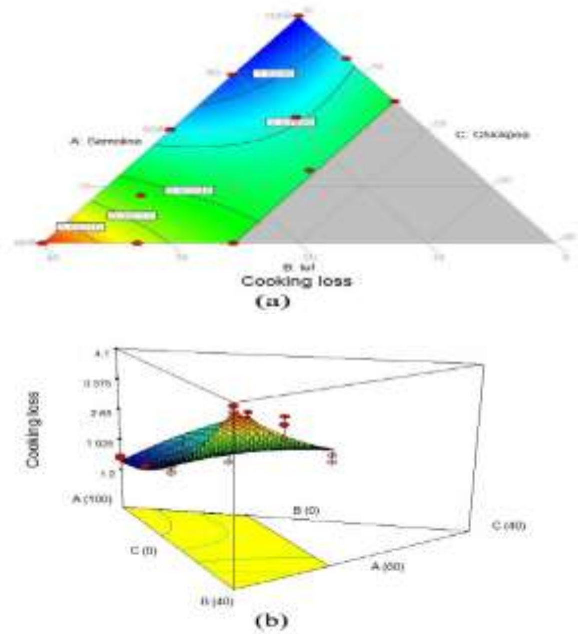

Figure 1: Effect of tef and chickpea blending with durum wheat semolina on cooking loss of cooked macaroni (a) Contour graph and (b) Response surface (3D)

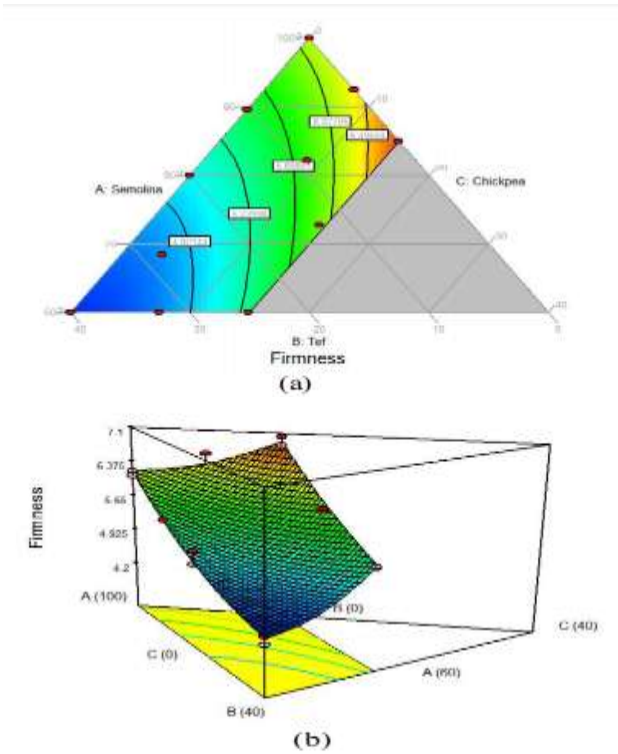

Figure 2: Effect of tef and chickpea blending with durum wheat semolina on firmness of cooked macaroni (a) Contour graph and (b) Response surface (3D).

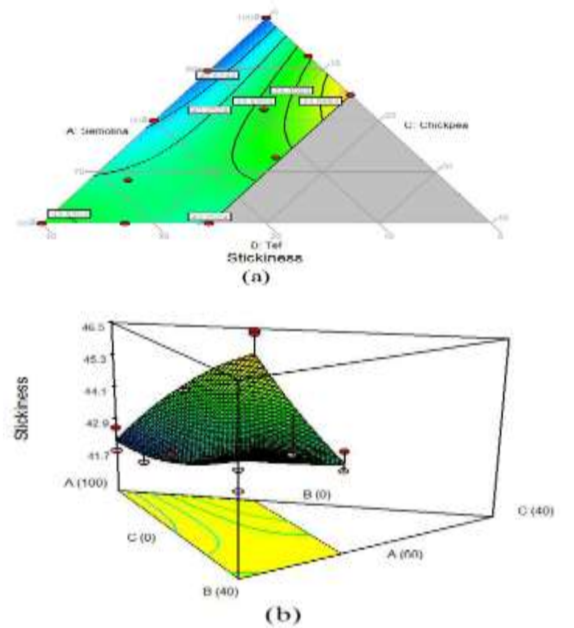

Figure 3: Effect of tef and chickpea blending with durum wheat semolina on stickiness of cooked macaroni (a) Contour graph and (b) Response surface (3D)

Table 4: Analysis of variance for evaluation of models for quality parameters of formulated macaroni

Predictive model	Cooking and textural analysis				
	Cooking weight	WAC	Cooking loss	Firmness	Stickiness
Adj R^2	0.97	0.73	0.98	0.95	0.93
R^2	0.99	0.89	0.99	0.97	0.97
Lack of fit	0.27	0.002	0.13	0.07	0.98
C.v.%	1.16	3.48	4.80	3.35	0.87
Model (Prob>F)	< 0.0001	< 0.0255	< 0.0001	< 0.0001	0.0006

Color score

As compared with durum semolina macaroni, tef incorporated macaroni showed a significant reduction (60%) in color score as the replacement level increased to 40% tef (Table 3).The macaroni samples made by using higher incorporation (>25%) tef flour had an intense dark brown color while those containing lower amounts of tef flour (<20%) showed a light brown color in comparison with the bright yellow color of the durum wheat macaroni. On the contrary, the macaroni samples made from semolina with small amounts of chickpea flour (up to 15%) appeared to have better for color score compared with control, which indicates good quality. These results acceptable as compared with earlier reported for spaghetti made from semolina expected 10 average color scores by Rayas-Durati et al. (1996) and 8.6 average color score by the U.S. durum wheat survey data five-year average (2008-2013 crop years). In addition dried pasta fortified with green pea, chickpea, lentil and tef flour lied in the range reported in this study (Wood, 2009; Petitot *et al.,* 2010; Hager *et al.,* 2012).

Overall acceptance

Most studies on the sensorial evaluation of fortified pasta focused on the overall product acceptability (Petitot *et al.*2010). Blending ratio had a significant (p<0.05) effect on the overall acceptability of the blend macaroni among the 11 experimental formulations based on panelist preference. Addition of more proportion of semolina exclusively or semolina with only chickpea flour produced a macaroni with the highest overall acceptability. No significant difference observed between the control macaroni and semolina-chickpea macaroni blend. In contrast, tef based macaroni had less overall acceptability. These results were in line with the trend of pasta fortified up to a 10-15% substitution with chickpea flour were generally well accepted (Goni and Valentin-Gamazo, 2003; Zhao *et al.,* 2005; Wood, 2009 and Petitot *et al.,* 2010).

Optimization

The optimization on the basis of cooking and textural properties of macaroni, the best mix ratio for producing macaroni from durum wheat semolina, tef flour and chickpea flour (Figure 4). For optimum formulation for better firmness, lower stickiness and lower cooking loss were found to be 67.08 g/100g semolina, 17.93 g/100g tef flour and 15 g/100g chickpea flour.

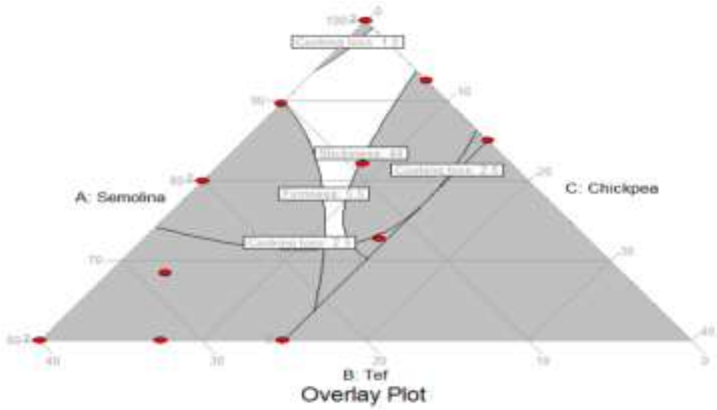

Figure 4: Contour plots illustrating optimization responses for cooking and textural quality using graphical optimization.

Conclusions

The fortification of durum wheat semolina with tef and chickpea flour considerably increased the level of nutritional contents in the macaroni. Exclusively chickpea fortified with incorporation level up to 15% with semolina produced a macaroni comparable color score with durum wheat semolina macaroni. Similarly, though the addition of tef flour considerably increased the cooking loss and it also considerably improved the water absorption capacity/index of the macaroni. The optimum formulation with durum wheat semolina (67.08%), tef (17.93%) and chickpea (15%), macaroni with optimum firmness, lower cooking loss and stickiness of 5.75N, 2.5% and 44N, respectively was obtained. Therefore, macaroni processing industries and consumers can apply this finding to get nutritionally enhanced macaroni and diversify products from tef and chickpea.

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