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Optimization of Fortified Dough Composition for Spaghetti Production using Strong Wheat Flour

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ABSTRACT: The effects of dough fortification with different amounts of gluten and full fat soya flour on the quality of spaghetti were investigated. Rheological properties of dough, quality and sensory characteristics of spaghetti with different amounts of gluten (8 to 14%) and full fat soya flour (0 to 20%) were evaluated. Fortification caused improvement in some characteristics such as dough stability time and loosening degree and also had a negative effect on water absorption and dry spaghetti firmness. Some characteristics such as cooking loss, stickiness, cooking time and sensory features were improved with the addition of gluten while full fat soya flour showed negative effects. Dough development time was improved with more full fat soya flour contents while gluten showed unexpected effects. The optimal dough (12% gluten and 5% full fat soya flour) had improved stability time (68.5%), loosening degree (23%), cooking loss (30.61%), stickiness (15.79%), cooking time (23%) and sensory features (4.6%) as compared to the unfortified spaghetti. It was concluded that fortified dough is not recommended for short spaghetti products due to the higher dough development time than unfortified dough.

Keywords: *Dough, Proteins, Rheology, Sensory Properties, Spaghetti*.

Introduction

Protein is a consequential component which affects the technological features of wheat flour in spaghetti production. It is known that the amount and type of protein can impress the dough rheological trait and pasta quality but the efficacy of the gluten and soya flour protein is not well determined. Previous researches have been carried out to investigate the effects of the type and amounts of different protein sources on the quality of spaghetti. Hard wheat flour (HWF) is the main ingredient of pasta products in some part of the world namely Iran which is deficient in lysine. Since, wheat flour is the basic and common food in developing countries, its fortification is a promising strategy to combat nutritional deficits (Pataco *et al*., 2015). Quality attributes of durum semolina dough fortified with desi chickpea flour was studied. This product had lower cooking loss and stickiness as well as better firmness and sensory properties than the control. Pasta firmness is dependent on gluten content and there is a relation between cooking loss and the protein–polysaccharide matrix (Wood, 2009). Padalino *et al.* (2015) focused on the maize-based spaghetti fortified with chickpea flour. Poor elasticity and increased firmness was the result of using 15% chickpea flour. Guar flour in comparison to pectin and agar showed the best overall sensory acceptance. Martinez *et al*. (2014) investigated the quality of pasta made from bread wheat flour altered with wholemeal amaranth flour. They proposed a maximum

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substitution level of 30% w/w. Maud *et al.* (2010) introduced a fortified spaghetti by adding 35% legume flour (split pea or faba bean) to durum wheat semolina. The product, of course, had higher cooking loss, lower breaking energy and weak structure via the presence of non-gluten proteins and insoluble fibers. The quality was improved by applying very high temperatures during drying cycle, reflecting strengthening of the protein network. Anton *et al.* (2009) fortified the corn starch puffed snacks by adding navy and red bean flours. The fortified product was denser, harder, less expanded and deformed than the control. Common bean flour caused lower cooking time, water absorption and firmness as well as higher cooking loss (Gallegos-Infante *et al.*, 2010). Sissons *et al.* (2007) reported the impact of glutenin and gliadin on the dough strength from semolina. Quality of fortified batter and sponge cake with soya protein isolate was studied by Majzoobi *et al.* (2014). They observed that soya protein isolate had decreased the cake density, springiness, cohesiveness and chewiness while increased batter consistency and density, cake volume, height, hardness and gumminess. Soya protein isolate had also negative effect on the product colour (Majzoobi *et al.* 2014). Soya flour influenced the qualitative and rheological properties of spaghetti produced from semolina (Baiano *et al.* 2011). The results expressed dough weakening, increased ratio of the tenacity to extensibility and lower organic matter releasing in optimal cooking time as the main impacts of soya flour (Baiano *et al.*, 2011). Nasehi *et al.* (2009) deliberated the impacts of full-fat soya flour (FFSF) on the cooking and colour properties of spaghetti. Their findings demonstrated lower cooking time, cooking weight, intensity and colour characteristics as well as higher cooking loss and saturation for the fortified product (Nasehi *et al.*, 2009 b). Pectin and hydroxypropyl methylcellulose showed weakening effect on gluten. Arabic gum affected the viscometric properties of starch (Barcenas *et al.*, 2009). Nasehi *et al.* (2011) findings demonstrated that fortified spaghetti experienced higher acidity and undesired colour changes in storage period. Sereewat *et al.* (2015) indicated that spaghetti produced from defatted soya flour (DSF) had more protein content (near two times) and greater hardness as compared to the spaghetti produced from rice flour. Sensory properties of spaghetti made from rice flour, DSF and the modified starch was analogous to commercial spaghetti made from durum semolina (Sereewat *et al.*, 2015). Saperstein *et al.* (2007) investigated eleven different durum wheat genotypes from North America and Italy. They found that baking quality is in direct relation to the wheat genotypes (Saperstein *et al.*, 2007). In the process time, soya globulins interacted with semolina proteins and lead to form high molecular weight polymers such as sodium dodecyl sulphate-unextractable components (Lamacchia *et al.*, 2012). Addition of full-fat soya flour (FFSF) had a negative impact on the colour attribute, but no effect on the firmness and surface condition of spaghetti (Nasehi *et al.*, 2009a). Raina *et al*. (2005) findings showed that pasta made from pre-gelatinized broken rice flour is firmer and has larger shear strength and less stickiness and adhesiveness as compared to the native broken rice flour.

In this work, dough rheological properties as well as qualitative and sensory characteristics of simultaneously fortified hard wheat flour (HWF) spaghetti with different amounts of gluten and full fat soya flour (FFSF) were evaluated in order to determine an optimal dough formulation.

Materials and Methods

The HWF was supplied by Roshan Flour Company (Tehran, Iran). FFSF and Gluten were provided by Zarin Gol Company (Agh Gala, Iran).

- Flour analysis

Moisture determinations for HW flour and FFSF were carried out according to AACC 44-15.02 and AACC 44-31.01, respectively. Protein determinations for HWF and FFSF were carried out according to AACC 46-19.01. Ash quantifications for HWF and FFSF were obtained according to AACC 08-01.01 and AACC 08-16.01, respectively. Total fat for HWF and FFSF were determined according to AACC 30-25.01. Fiber determinations for HWF and FFSF were carried out according to AACC 32-10.01.

- Spaghetti production

To prepare spaghetti samples, designed amounts of HWF, gluten and FFSF were poured into the mixer (Anselmo, Italy) and mixed with distilled water for 12 min at 70 rpm until reach to 36% humidity dough. Extrusion was accomplished using a single-screw laboratory scale extruder with 60 bars pressure and 65°C. The product with an average diameter of 1.50±0.05 mm were dried at 75 °C for 8 hours and then packed in poly propylene covers (Nasehi *et al.*, 2011).

- Dough analysis

To prevent possible changes in dough quality, all the measurements were performed immediately after dough preparation. Water absorption, dough development time, dough stability time and the dough loosening after 10 min were determined using Farinograph (FE022N, Brabender, Germany) as the standard instrument in accordance to the international standard methods AACC 54-21. 02.

- Spaghetti analysis

In order to determine the spaghetti cooking time, 25 g of spaghetti (5 cm length) was added to 300 mL of distilled boiling water. Then, at 20 s time intervals, a piece of spaghetti has been tested until the complete loss of its white middle colour. To measure the spaghetti cooking loss, 100 g sample was cooked according to the above mentioned procedure. Cooking water was dried in an oven at 115°C for 1 hour to complete water evaporation. The dried residue obtained was considered as the cooking loss. Stickiness was measured for 6 g cooked spaghetti at proper cooking time using a texture analyzer (TA-XT2). A mobile aluminum probe (19×40 mm) with 4 mm. s^{-1} created a 5200 N. m^2 force. To achieve maximum power, probe was raised and separated from the spaghetti surface. Maximum indent under the baseline indicates the stickiness. To determine the resistance to defeat for a spaghetti filament (firmness), a dry uniform strand of spaghetti was forced by 80 mm. min^{-1} mobile probe. 10 times the height of the peak indicates the required power to default the product (Padalino *et al.*, 2015 a).

- Sensory evaluation

Random numerical coded spaghetti samples were evaluated by five trained assessors. They evaluated the colour, stickiness, chewiness and flavor that consisted of taste and aroma with scoring numbers of 1 to 5. Smaller numbers indicate lower sensory acceptance and the greater numbers show more favorable status. The samples and the control were evaluated by 30 home consumers.

Results and Discussion

- FFSF and HWF composition

Chemical composition of applied FFSF and HWF were analyzed as presented in Table 1.

Table 1. Chemical composition of applied FFSF and HWF

	Fiber (%)	Total fat (%)	Protein (%)	Moisture (%)	Ash (%)
FFSF	14	17	37.5	5	5
HWF	0.3	0.9	8	14	0.5

- Dough rheological properties

Water absorption for different dough samples is presented in Figure 1. This is an important factor in spaghetti production where it directly affects the drying time. Thus, processors are looking to achieve better dough with less water absorption. As the results have shown, the maximum and minimum water absorption percentages (70.85 and 52.26%, respectively) were obtained for the highest fortified dough (containing 14% gluten and 20% FFSF) and the normal dough (containing only 8% gluten and without any FFSF), respectively. Figure 1 state that water absorption was increased with an increase in the amount of FFSF in the dough formulation for each constant gluten series treatments. Similarly an increase in the gluten caused a rise in water absorption percent.

Dough development time is the main effective parameter in spaghetti production process. Therefore, less development time leads to more ease of dough plasticity and lower pressure to press template. As Figure 2 presents, dough development time increases by using greater amounts of gluten in the dough formulation. While FFSF had shown a good impact on dough development time, therefore the higher FFSF caused lesser dough development times. Minimum and maximum dough development time (2.03 and 6.02 min, respectively) were observed for FFSF fortified sample (with 8% gluten and 20% FFSF) and gluten enriched sample (contained 14% gluten and without any FFSF), respectively.

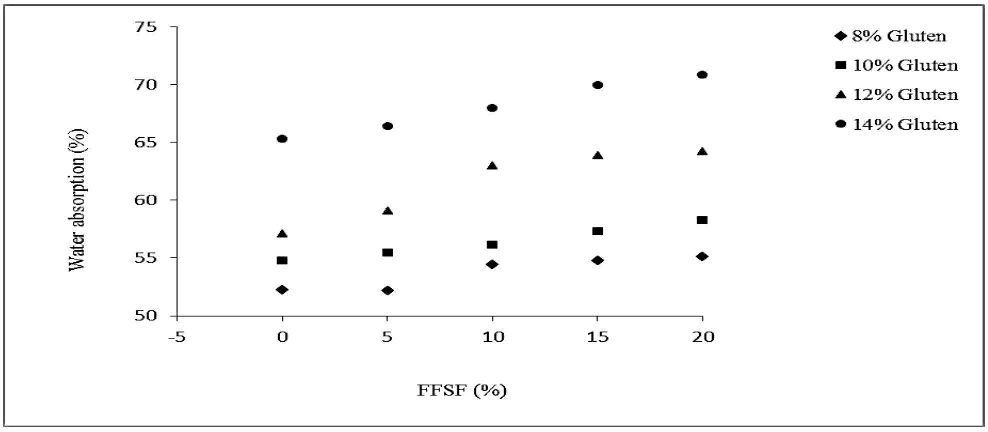

Fig. 1. Water absorption percentage for different dough samples with various amounts of gluten and FFSF in spaghetti production from fortified hard wheat flour

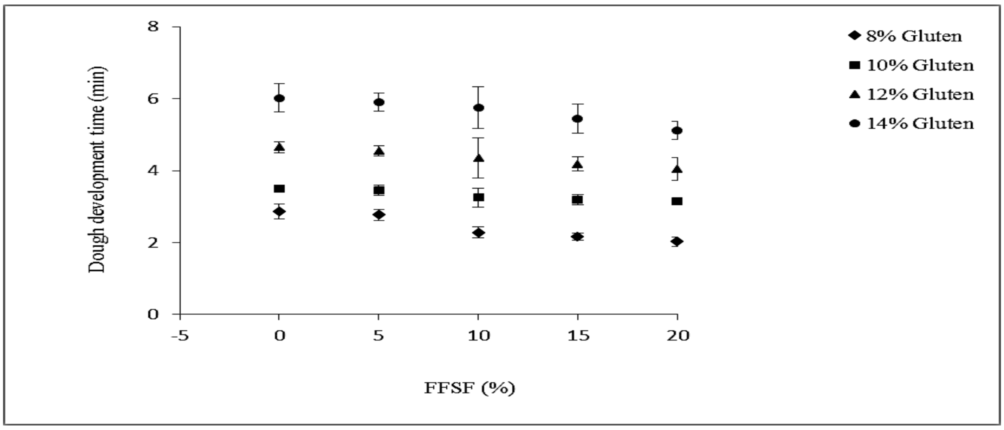

Fig. 2. Dough development time for different dough samples with various amounts of gluten and FFSF in spaghetti production from fortified hard wheat flour

Dough stability time was measured for all studied samples according to Farinograph assessments. Figure 3 demonstrates trend of dough stability time with respect to gluten and FFSF amounts in dough formulation. Based on the obtained results, more contents of both two protein fortifiers caused to increase dough stability times. Maximum value (10.16 min) was observed for the highest enriched sample (14% gluten and 20% FFSF). The minimum stability time (3.65 min) was found for less enriched dough sample (8% gluten and without FFSF).

Dough loosening degree after 10 min was evaluated and is presented in Figure 4. The results indicate positive effect of gluten and FFSF on dough strength. Therefore, maximum strength (the lower dough loosening degree) equal to 45.65 Brabender degrees was obtained for the highest enriched sample (14% gluten and 20% FFSF). The minimum strength (74.15 Brabender degrees) was found for the less enriched dough sample (8% gluten and without FFSF).

- *Spaghetti qualitative properties*

Cooking loss and stickiness experienced a rising trend when FFSF was added to dough formulation. A decreasing profile was observed for cooking loss and stickiness changes by increasing the gluten content in dough. As Figures 5 and 6 showed, the maximum cooking loss and stickiness (17.68% and 956 N. m^2, respectively) were obtained for the highest FFSF enriched sample (8% gluten and 20% FFSF). On the

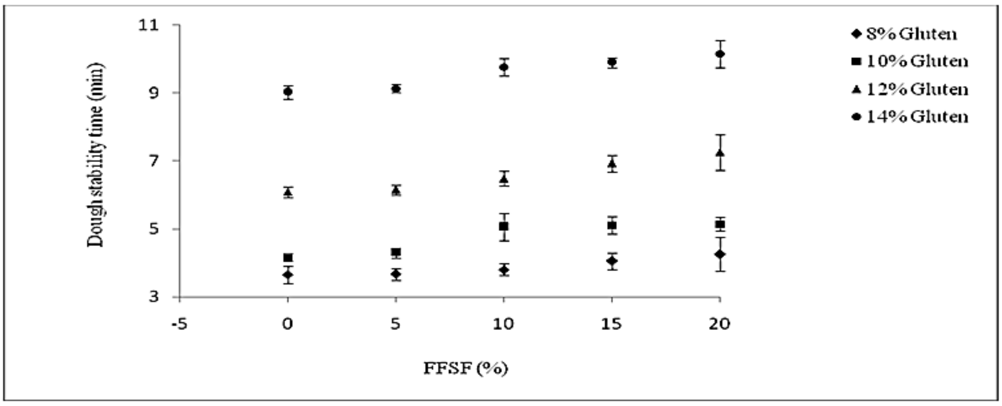

Fig. 3. Dough stability time for different dough samples with various amounts of gluten and FFSF in spaghetti production from fortified hard wheat flour

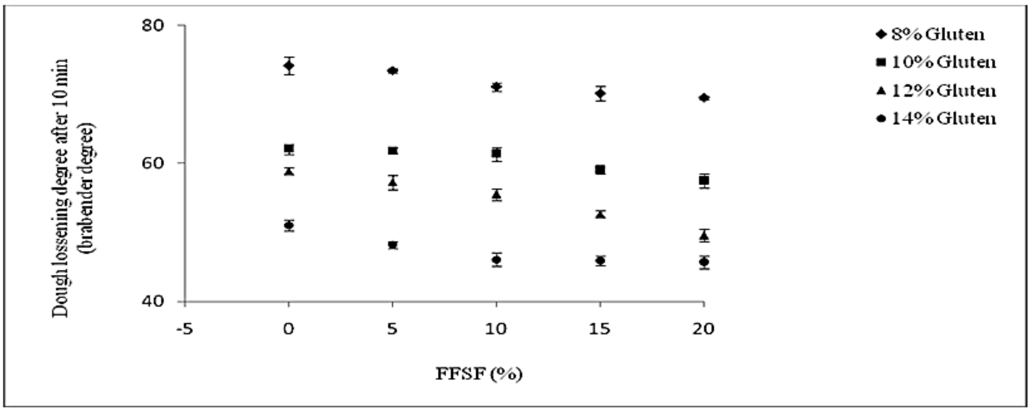

Fig. 4. Dough loosening degree after 10 min for different dough samples with various amounts of gluten and FFSF in spaghetti production from fortified hard wheat flour

other hand, minimum cooking loss and stickiness (6.57% and 452 N. m^2, respectively) were obtained for the highest gluten enriched dough (14% gluten and without FFSF).

When cooking the spaghetti in boiling water, starch granules are gelatinized and simultaneously, gluten has been denatured. When a great numbers of starch granules are gelatinized, the time is defined as the best proper cooking time. The results have shown the positive effect of gluten as well as the negative impact of FFSF on spaghetti cooking time (Figure 7). As it is observed in Figure 7, the maximum cooking time (19.45 min) was obtained for the highest gluten enriched spaghetti (14% gluten and without any FFSF) and the minimum cooking time (11.58 min) was obtained for the highest FFSF enriched spaghetti (8% gluten and 20% FFSF).

The addition of gluten and FFSF caused an undesirable change in spaghetti quality; lower resistance to default for a spaghetti filament (firmness). Obtained results have shown minimum firmness (848 N. m^2) for full fortified spaghetti (14% gluten and 20% FFSF), while common spaghetti sample (8% gluten and without any FFSF) had the maximum firmness equal to 1285 N. m^2 (Figure 8).

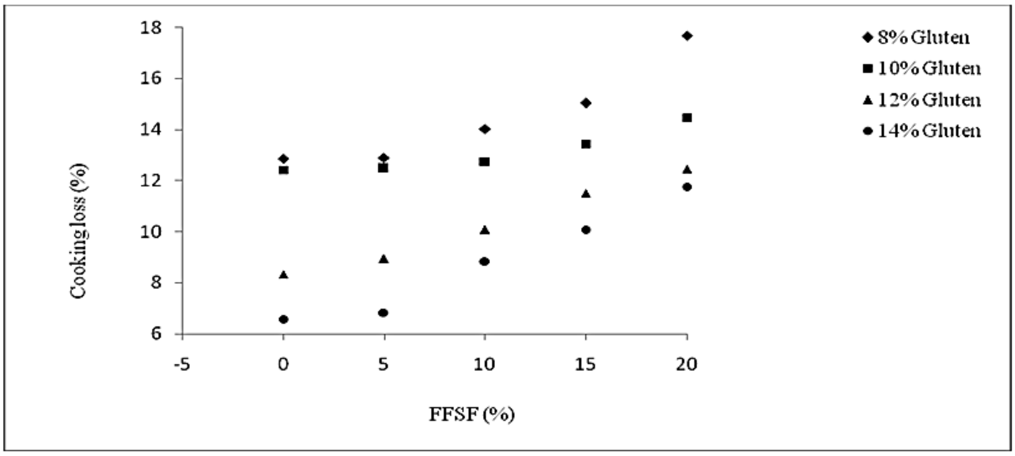

Fig. 5. Cooking loss for different spaghetti samples with various amounts of gluten and FFSF in spaghetti production from fortified hard wheat flour

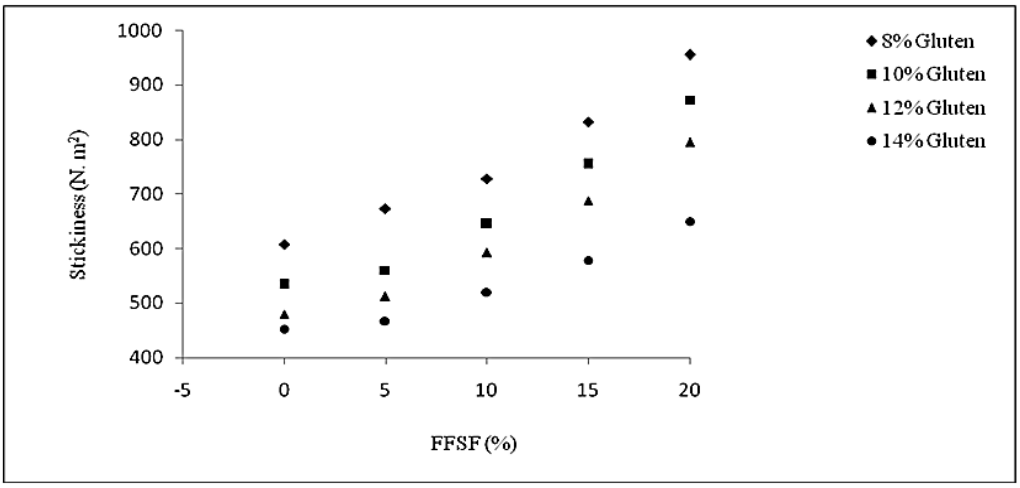

Fig. 6. Stickiness for different spaghetti samples with various amounts of gluten and FFSF in spaghetti production from fortified hard wheat flour

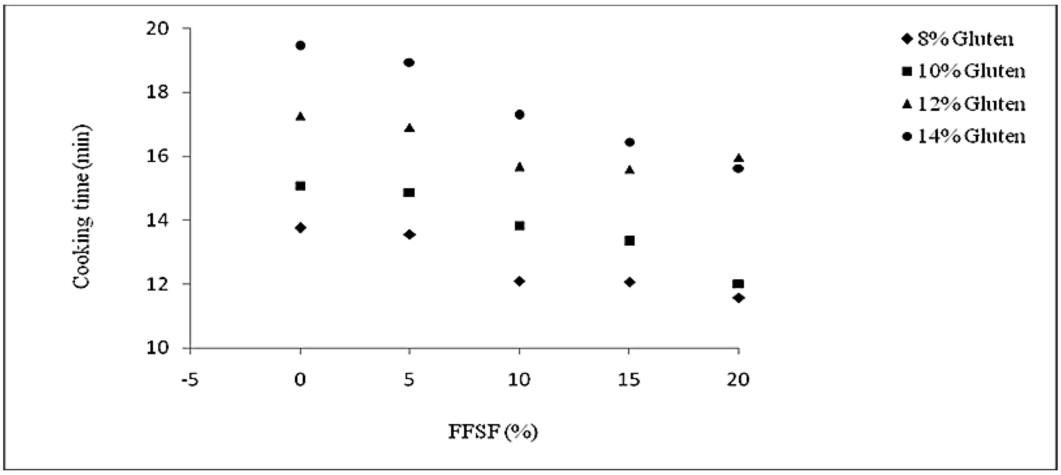

Fig. 7. Cooking time for different spaghetti samples with various amounts of gluten and FFSF in spaghetti production from fortified hard wheat flour

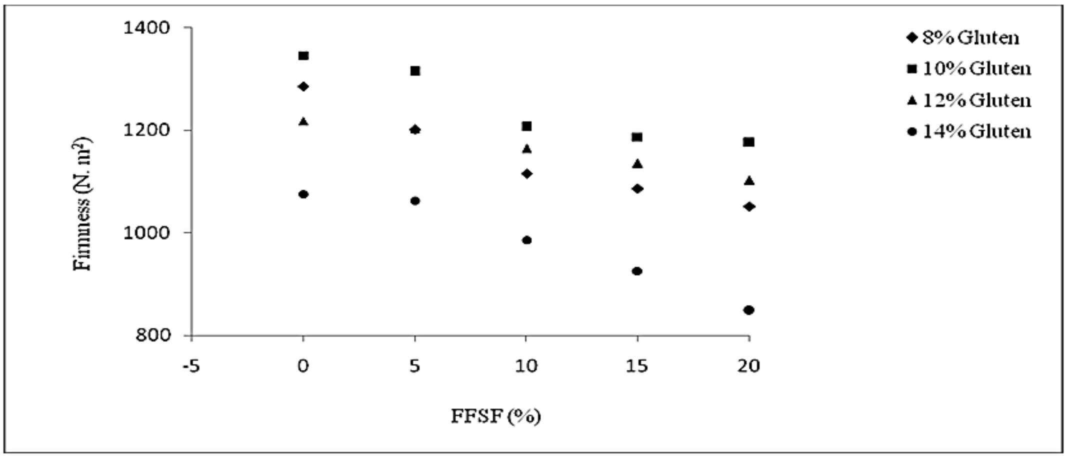

Fig. 8. Resistance to default for a spaghetti filament (firmness) for different spaghetti samples with various amounts of gluten and FFSF in spaghetti production from fortified hard wheat flour

- *Sensory characteristics of cooked spaghetti*

Sensory characteristics points (from 1 to 5) for different enriched spaghetti samples with various concentrations of gluten and FFSF based on the trained assessors and then home arbiters votes are presented in Table 2. Colour, taste and smell, stickiness and chewiness had some unfavorable changes and lower points with adding more FFSF content to spaghetti components (Table 2). The findings indicate that adding more amounts of FFSF had caused lower total sensory acceptance of cooked spaghetti (Figure 9). The addition of gluten had a positive influence on sensory properties (Figure 9). The top selected sample of sensory features (91% acceptance) is the gluten enriched spaghetti (14% gluten without any FFSF) and the least selected sample (only 55% acceptance) is FFSF enriched sample (8% gluten and 20% FFSF).

Spaghetti fortification with FFSF and gluten had undesirable effects on two quality factor; water absorption and resistance to default for a spaghetti filament (firmness).

As Figure 1 presents, water absorption of full fortified sample (14% gluten and 20% FFSF) was 35% higher than the ordinary sample (only 8% gluten and without any FFSF). The analysis of the results have more than the differences between samples with 5% FFSF and 0% FFSF. Therefore, a

Table 2. Sensory characteristics points for enriched spaghetti samples with different amounts of gluten and FFSF

Colour				
Gluten (%)	**8**	**10**	**12**	**14**
FFSF (%)				
0	4.25	4.16	4.32	4.12
5	4.20	4.12	4.28	4.10
10	3.28	3.45	3.56	3.32
15	3.00	3.12	2.90	2.75
20	2.98	3.06	2.83	2.74
Taste and smell				
Gluten (%)	**8**	**10**	**12**	**14**
FFSF (%)				
0	4.50	4.46	4.53	4.48
5	4.42	4.37	4.44	4.40
10	4.18	4.23	4.12	4.15
15	2.90	3.10	3.25	3.14
20	2.67	2.75	2.85	2.82
Stickiness				
Gluten (%)	**8**	**10**	**12**	**14**
FFSF (%)				
0	3.98	4.15	4.37	4.76
5	3.90	4.05	4.22	4.13
10	3.25	3.74	4.05	4.45
15	2.97	3.38	3.80	3.91
20	2.86	3.12	3.56	3.85
Chewiness				
Gluten (%)	**8**	**10**	**12**	**14**
FFSF (%)				
0	3.75	4.28	4.62	4.85
5	3.70	4.20	4.55	4.74
10	3.16	3.68	4.25	4.26
15	3.04	3.07	3.98	3.29
20	2.50	3.02	3.76	3.06

moderated enriched sample (12% gluten and 5% FFSF) was selected as the optimal fortification condition. For the moderate enriched sample, the rise in water absorption was calculated only 13% more than the ordinary sample. Some previous researches are in agreement with our findings (Icard and Feillet, 1999; Orlando and Stauffer, 2002; Park and Kim, 1990). They reported the same unfavorable changes in water absorption with adding soya protein isolate to the composition. Although more water absorption levels are accomplish due to some proper technical features in spaghetti production, but this can cause the dough to unclench with improper cooking quality. Hydroxyl groups of gluten cause more hydrogen bonds and water exchange consequently increase the water absorption. Spaghetti firmness was decreased while gluten and FFSF contents were increased.

Therefore dry spaghetti firmness of full fortified sample was 34% less than the ordinary sample. For the moderate enriched sample, dry spaghetti firmness was only 6.5% less than the ordinary sample.

On the other hand, spaghetti fortification with FFSF and gluten had good positive impacts on dough stability time and dough loosening degree after 10 min. The best results were observed when full enrichment shown that in all gluten treatments, the observed differences between samples contained 5% FFSF and 10% FFSF is much has been performed (Figure 3). Measured stability time for full fortified sample was 2.8 times more than the ordinary sample (8%

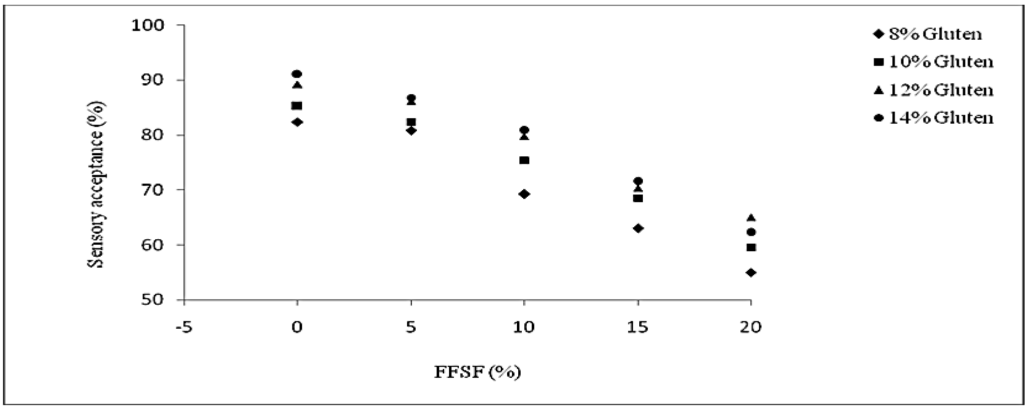

Fig. 9. Total sensory acceptance percent for different spaghetti samples with various amounts of gluten and FFSF in spaghetti production from fortified hard wheat flour

gluten without any FFSF). With regard to Farinograph standards, our ordinary weak dough was converted to a very strong one via gluten and FFSF full fortification. Dough stability time for the moderate enriched sample was evaluated 1.7 times (68.5%) higher than the ordinary sample. Dough loosening degree after 10 minutes is another improved factor via dough fortification (Figure 4). Since, the lower loosening degree indicates more strength; full fortified sample experienced more than 38% increased strength in comparison to the ordinary sample. The moderate sample was also 23% stronger than the ordinary sample.

In some cases, gluten had a positive effect and FFSF showed a negative effect on spaghetti characteristics. Cooking loss, stickiness, cooking time and sensory features had been improved with the addition of gluten to dough composition. On the other hand, adding FFSF had an undesirable negative effect on the mentioned properties. Cooking loss and stickiness were increased by 37.4% and 57.24%, respectively and cooking time and sensory features passed a decreasing rate of 15.78% and 32.25%, respectively when 20% FFSF was added to dough mixture. Nasehi *et al.* demonstrated similar reports in concerned with cooking time and colour (Nasehi *et al.*, 2009, b). The addition of 14% gluten without any FFSF to dough led to an improved cooking loss (50%), stickiness (25.66%), cooking time (41.45%) and sensory features (10.44%) as compared to the ordinary sample. However, the moderate enriched sample had better characteristics in cooking loss (30.61%), stickiness (15.79%), cooking time (23%) and sensory features (4.6%) as compared to the ordinary sample. Nasehi *et al.* (2009) reported similar findings for unfavorable raised cooking loss as a result of adding non-gluten proteins (such as soya protein) to dough formulation. These proteins weakened gluten network and total spaghetti structure (Nasehi *et al.*, 2009 a). The positive effects of gluten on cooking loss were emphasised by some previous researches (Wood, 2009).

In the case of dough development time, different trend has been observed. Gluten had a negative impact on this factor while FFSF showed a good improving effect. Full gluten enriched sample (14% gluten without any FFSF) was the least and full FFSF fortified sample (20% FFSF and 8% gluten) was the best as compared to the ordinary sample.

Conclusion

The addition of gluten and FFSF have shown different effects on qualitative, sensory and rheological properties of spaghetti produced from HWF. Some characteristics such as dough stability time and dough loosening degree after 10 min were improved while some others such as water absorption and resistance to default for a spaghetti filament (firmness) had negative changes. In some cases such as cooking loss, stickiness, cooking time and sensory features, gluten had improving while FFSF showed undesirable effects. Therefore an optimal fortified composition was proposed with 12% gluten and 5% FFSF in dough mixture.

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