

## Effects of Defatted Soy Flour, Xanthan Gum, and Processing Temperatures on Quality Criteria of Spaghetti

A. Ansari<sup>1</sup>, A. Kalbasi-Ashtari<sup>2\*</sup>, and A. Gerami<sup>3</sup>

### ABSTRACT

Spaghetti samples were prepared by replacing wheat flour with defatted soy flour (DSF) at 0, 10, and 20% levels (w/w). Each sample had 4% gluten. In addition, xanthan gum was added at three levels (0.0, 0.2, and 0.4%) to spaghetti dough containing 20% soy flour as a modifying agent. Samples were extruded at 35 or 50°C and dried at, respectively, 52°C for 21h or 72°C for 6 hours. The color, protein content, cooking loss, cooked weight, and firmness of all spaghetti samples were measured. A trained sensory group evaluated chewiness, firmness, stickiness, color, and flavor. The overall results showed that increasing protein level in spaghetti caused an increase in the firmness and cooking loss with a decrease in cooked weight and consumer acceptance. However, when xanthan gum was added to spaghetti dough containing 20% DSF, the positive properties of spaghetti, including cooked weight and consumer acceptances, were improved significantly and its negative aspects, including firmness and cooking loss, were reduced noticeably. When xanthan gum and DSF levels reached, respectively, 0.4 and 20%, and the spaghetti dough was extruded at 50°C followed by drying at average temperature of 72°C, the best spaghetti in terms of physico-chemical and organoleptic properties was obtained.

**Keywords:** Color criteria, Cooking loss, Cooking weight, Drying and extrusion temperature, Gluten, Firmness, Pasta.

### INTRODUCTION

Pasta is a traditional product generally obtained from the hardest wheat flour (semolina) usually from durum wheat (*T. durum*). However, it is not possible to raise durum wheat in some countries; therefore, common wheat flour (*T. aestivum*) is used in some parts of the world. While pasta produced from durum semolina contains a high quality and quantity of gluten proteins, those produced with common wheat flour may not have sufficient gluten of the right composition to make high quality pasta. Some researchers have focused on the possible role of cereals, legumes, and especially soy products as

preventative measures to reduce the risk of cardiovascular disease through food choices (Anderson, 1995; FDA, 1999 and Endres, 2001). Legumes, including soybean, have a potential to reduce the levels of total and low-density lipoprotein (LDL) and cholesterol levels in human blood (Endres, 2001; Sirtori *et al.*, 2004; Doxastakis *et al.*, 2007).

Since defatted soybean is rich in lysine and isoflavone (as an antioxidant), it has been used in the formulation of various food and, recently, in pasta and macaroni products (Degenhardt and Winterhalter, 2001; Edres 2001; Doxastakis *et al.*, 2007; Rocchia *et al.*, 2009). There is a general agreement that protein content affects cooking properties and

<sup>1</sup> Science and Research Center Branch, Islamic Azad University, Tehran, Islamic Republic of Iran.

<sup>2</sup> Department of Food Science and Technology, Faculty of Agricultural Engineering and Technology, University of Tehran, Islamic Republic of Iran.

\* Corresponding author, email: akalbasi@ut.ac.ir

<sup>3</sup> Islamic Azad University, Qazvin Branch, Qazvin, Islamic Republic of Iran



gluten strength (Malcolmson and Matsuo, 1993; Navaro *et al.*, 1993; Dexter, 1981; Del Nobile, 2004; Sissons *et al.*, 2005, 2007). Manser (1981), Kexuan Fang (1996), and Baiano *et al.* (2005) evaluated these cooking properties of pasta in terms of stickiness, firmness, cooking loss, and cooked weight.

Different systems of extrusion and drying, including low temperature (LT), high temperature (HT) and ultra high temperature (UHT) have been used for pasta drying (Braibanti, 1980; Mastuo and Dexter, 1981; Wyland, 1981; Del Nobile *et al.*, 2005). Choosing appropriate temperature for extrusion and drying of spaghetti is important since it affects quality of the final product due to the fact that extrusion temperature has a considerable effect on the solubility and disulfide distribution of wheat proteins (Li and Lee, 1997). When spaghetti is made with whole wheat instead of semolina, and dried at high-temperature (70°C) instead of low temperature (40°C), its original color is enhanced and turned to reddish brown. Also, its mechanical strength becomes lower than those produced with semolina (Manthey and Schorno, 2002). High temperature drying improved the pasta cooking quality (Manser, 1980; Resmini and Pagani, 1988; Dexter *et al.*, 1981) and reduced the cooking loss, decreased cooked weight, and increased pasta firmness (Wyland, 1981; Aktan, 1992; Guler *et al.*, 2002; Baiano *et al.*, 2005).

Xanthan gum is a distinctive hydrocolloid produced by fermentation of *Xanthomonas Campestris*. It has outstanding stability in thermal and acid food with a heteropolysaccharide structure. Xanthan gum is free flowing powder with white to cream color and it is soluble in hot and cold water. Since it keeps low-shear viscosity even at high shear rates, it is easy to pour and mix with other materials (Kohajdová and Karovičová, 2009). It keeps the particles in suspensions and is used as a stabilizer and emulsifying agent at concentrations of 0.1–0.4% in different foodstuffs including bakery products (Urlacher and Dalbe, 1992; Morris, 1995; Becker *et al.*, 1998; Garcia-Ochoa *et al.*, 2000; Chantaro and Pongsawatmanit, 2010).

The objective of this study was to incorporate different levels of defatted soybean flour (DSF) and xanthan gum in spaghetti formulation and use different extrusion and drying temperatures to improve the health and texture values of wheat pasta and compare their cooking quality, physico-chemical and sensorial properties with the regular common wheat spaghetti produced extensively in the Middle East markets, as a control.

## MATERIALS AND METHODS

### Materials

Commercial wheat flour (with 10.52% moisture, 11.80% protein, 1.76% lipid, 0.82% ash, and 75.10% starch), DSF (with a protein dispersive index or PDI of 70), gluten, and xanthan gum were prepared from different sources in local markets. PDI is a consistent criterion of soybean meal that responds to heating time and it is an indicator of minimum heat required to denature its protein. When heating time or temperature of soybean meal in extruder increases, the PDI decreases significantly (Batal *et al.*, 2000; Riaz and Cheewapramong, 2009).

### Equipment

A pilot plant for macaroni production belonging to Samira Macaroni Co. (Tehran, Iran) was used for this experiment. The plant had a Buhler extruder working at 35°C with a kneading time of 10 minutes and 1 ton h<sup>-1</sup> capacity (Buhler Co., Swiss) and a Pavan extruder working at 50°C with kneading time of 15 minutes and 2 ton h<sup>-1</sup> capacity (Pavan Co., Italy). The Buhler and Pavan extruders were attached to low and high temperature driers, respectively. Since this project was done in scale up system, it had two processing treatments. The first one was a combination of low temperature extruder and drier and the second one was a sequence of high temperature extruder and drier.

### Spaghetti Preparation

Spaghetti was made with two different formulas. In the first, wheat flour, gluten with 72% purity, and water (at 42°C) were mixed in specific ratios (mentioned in Table 1). To evaluate the effects of DSF on spaghetti quality, it was replaced with wheat flour at 0, 10, and 20% (w/w) levels. In the first experiment, all the prepared samples of dough spaghetti (with 30% moisture content) were extruded with Buhler Equipment at 35°C and dried at average low temperature (LT) of 52°C for 21 hours. Later, the same samples were extruded with Pavan Equipment at 50°C and dried at an average high temperature (HT) of 72°C for 7 hours. The overall extrusion and drying temperatures of [35+52°C] and [50°+72°C] were used, respectively, for low and high heating to see their effects on quality criteria of the final product. The second formulas were similar to the first, but the resulting dough samples had three levels (0.0, 0.2 and 0.4%) of xanthan gum. While all the prepared samples (including the control) had 4% gluten, the DSF and xanthan levels in control sample were zero.

### Physico-chemical and Color Properties

Moisture content, ash, and protein content were measured with three replicates using AOAC methods (2000). The color criteria (L, a, and b) of the dried spaghetti were measured with a Hunter Lab Colorimeter (Model Hunterlab-D25-9000, USA). The L, a, and b values measure, respectively, the lightness or black to white (0-100), redness, and yellowness (when they are positive) of spaghetti. Strands of spaghetti were stacked

two layers parallel to each other to form a flat surface. The values of L, a, and b were read for three independent triplicates of each sample and their means were recorded.

### Measuring Cooking Properties

The AACC Method 16-50 (2000) was used to determine optimum cooking time, cooking loss, and cooked weight. The cooking loss and cooked weight of spaghetti were measured by heating 25 g of spaghetti in 300 mL boiling distilled water for 10-15 minutes. According to the approved method of 16-50 (AACC 1995), the optimal cooking time was defined when the white center and core color of un-gelatinized starch in spaghetti strands had just disappeared. After cooking, spaghetti was drained and the cooking water collected. Cooked spaghetti was rinsed with water for 30 seconds and drained for one min to expel the remaining water. The rinsate was combined with the cooking water and weighed after complete evaporation (reaching dryness) and expressed as a percentage of the original pasta weight as a cooking loss. At this stage, spaghetti samples were weighed to determine the cooked weight.

### Firmness

Firmness of spaghetti after cooking was measured with an Instron Texture Analyzer (Model Housfield-H5KS, England) using the AACC Method 16-50 (2000). The resulting data or firmness was expressed as the peak force needed to accomplish the first compression or the amount of energy required for shearing of five coded spaghetti strands. While firmness is defined the

**Table 1.** Profile of high temperature (HT) drying system for 7 hours (420 minutes) with weighted average temperature ( $T_{wa}$ )<sup>a</sup> of 72°C in Pavan System.

Time (Min)	45	25	25	25	5	45	45	45	45	45	25	Total= 420 min
Temp (°C)	62	65	75	86	90	82	82	75	74	65	68	Ave temp= 72°C

<sup>a</sup>  $T_{wa} = (t_1.T_1 + t_2.T_2 + \dots + t_{12}.T_{12}) / (t_1 + t_2 + \dots + t_{12})$  where,  $t$  and  $T$  are the time and drying temperature for each time interval, respectively.



positive area under the compression process, adhesiveness is negative area under the peak force and representing the energy necessary to drag the compressing plunger away from the spaghetti sample.

### Scanning Electron Microscopy (SEM)

Morphological observations of the spaghetti particles (before cooking as a food) were made by a Scanning Electronic Microscope (Model LEO 440i, England). The previously dried samples of spaghetti were coated with gold particles and their images taken at 500 and 1,500x magnifications. Three images were collected for each sample.

### Sensory Evaluation

Spaghetti samples were cooked according to Method 16-50 (AACC-1985). Five trained panelists judged each warm spaghetti sample on three separate occasions. According to Martineze *et al.* (2007), the color, hardness, chewiness, flavor and stickiness of individual samples were defined by, respectively, the yellow pigment of spaghetti surfaces, force required to cut through sample strand of spaghetti using front teeth, length of time required to masticate the spaghetti to a state of swallowing, time extent to which two pieces of spaghetti attach together when separated, and mouth or taste feeling of spaghetti after chewing.

While the color, flavor, and chewiness were considered positive attributes designating the highest quality for spaghetti when they achieved the score of 3 on a scale of 1, 2 and 3, the stickiness and hardness

were negative attributes, reflecting the lowest quality when they attained the value of -3 on a scale of -1, -2 and -3. Chewiness got a minimum score when stickiness to the tooth reached the highest level. In other words, adhesiveness increased when stickiness decreased. Then, the sums of positive and negative scores of the above-mentioned organoleptic criteria were obtained for each prepared spaghetti sample and were called the overall acceptance.

### Statistical Analysis

The effects of different variables including DSF at three levels (0, 10, and 20%) and processing treatments at two different conditions ([extrusion at 35°C & drying at average of 52°C], and [extrusion at 50°C and drying at average of 72°C]) on the physicochemical and organoleptic characteristics of the produced spaghetti were evaluated. The resulting data was statistically analyzed using MINITAB-14 and GLM procedures. Then, the best formula was selected and compared with addition of Xanthan gum in dough formula at three levels (0, 0.2, and 0.4%). Two-way analysis of variance (ANOVA) was used and means were compared by using the statistical formula of least significant differences (LSD).

## RESULTS AND DISCUSSION

### Physicochemical Properties

The temperature variations versus dehydration time along with weighted average temperatures in the two dryers are

**Table 2.** Profile of low temperature (LT) drying system for 18 hours (260 minutes) with weighted average temperature ( $T_{w.a}$ )<sup>a</sup> of 52°C in Buhler System.

Time (Min)	30	150	390	600	90	Total= 1260 min
Temp (°C)	40	55	52	54	42	Ave Temp= 52°C

<sup>a</sup>  $T_{w.a} = (t_1.T_1 + t_2.T_2 + \dots + t_5.T_5) / (t_1 + t_2 + \dots + t_5)$  where,  $t$  and  $T$  are the time and drying temperature for each time interval, respectively.

**Table 3.** Physico-chemical properties of spaghetti made different levels of defatted soy flour (DSF) and processed at industrially common conditions (50 °C extrusion+72°C drying) <sup>a</sup>.

Proportion of DSF-WF-G <sup>b</sup> in 100 units weight of spaghetti dough	Moisture (%) <sup>c</sup>	Ash (%)	pH	Protein % (Wet basis)
00-96-4	11.63 <sup>b</sup>	0.52% <sup>a</sup>	5.7 <sup>b</sup>	11.7 <sup>a</sup>
10-86-4	11.62 <sup>b</sup>	0.90% <sup>b</sup>	5.7 <sup>b</sup>	13.6 <sup>b</sup>
20-76-4	11.60 <sup>b</sup>	1.20% <sup>c</sup>	5.8 <sup>b</sup>	16.7 <sup>c</sup>

<sup>a</sup> Means of data with the least significant difference (LSD)  $P < 0.05$ . The similar letters were not significantly different; <sup>b</sup> Proportions of defatted soy flour, wheat flour and gluten, in 100 units of spaghetti dough respectively defatted soy flour, wheat flour, and gluten, <sup>c</sup> Moisture content was expressed on dry basis.

shown in Tables 1 and 2. Table 3 shows different physicochemical properties of the dried spaghetti due to the addition of DSF to their formula. DSF addition increased protein of dried spaghetti from 11.6 to 16.7% due to the high protein content of soy flour and ash. Substituting wheat flour with DSF in spaghetti dough did not cause any noticeable change in the shape of strands. Additionally, the diameter of spaghetti strands in various samples containing DSF was about  $1.69 \pm 0.04$  mm (very close to the control sample).

### Colorimetric Values

The “L” and “b” values of the dried spaghetti containing 10 and 20% DSF were significantly lower than the control (Table 4) due to the low yellow pigment and duller color of DSF. Conversely, the “a” values of the dried spaghetti made with DSF were significantly higher than control pasta, being more red at 20% vs. 10% DSF. Furthermore, the “b” values of dried spaghetti having 20%

DSF were significantly lower than those with 10 and 0% DSF. When spaghetti was extruded at 50°C and dried at 72°C for 7 hours instead of extrusion at 35°C and drying at 52°C for 21 hours, its b value increased slightly due to faster destruction of lipoxygenase and more stabilization of the yellow pigments, which degrades yellow pigments (Table 5). This was mainly due to the higher heat that the product was exposed to during drying time, rather than the temperature of short time extrusion process in both cases. Nasehi *et al.* (2009I) did not find any significant differences in the color properties of formulated spaghettis when extruded for few minutes (less than 10 minutes) and between 35 to 70°C. Some researchers have reported that the lightness reduction of the resulting spaghetti was due to addition of DSF in dough formulation and occurrence of non-enzymatic browning (Acquistucci, 2000; Garcia *et al.*, 2004). These researchers explained that more compounds (such as lysine) were generated in HT than in LT drying of spaghetti.

**Table 4.** Effects of adding defatted soy flour (DSF) (%) color values and cooking qualities of spaghetti made with different formula and processed at conventional conditions (50°C extrusion+72°C drying) <sup>a</sup>.

Proportion of DSF-WF-G <sup>b</sup> in 100 units of spaghetti dough	L	a	b <sup>2</sup>	Cooked weight (g)	Cooking loss (%)	Firmness (N)
00 - 96 - 4	54.0±0.17 <sup>a</sup>	5.9±0.22 <sup>a</sup>	43.65±0.14 <sup>a</sup>	246.4±0.09 <sup>a</sup>	6.29±0.01 <sup>a</sup>	1.75±0.08 <sup>b</sup>
10 - 86 - 4	52.4±0.18 <sup>b</sup>	8.4±0.24 <sup>b</sup>	35.65±0.13 <sup>b</sup>	239.8±0.08 <sup>b</sup>	7.62±0.01 <sup>b</sup>	1.87±0.07 <sup>b</sup>
20 - 76 - 4	49.8±0.19 <sup>c</sup>	9.0±0.26 <sup>c</sup>	35.30±0.13 <sup>b</sup>	239.5±0.08 <sup>b</sup>	7.68±0.01 <sup>b</sup>	2.30±0.09 <sup>a</sup>

<sup>a</sup> Means of data with different alphabetical symbols are significantly different  $P < 0.05$ . <sup>b</sup> Defatted soy flour-wheat flour, and gluten, <sup>c</sup> Chroma=  $(a+b)^{0.5}$ .

**Table 5.** Effects of extrusion and drying temperatures on mean color values and cooking qualities of spaghetti processed with 20% defatted soy flour (DSF) <sup>a</sup>.

Extrusion and drying temperatures	<i>L</i>	<i>a</i>	<i>b</i>	Cooked weight (%)	Cooking loss (%)	Firmness (N)
35 °C (E)+52°C (D)	52.27±0.14 <sup>a</sup>	7.64±0.18 <sup>b</sup>	37.98±0.13 <sup>a</sup>	246.1±0.23 <sup>a</sup>	7.1±0.01 <sup>a</sup>	1.85±0.06 <sup>a</sup>
50 °C (E)+72°C (D)	51.86±0.14 <sup>b</sup>	7.89±0.18 <sup>b</sup>	38.42±0.13 <sup>b</sup>	239.8±0.23 <sup>b</sup>	6.2±0.01 <sup>b</sup>	2.09±0.06 <sup>b</sup>

<sup>a</sup> Means of data with different alphabetical symbols are significantly different  $P < 0.05$ .

### Cooked Weight

The cooked weight of spaghetti with 10 and 20% DSF was significantly lower than the control (Table 4). The addition of non-gluten-forming proteins such as legume's protein can disrupt S-S bonds during gluten formation in dough mixing and this can reduce the ability of dough to hold water and affect cooked weight (Lorimor *et al.*, 1991). Doxastakis and Papageorgiou (2007) added lupin flour (as a source of protein) to wheat flour and found similar reduction in pasta weight. Rocchia *et al.* (2009) mixed soy flour with wheat flour and found soy weakened the gluten by breaking S-S bonds, forming more SH units. The water holding capacities of starch and gluten protein are not equal throughout the cooking process. The weak and discontinuous protein matrixes such as soy-protein permit releasing a greater amount of starch during starch gelatinization, and the cooked weight of spaghetti decreases and cooking loss would increase, as was observed (Table 4).

The low extrusion temperature (between 35 to 50°C) did not affect the cooking properties including the cooked weight of spaghetti. Therefore, the differences of cooked weight and water absorption of spaghetti extruded at 35 and 50°C were not significant. However, when extrusion temperature increases from 50 to 100°C, about 10-30% reduction in cooked weight and 10-40% increase in cooking loss of finished pasta is observed mainly due to the

starch gelatinization process (Oliveira *et al.*, 2004). In fact, the cooking quality of pasta degraded mainly at extrusion temperature of more than 70°C (Abecassis *et al.*, 1994). Furthermore, when the die temperature of extruder increases from 60 to 160°C, the soluble protein content of the final product decreases (up to 70%), mainly because of increase in the content of large molecular weight proteins (Li and Lee, 1997). Damaged starch can be created during high temperature extrusion (and also by mechanical means) and amylolytic enzymes can act on damaged starch (Lintas and Appolina, 1973), which could reduce swelling and pasta hydration (weight gain).

When the drying temperature of spaghetti increased from 52 to 72°C, due to the starch gelatinization process and low gluten content (4%), the water holding capacity of spaghetti diminished and its cooked weight decreased significantly (Table 5). However, when Cubadda *et al.* (2007) made pasta dough with high gluten content (more than 12.5%) and dried at HT (greater than 70°C), they observed positive and noticeable effects on its cooking quality, stickiness, and hardness. While in HT drying starch of spaghetti swelled less than the ones dried at LT, more protein denaturation happened and a stronger gluten network formed, which led to increase in water holding capacity and cooked weight (Wyland, 1981; De Zorzi *et al.*, 2007; Lamacchia *et al.*, 2007).

### Cooking Loss

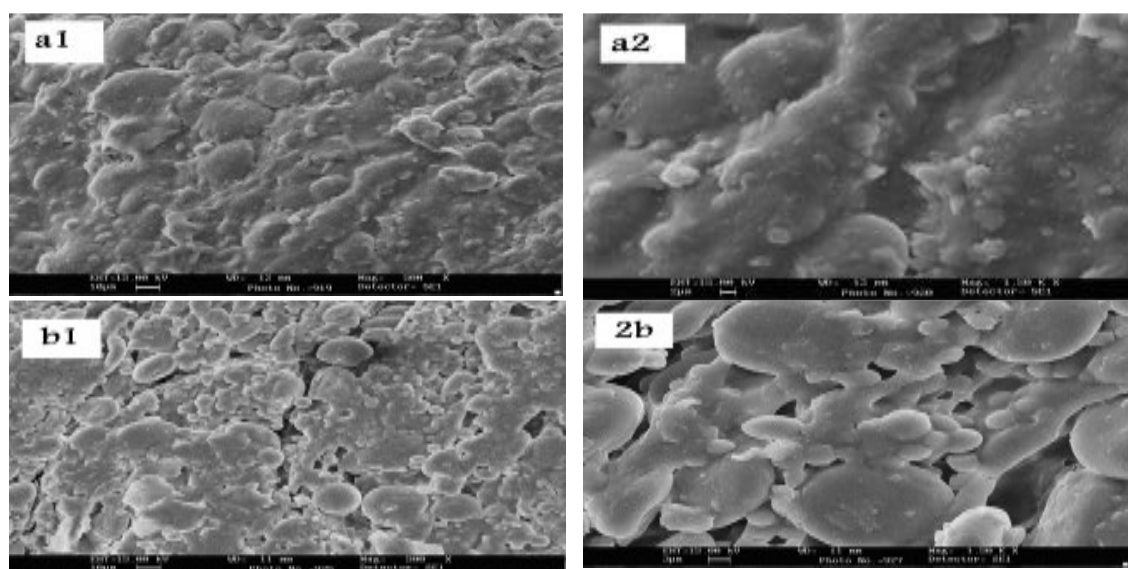
The release of dry matter during water cooking of spaghetti is another important

quality indicator. Low amount of residue in cooking water is desirable for high pasta quality. When the level of DSF increased from 0, to 20%, the cooking loss of spaghetti increased significantly (Table 4). Furthermore, soy protein interacts directly and indirectly with the wheat gluten network. Electrophoresis demonstrated that the presence of soy protein in the washed fraction of gluten was due to the weakening power of soy protein, and they were the indications of strong association (covalent and non-covalent) between the two proteins of soy flour and gluten (Ribotta *et al.*, 2005). Furthermore, since the gluten-soy protein matrix has a porous network, soy protein (with a globular shape) aggregated and immersed into the gluten fibrils (Roccia *et al.*, 2009). Additionally, mixing of non-gluten forming proteins with spaghetti dough caused a dilution effect due to the competition between legume proteins and wheat gluten for water. Because of this, a greater amount of starch granules leached in cooking water during starch gelatinization (Lorimer 1991 *et al.*, Ryan and Brewer 2007, Doxastakis and Papageorgiou 2007). Figure 1 shows scanning electron microscopy (SEM) of spaghetti dried with

and without DSF. Although the two types of spaghetti had a mixture of spherical, cylindrical, and occasionally filamentous particles, the 500 and 1,500 magnifications showed distinctive differences in their structures. In spaghetti without DSF, there was a gluten network (a continuous relationship between the developing gluten film and location of starch granules) and starch granules surrounded by wheat gluten. However, spaghetti with 20% DSF had a discontinuity. Because its matrix had more evident cracks and its gluten network was more porous, the cooked weight related to water holding capacity decreased and cooking loss increased (Table 4).

Extrusion of spaghetti at high pressure and temperatures higher than 50°C causes more damage to the continuous gluten matrix, resulting in the release of more gelatinized starch granules into the cooking water. In this condition, the soluble solid or cooking loss increases noticeably in the extrusion of wheat-soybean pasta (Oliveira *et al.*, 2004).

When drying temperature increased, the gluten-network became more tight (because of porosity reduction) and cooking loss of spaghetti significantly decreased. The partial coagulation of gluten structure during the



**Figure 1.** SEM of control samples of spaghetti with 500x (a1) and with 1,500x (a2), and also formulated sample containing 20%DSF with 500x (b1) and with 1,500x (b2) magnifications, both processed at conventional method (50°C extrusion+72°C drying).



drying process at HT formed a gluten network with lower levels of cracks and, therefore, prevented starch release during the cooking process (Destefains and Sgrulletta 1990, Grant *et al.* 1993, Fang and Khalil 1996, Baiano *et al.* 2005, and Lamacchia *et al.* 2007). According to Yada (2004), the size of gluten polymers increases strongly and forms a tight and bulky network when heated above 50°C. Figure 2 shows the SEM of formulated spaghetti made with 20% of DSF and processed under two extrusion and drying conditions (HT and LT). Low processing temperatures (for extrusion and drying) had more porosity than high processing temperatures. Furthermore, both factors of DSF content and low heating conditions had synergic effects on increased cooking loss of the finished spaghetti due to production of high levels of internal cracks.

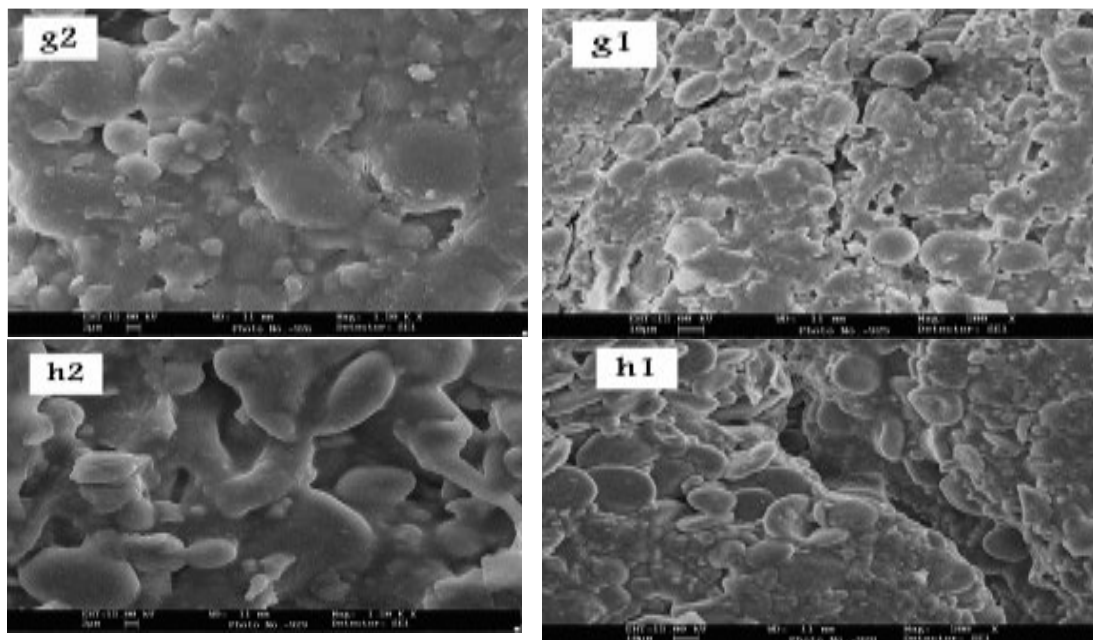
### Firmness

When the level of DSF increased to 20%, the firmness of cooked spaghetti increased significantly (Table 4). Additionally, the

high drying temperature increased the firmness of cooked spaghetti. This effect could be partly due to coagulation of the combined soy protein and gluten matrix network, and also to reduction of starch swelling (Aktan 1990, Malcolmson *et al.* 1993, Fang and Khalil 1996, and also Doxastakis and Papageorgiou 2007). Generally, high temperature is a major factor increasing the structure of large protein polymers and decreasing large monomeric-protein of gluten that results in increasing strength and firmness of spaghetti (Lamacchia *et al.*, 2007). They reduced porous spaces and formed a continuous gluten network. Statistical analysis showed that both DSF and drying temperature had a synergic effect on firmness of the finished spaghetti.

### Addition of Xanthan Gum

Incorporation of full-fat soy flour (up to 12.5%) with spaghetti dough did not increase the firmness of the resulting spaghetti, probably because of its fat content (Nasehi *et al.*, 2009II). Also, DSF with



**Figure 2.** SEM of formulated spaghetti with 20% DSF dried at LT (h1 at 500x and h2 at 1,500x) and HT (g1 at 500x and g2 at 1,500x).



**Table 6.** Effects of adding 20% defatted soy flour (DSF) and xanthan gum (%) on the color values and cooking qualities of spaghetti extruded at conventional conditions (50°C Extrusion+72°C drying) <sup>a</sup>.

Proportions of X –DSF–WF–G <sup>b</sup> in 100 units of spaghetti dough	Cooked weight (%)	Cooking loss (%)	Firmness (N)	L	Chroma <sup>c</sup>
0.00-20-76-4	240.2 <sup>a</sup>	7.3 <sup>a</sup>	2.23 <sup>b</sup>	50.23 <sup>b</sup>	35.68 <sup>b</sup>
0. 2-20-75.8-4	245.4 <sup>b</sup>	6.4 <sup>b</sup>	2.20 <sup>b</sup>	49.35 <sup>b</sup>	36.05 <sup>b</sup>
0. 4-20-75.6-4	248.7 <sup>c</sup>	6.1 <sup>c</sup>	1.73 <sup>a</sup>	50.22 <sup>b</sup>	35.66 <sup>b</sup>

<sup>a</sup> Means of data with the least significant difference,  $P < 0.05$ ; <sup>b</sup> Xanthan gum-defatted soy flour-wheat flour-, and gluten, Respectively, <sup>c</sup> Chroma= (a+b) <sup>0.5</sup>.

spaghetti dough did not improve all of its quality indicators including firmness, cooking loss, cooked weight, and sensorial properties regardless of its processing (extrusion and drying) temperatures (Table 6). To modify these unacceptable quality characteristics, a hydrocolloid of xanthan gum was added at two different levels and spaghetti was made with the conventional processing method (50°C extrusion+72°C drying). Statistical analysis showed that addition of 0.4% level xanthan gum to pasta dough containing 20% DSF significantly improved its cooked weight, and reduced cooking loss and mechanical firmness (Table 7). Morris (1990) reported that interaction of protein and hydrocolloid fills the cracks of the combination of soy protein-gluten network and makes a protein matrix which has higher moisture holding capacity. Furthermore, when the mixture of DSF and xanthan gum was added to spaghetti dough, the textural property (firmness) and color parameters (lightness and chroma) of the resulting product was very similar to the control samples, and no significant differences were detected among

them (Table 6).

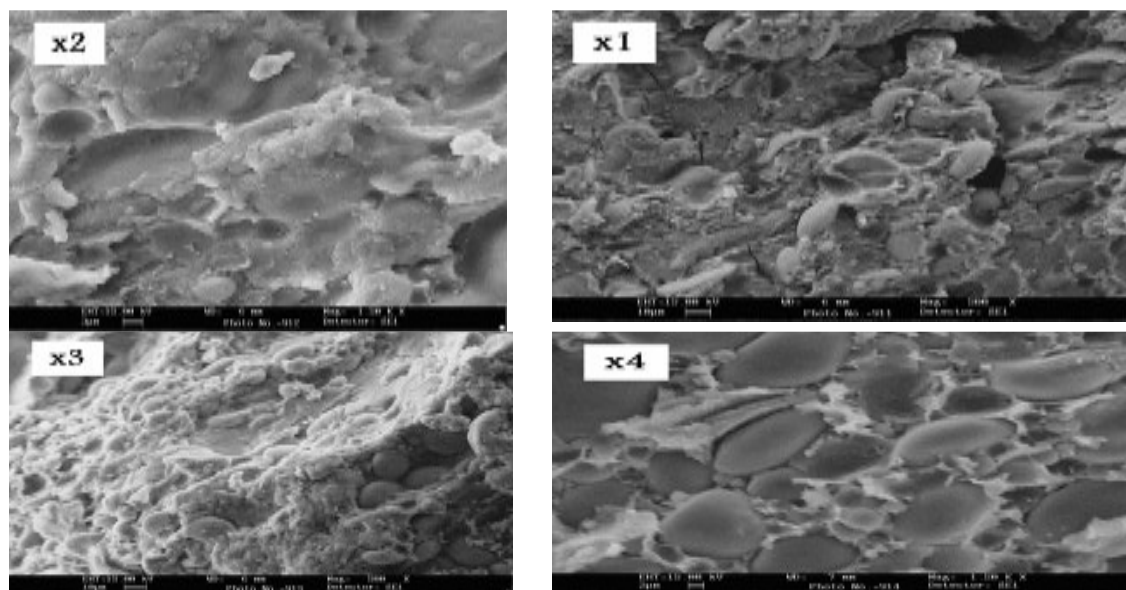
### Sensory Evaluation

The particle size of powdered raw materials has noticeable effects on sensory criteria of the resulting spaghetti. According to Manthey and Schorno (2002), the hydration rate of raw materials affected the appearance and hardness of spaghetti during different processes, and the particle size of wheat flours has effects on its water uptake. The particle size experiment of wheat flour, DSF, and gluten powders showed that more than 57, 70, and 80% pass through the 125 µm sieve, respectively. The overall acceptance results showed that spaghetti prepared with 20% DSF and processed at (50°C extrusion+72°C average drying temperature) improved to some extent the favorable sensorial values (such as color and flavor) and reduced the unfavorable ones such as stickiness compared to the LT sample (produced at 35°C extrusion+ 52°C drying) and the control sample. However,

**Table 7.** Effects of adding defatted soy flour (DSF) (%) and xanthan (%) on the sensory criteria of produced spaghetti (extruded at 35°C and dried at 52°C) <sup>a</sup>.

X – DSF – WF – G <sup>b</sup>	Color	Flavor	Chewiness	Hardness	Stickiness	OA <sup>c</sup>
0.00-00-96-4	2.18±0.45 <sup>a</sup>	2.42±0.28 <sup>a</sup>	2.37±0.51 <sup>a</sup>	-(1.42±0.21) <sup>a</sup>	-(2.03±0.61) <sup>a</sup>	3.52
0.00-10-86-4	2.62±0.49 <sup>b</sup>	2.48±0.34 <sup>a</sup>	2.20±0.47 <sup>a</sup>	-(2.53±0.39) <sup>b</sup>	-(1.50±0.53) <sup>b</sup>	3.27
0.00-20-76-4	2.83±0.51 <sup>b</sup>	2.57±0.41 <sup>a</sup>	2.43±0.63 <sup>a</sup>	-(2.78±0.46) <sup>b</sup>	-(1.24± 0.46) <sup>b</sup>	3.81
0. 2-20-75.8-4	2.26±0.58 <sup>a</sup>	2.80±0.37 <sup>b</sup>	2.70±0.49 <sup>b</sup>	-(1.35±0.27) <sup>a</sup>	-(0.93±0.29) <sup>c</sup>	5.48
0. 4-20-75.6-4	2.51±0.47 <sup>b</sup>	2.89±0.32 <sup>b</sup>	2.91±0.75 <sup>b</sup>	-(1.16±0.28) <sup>c</sup>	-(0.82±0.24) <sup>c</sup>	6.33

<sup>a</sup> Means of data with the least significant difference,  $P < 0.05$ ; <sup>b</sup> Proportions of xanthan gum, defatted soy flour, wheat flour and gluten, in 100 units of spaghetti dough respectively, <sup>c</sup> Overall acceptance or the summation of positive and negative sensory scores of color, flavor, chewiness, hardness and stickiness after observation and tasting of cooked spaghetti.



**Figure 3.** SEM of formulated spaghetti dough with mixture of 20% DSF and xanthan gum, dried at LT (x1 at 500x and x2 at 1,500x) and HT (x3 at 500x and x4 at 1,500x).

hardness of spaghetti as a disapproving sensory criterion increased noticeably. This was the main reason that xanthan was used as a conditioning agent. The analysis of sensory data showed that the spaghetti enriched with DSF, tendered with xanthan gum at 0.4%, extruded at 50°C, and dried at average temperature of 72°C (with the range of 62 to 90°C) had a higher organoleptic values for color, flavor, chewiness hardness, and stickiness than the control sample, and its overall acceptability score improved greatly by 80% (Table 7). Lamacchia *et al.* (2006) used sensory evaluation technique for cooked pasta dried at three different temperatures of 60, 75, and 90°C and concluded that pasta made at high drying temperature had much better sensorial properties than the ones produced at lower temperature.

## CONCLUSIONS

The results obtained in this investigation indicated that the defatted soy flour (DSF) could be a valuable ingredient for production of spaghetti as a source of

protein. The yield and organoleptic characteristics of cooked spaghetti diminished considerably when DSF was used alone in primary dough. However, the conventional spaghetti dough made with 20% DSF and 0.4% xanthan gum followed by extrusion at 50°C and drying at average temperature profile of 72°C for 7 hours had cooked weight and cooking loss very similar to the control samples. Furthermore, the panelists preferred its color, flavor, chewiness, firmness, and stickiness, in comparison to the control samples. Fortification of pasta products (such as spaghetti and macaroni) and increasing their nutritional value with defatted soy flour have been accepted by the U.S. military, government feeding programs, and for school lunches (Singh *et al.*, 2008). Since substituting DSF up to 35% in spaghetti made with all durum wheat upsurges protein contents of the final product, which is accepted by the consumers (Shogren 2006), incorporating 20% DSF to non-durum wheat flour along with 0.4% xanthan gum is suggested to pasta manufacturers.

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## اثرات آرد سویای بدون چربی، صمغ گزانتان و دماهای فراوری بر شاخص های کیفی ماکارونی

۱. انصاری، ا. کلباسی اشتری، و ع. گرامی

### چکیده

آرد سویای بی چربی در دو سطح ۱۰ و ۲۰ درصد به جای آرد گندم در خمیر اسپاگتی (ماکارونی) به گونه ای جایگزین شد که هر نمونه دارای ۴ درصد گلوتن بود. سپس خمیر گزانتان در دو سطح ۲ و ۴ درصد به نمونه های خمیر اسپاگتی حاوی ۲۰ درصد آرد سویای بی چربی اضافه گردید. آنگاه نمونه های خمیر محصول در درجه حرارت های کم (اکستروژن یا فشردن همراه با حرارت در سی و پنج درجه سانتیگراد و خشک کردن در میانگین پنجاه و دو درجه سانتیگراد به مدت هفت ساعت) فراوری گردید. همزمان نمونه شاهد محصول بدون آرد سویا و گزانتان و در درجه حرارتهای زیاد یا حالت کلاسیک تولید شد. سپس نمونه های اسپاگتی تولیدی در شرایط استاندارد پخت و ویژگیهای فیزیولوژیکی آنها مانند رنگ، پروتئین، وزن پخت شده، ضایعات پخت و سفتی بافت اندازه گیری گردید. در مرحله بعد یک گروه ارزیاب آموزش دیده بازتاب حسی خود را برای رنگ، طعم، جویدن، سفتی و چسبندگی (احساس دهان) ابراز نمودند. نتایج کلی نشان داد که با زیاد کردن پروتئین در خمیر اسپاگتی میزان سفتی بافت و ضایعات پخت محصول افزایش و از سوی دیگر وزن پخت شده و درجه



پذیرش مصرف کننده کاهش می یابد. از طرف دیگر با افزایش درجه حرارت های فرآوری (اکستروژن و خشک کردن) وزن پخت شده اسپاگتی و ضایعات پخت آن کمتر و سفتی محصول بیشتر گردید. هنگامی که میزان آرد سویای بی چربی و گزانتان در خمیر اسپاگتی به ترتیب به ۲۰ درصد و ۴ دهم درصد رسیده و محصول در درجه حرارت های زیاد فرآوری گردید ویژگی های مطلوب محصول مانند وزن پخت شده و شاخص های پذیرش محصول به شکلی معنی دار بهبود یافته و خصوصیات نامطلوب محصول مانند ضایعات پخت به صورت محسوسی کاهش یافت.