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Review article

Technological functionality, sensory properties, and nutritional value of pasta products enriched with different dietary fiber resources: a review

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A B S T R A C T

Today, due to the interest of consumers in nutritional properties of food, the demands for the production of functional foods have increased. Pasta is one of the most important and high-quality cereals products that have gained a special position for the production of functional foods, due to its high nutritional value, reasonable prices, ease of production and maintenance, and quality stability during its storage. Pasta could be therefore considered as a unique and suitable matrix for enrichment with dietary fibers, which contain micronutrients, phenols, sterols, tocopherols, metal ions, and essential amino acids. The purpose of this paper is therefore to review the effects of adding various dietary fiber sources including cereals, legumes, fruits and vegetables, hydrocolloids and starch resistant, to the characteristics of the pasta product. In general, the study of all dietary fiber sources shows that resistant starches have the potential to improve the quality and sensory properties of the product.

Keywords: Dietary fiber, Pasta, Functional food

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1. Introduction

Dietary fibers are considered as an essential component of a healthy diet, and they are resistant to digestion and absorption in the small intestine and undergo fermentation by colonic bacteria in the large intestine (Veronese et al., 2018). Dietary fibers encompass cellulose, hemicellulose, arabinoxylans, arabinogalactans, poly-fructose, oligosaccharides (inulin, gum, pectin and mucilage), cell-wall components (lignin, waxes, chitin, phytates, saponins, tannins and suberin) and resistant starches (Makki et al., 2018; Soliman, 2019). The consumption of dietary fibers is indispensable for reducing glycemic index, cholesterol and triglycerides, and increasing the absorption of vitamins and minerals (Anderson et al., 2009). However, consumers instinctively prefer low-fiber foods and, therefore, it is necessary to design some ways to incorporate high amount of dietary fiber into food products and create functional foods with beneficial effects.

Pasta is considered as a unique and suitable matrix for enrichment with dietary fiber (Table 1) and it has higher suitability than biscuits or other snack foods, and constitutes a dominant part of the diet worldwide (2-30 kg/year consumption) (Shahidi et al., 2008). In addition, its texture is more stable than the bread and is not easily degraded by addition of additives and in a complex food composition (Davoudian et al., 2019). In this context, dietary fiber-enriched pasta products have generally higher acceptability and lower perishability than the enriched breads. Also, at the same amount of enrichment, pasta products present higher beneficial effects; the β-glucan-enriched pasta products have the potential to reduce serum cholesterol more efficiently in comparison to enriched breads (Chillo et al., 2010).

It is also noteworthy that the complex and compact network of the cooked pasta is degraded more slowly by the starch digestive enzymes than in other matrixes. And pasta is a good carrier of biologically active molecules, which allows nutritional and sensory properties to be improved (Palavecino et al., 2020). In this way, the long shelf-life in conjugation with minimal in-home preparations, make pasta a superb candidate to meet the worldwide requirement for the production and availability of convenience foods with health-promoting effects.

In this review paper, the functional, structural, and nutritional properties of pasta products containing various fiber sources including cereals, legumes, fruits and vegetables, hydrocolloids, and resistant starches are highlighted.

2. Cereal-based pasta products

Bran and germ that contain minerals, vitamins, natural antioxidants, and dietary fiber with various health benefits are

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removed during milling process. However, studies dealing with the addition of bran into semolina or the use of whole-durum flour in pasta products have shown that the final product has a dark color and less cooking quality than the sample made from semolina (Table 2) (Edwards et al., 1995). In a study, Manthey and Schorno (2002) prepared the whole wheat flour with the same particle size distribution and higher protein and ash contents than semolina. However, the semolina had higher Falling number and lower amount of starch damage, due to the existence of α-amylase in the germ and aleurone layer, which are discarded during milling process. Starch damage increases the stickiness of the final product owing to its higher water absorption (4-5 times) than normal starch. The water absorption and dough development time in mixograph are increased as function of bran levels. In other words, the mixing time of the dough should be increased to obtain a better texture. The product obtained from whole wheat flour has a rough surface, lower lightness and yellowness, and higher redness than samples made from semolina (Grant et al., 1993; Nasehi et al., 2015).

The bran is also able to reduce the diameter of the final product through weakening the gluten network and decreasing the thickness of spaghetti during drying step. Additionally, the bran causes surface roughness and disturbance in thickness measurement. The cooking time of spaghetti made from semolina is more than the whole wheat flour, because the pores caused by bran particles facilitate the water absorption and reduce the cooking time of the product. The cooking loss of spaghetti obtained from the whole wheat flour during optimum and over cooking was more than the control, mainly due to the fact that bran particles and germ disintegrated the protein network and the particles have water-soluble components (Kordonowy & Youngs, 1985). The presence of the bran particles facilitates the water absorption in the starch and releases a larger amount of amylose from the starch granules to the cooking water. The cooking time increases and the cooking loss decreases as a function of dryer temperature because higher temperature strengthens the gluten network and protects the starch granules during cooking (Edwards et al., 1995). The firmness of semolina spaghetti after optimum or over cooking is higher than the product made from whole wheat flour. The firmness of the product is related to the moisture content of the gluten which results a high cooking quality. Also, the firmness of the samples dried at high temperatures was found to be higher after the over cooking (Aktan & Khan, 1992). In another research, it was however reported that pasta samples enriched with bran had good cooking quality and higher soluble polyphenols (53%), alkylresorcinols (121%), arabinoxylans (64%), dietary fiber (113%), and resistant starch (20%) compared to the control sample (Ciccoritti et al., 2019).

The amount of soluble minerals such as zinc, iron, manganese, and magnesium is increased as a function of bran level. Magnesium, calcium, and manganese losses in the cooked samples reduced as bran levels increased, mainly due to the mineral binding ability of dietary fibers. However, the bran removes some important minerals due to its binding power and this depends on pH value and mineral concentration and solubility (Graf & Dintzis, 1982; Kordonowy & Youngs, 1985).

Barley is rich in β-glucan, tocopherols, tocotrienols, arabinoxylans, and soluble dietary fibers. These compounds have the potential to reduce serum cholesterol and glucose in humans and animals (Yokoyama et al., 1997). The products made from a mixture of 45% semolina, 5% active gluten and 50% barley flour were darker in color and had good cooking qualities despite higher stickiness and lower hardness. Also, no significant difference was found between the amount of β-glucan in cooked and uncooked products (Marconi et al., 2000). The texture index in sensory evaluation of the pasta product containing 75% barley flour declined sharply (Berglund et al., 1992), while Melland et al. (1984) showed that all of the sensory features had appropriate scores, except for the color, which had an opposite trend. However, the enrichment with barley flour up to 40% had a slight effect on the cooking loss, water absorption, and firmness of noodles compared to oat, quinoa, amaranth, and buckwheat (Basinskiene & Schoenlechner, 2007). The β-glucan fiber disintegrates the protein-starch network and alleviates starch digestion through restricting starch gelatinization and sugar release. Incorporating β-glucan into pasta product did not have a significant effect on the optimum cooking time of the product. The sensory properties of the pasta product containing a small amount of β-glucan were similar to that of the control sample. However, a bran after-taste with rubbery and gummy features detected as β-glucan levels increased (Chillo et al., 2010).

Oat contains 1.4–2.2% arabinoxylan and 2–7% β-glucan with higher molecular weight than that of barley β-glucan. There are few published studies on the enrichment of pasta products with oat flour. The use of whole oat flour in the formulation of pasta products increases viscosity and reduces firmness, elasticity, lightness, sensory properties, and chewiness (Bustos et al., 2011).

Buckwheat is extensively used in East-Asia to produce noodles. The pasta product containing 5-30% buckwheat flour had acceptable sensory and rheological properties; whilst, the product was brown in color. Despite a relative increase in water absorption, buckwheat flour did not affect the cooking time of the pasta products dried at 30–40 °C. Cooking loss increased and firmness decreased as buckwheat flour levels increased in the product (Rayas-Duarte et al., 1996).

3. Pasta products based on legumes and oil resources

Legumes flour has also been used to fortify pasta products and had the same effect on the product properties (Table 2). However, unpleasant flavors and odors are produced from the oxidation of lipid-rich legumes, therefore thermal treatments are needed to deactivate lipoxygenase enzymes. Gimenez et al. (2012) showed that the enrichment of pasta product with broad bean led to a rise in cooking loss and a decrease in dough stability and water absorption. The decreased water absorption had a significant effect on the sensory parameters and increased the firmness of the enriched pasta product after over cooking. Moreover, it should also be pointed out that the pasta product had lower optimum cooking time in conjugation with increased protein and oil contents. Obviously, the composition of fatty acids and especially the amount of linoleic acid is effective in determining the spaghetti shelf-life. Morad et al. (1980) also showed that the color and hardness of the samples were similar to the control samples. The addition of non-glutinous proteins may weaken the gluten network and overall structure of spaghetti, thereby leading to solids leach out from the product. Moreover, its addition did not have any effect on protein digestibility of the spaghetti, probably due to the lack of anti-nutritional compounds, and the amount of lysine in all samples increased as degree of substitution increased (Morad et al., 1980).

It was also shown that the pasta product enriched with peanut flour had a surface roughness and increased cooking time, cooking loss, and firmness (Zhao et al., 2005). However, the use of high drying temperatures could mask negative qualities of legume flours. Nevertheless, these conditions deteriorate the color and taste of products due to the Maillard reaction and also lead to a decrease in consumer acceptability. In addition, the protein network disintegration and low starch gelatinization degrees were observed in legume flour-enriched pasta, mainly due to lower swelling degree derived from the differences between particles size distribution (Petitot et al., 2010). Edwards et al. (1995) showed that samples containing chickpea fiber had a lower firmness compared to the control sample after optimum and over cooking. Peanut fiber and its insoluble components disintegrate the starch and protein networks, resulting in a product with less firmness. The increased cooking loss after over cooking indicates that peanut fiber disintegrates the protein network and releases higher amylose content during cooking of the product, which had also lower swelling index and dry weight (Brennan, & Tudorica, 2007).

Gallegos-Infante et al. (2010) found that incorporating common bean (*Phaseolus vulgaris*) flour into semolina decreased the water absorption, cooking time, and moisture content of the product; whilst, the amount of resistant starch increased in the enriched pasta product. In another study, it was shown that the cowpea flour-enriched pasta product had increased water absorption and dough stability and reduced mechanical resistance index and sensory scores (i.e., mouth-feel, color, appearance, and acceptability). On the other hand, the cowpea flour increased the protein, ash and fat contents and decreased the carbohydrate level of the product. It also led to a product with reduced lightness index and increased reddish and yellowish color indices. Despite high water absorption of dough, the product had lower water absorption probably due to high levels of cowpea, which led to exposure of hydrophilic groups upon heating and subsequently lower water absorption capacity. It is also noteworthy that although conventional cooking reduced the cooking loss of the legume-rich product, this effect was decreased as a result of over cooking (Bergman et al., 1994).

In a study conducted by Eftekhar-Fasaiy (2003), it was revealed that the addition of white bean flour reduced the moisture content, cooking time, cooked weight, and sensory properties and increased the ash content, cooking loss, and cracking of the pasta. On the other hand, the protein content of the samples increased and amino acid pattern was similar to that of FAO pattern (Eftekhar-Fasaiy, 2003). It has been also demonstrated that incorporating chickpea flour into pasta products reduced cooking loss and stickiness and increased firmness and resilience. And the overall acceptability of the pasta product was similar to the control sample (Wood, 2009). The evaluation of the lasagne dough containing chickpea flour also showed that the water absorption and the dough development time increased and the strength of dough reduced as a function of flour levels. But the water absorption of lasagne decreased during cooking, so that the textural properties of dough reduced mainly due to its lower consistency and firmness. Also, taste, color and overall acceptability decreased as chickpea flour levels increased (Sabanis et al., 2006). In another researches, it was shown that although the cooking loss, firmness and cooked weight of the pasta product reduced with an increase in legume flour level, the sensory analysis indicated an increase in the firmness and stickiness and decrease in the elasticity with the increase in the level of chickpea flour fortification, mainly due to the high protein content of the flour (Chillo et al., 2010; Zhao et al., 2005).

Soybean contains 12-14% soluble carbohydrate, 12-14% edible fiber, 18-22% fat, 12-14% moisture and 36-42% protein and other valuable compounds such as minerals (e.g., calcium, iron, and zinc), vitamins B_1, B_2 and niacin and antioxidant compounds such as isoflavones. Soybean, despite the lack of sulfur-containing amino acids, cysteine and methionine, has higher lysine content (4-times) than wheat and can compensate for the lysine deficiency in wheat products (Nasehi, 2007). Shogren et al. (2006) showed that sensory analysis of spaghetti fortified up to 35% with soy flour was similar to that of the control sample. However, the starchy mouth-feel in pasta products containing 25-50% defatted soy flour increased sharply, and pasta product with ≥ 35% soy flour showed higher beany and bitter flavors. On the other hand, the results of sensory and nutritional attributes of whole soy flour-fortified spaghetti suggest an improvement in protein, ash and fiber contents and undesirable changes in the flavor, fat and acidity indices (Nasehi et al., 2009a). In another research, the technological and digestible properties of pasta product containing 10% soybean flour were studied under laboratory conditions. The addition of soybean flour slightly reduced the amount of cooking loss and water absorption and the enriched product had higher hardness and adhesiveness than the control group (Chillo et al., 2010). However, Nasehi et al. (2009b) showed that the addition of whole soy flour to the formula declined the cooking time, cooked weight, and color intensity and increased the cooking loss of the spaghetti. In addition, the temperature and extruder speed did not have significant effects on the cooking and color characteristics. However, the optimization process based on the cooking characteristics showed that the best spaghetti contained 12% whole soy flour. In another study, they also showed that the addition of whole soy flour caused a decrease in mechanical strength and shear indices (Nasehi et al., 2016). Furthermore, investigating the effect of storage time on the characteristics of soy spaghetti showed an increase in acidity content and decrease in color indices during seven months of storage at environmental conditions. In other words, the shelf-life of the product is much lower than the control sample (Nasehi et al., 2011). On the other hand, the addition of 7% gluten to the spaghetti formulation containing 25% soy flour improved the cooking properties of spaghetti; the product had the highest cooked weight and protein content and the lowest cooking loss compared to the other samples (Nasehi et al., 2011).

It has been also showed that the replacement of wheat semolina with tiger nut flour (up to 40%) caused the improved nutritional value in terms of its dietary fiber, mineral content, oleic and linoleic acids, and the positive effects on the textural characteristics and cooking behavior. And formulations ranked moderate to good color, appearance, texture, and flavor scores (Martín-Esparza et al., 2018). Oil industrial by-products have been also used to improve the nutritional and sensory properties of pasta products. In this context, spaghetti enriched with 10% olive paste flour was considered acceptable to the sensory panel test and had higher flavonoids, total polyphenols, PUFA/SFA ratio, apigenin, luteolin, and quercetin than the control (Padalino et al., 2018). In a study conducted by Zarzycki et al. (2020), flaxseed flour and cake were used for pasta production. The enriched pasta samples were darker, redder, and less yellow compared to the control, along with longer cooking time and higher dietary fiber, protein, and fat contents. And the weight and volume increase index of the product were not significantly influenced upon enrichment.

4. Fruits and vegetables enriched pasta

The production of fruit/vegetable-enriched pasta is a straightforward strategy to increase the intake of vegetables, fruits, and their healthy compounds (Table 2). Incorporating orange pulp powder into bread dough, based on the farinograph test, led to an increase in water absorption and degree of softness and decrease in dough development time, dough stability and farinograph quality number (Ahmadi & Nasehi, 2017). Also, the dough enriched with potato, carrots and oranges skin fiber powders showed lower stability and higher development time and cooking loss, and all the fibers had high water absorption rates. Moreover, the sensory features such as appearance, color and flavor, and also the cohesiveness and stickiness of the product were lower than the control sample (Yaseen & Shouk, 2007). The addition of mango skin fiber caused an increase in cooking loss and firmness and a decrease in overall acceptability of the samples. In addition, the degree of taste deterioration was higher than that of texture (Ajila et al., 2010).

Spinach has been also used to create a green color and to improve the taste and nutritional value of pasta products. Adding spinach increases the vitamins K, E, C, and B and calcium, iron, and some amino acids. The point that should be considered in the use of spinach is the precise control of the dryer temperature in the range of 70–80°C, because high temperatures cause chemical interactions between magnesium and chlorophyll, yielding an undesirable olive color in the product. Also, the pressure inside the extruder should be increased to reduce the strength of strings of pasta products (Shahidi et al., 2007). Incorporation of spinach or amaranth powder (25%) in formulation yielded pasta products with the same amounts of protein, fat and fiber and also cooking time and cooked weight, while the product containing spinach powder had higher iron content and cooking loss and lower stickiness than the amaranth-fortified product. The textural analysis of uncooked samples showed that the treatments containing amaranth powder have higher firmness, which facilitates its transportation and handling. However, there was no difference between the hardness of samples after optimum cooking process. According to the sensory analysis, the samples enriched with spinach powder had higher color, odor, taste, texture, and overall acceptability scores (Borneo & Aguirre, 2008).

The main purpose of adding tomatoes is to give a red color to food products. The incorporation level depends on the tomato quality and tomatoes are added to products in dry powder form. Accordingly, the addition of tomato powder increased the redness and lightness indices of the pasta product and decreased its yellowness. In addition, the cooking loss, swelling index and water absorption of the enriched product were similar to the control sample. It is also worth to mention that the textural properties of the sample contained a small amount of powder was similar to that of the control, while the product became harder as tomato powder level increased; however, panelists reported similar stickiness and firmness scores to those of the control sample (Pasqualone et al., 2016). The incorporation of tomato peels at 15% w/w of semolina weight in the formulation of spaghetti increased the content of carotenoids and dietary fiber in samples as compared to the control sample. The study on cooking quality and textural evaluation of treatments reported that this enrichment caused a slight increase of cooking loss and consequently the pasta was more adhesive and hard. The overall quality of tomato peel-enriched spaghetti decreased significantly because the pasta showed low elasticity, unpleasant odor, and high firmness with respect to the control sample (Padalino et al., 2017).

In another study, it was shown that pasta product containing garlic powder and hydroxylpropylmethyl cellulose had better cooking, sensory, and textural properties than control sample. The dough was similar to control sample in terms of the water absorption, and the lightness and redness of samples decreased to a blue color, but yellowness increased in cooked samples. Additionally, the cooking loss and cooked weight in sample without hydrocolloid increased significantly compared to control and cooked weight reduced with the addition of gum (Rajeswari et al., 2013). Date seed contains a significant amount of dietary fiber, micronutrients, phenolic compounds (antioxidants), sterols, tocopherols, metallic ions and essential amino acids and it can be therefore used as a cheap and valuable source in the production of functional foods. In this way, Davoudian et al. (2019) studied the properties of picolli containing date seed powder and showed that the protein and moisture contents decreased and fat, ash and fiber contents increased as a function of date seed flour level. In addition, the increasing level of date seed flour increased the cooking loss and decreased the cooking time of pasta product. Interestingly, there was no significant difference between the overall acceptability of treatments and control sample, and the enriched past had higher phenolic compounds content. In general, optimum pasta product with desirable characteristics contained 10% date seed flour.

Table 1. The main fiber sources to enrich paste products.

Ingredient	Optimized level (%)	Reference
Amaranth leaves	25	Borneo et al. (2008)
Broad bean	30	Gimenez et al. (2012)
Buckwheat, Light	Up to 30	Rayas-Duarte et al. (1996)
Buckwheat, Dark	Up to 15	Rayas-Duarte et al. (1996)
Chickpea	Up to 10	Sabanis et al. (2006)
Chitosan	2	Padalino et al. (2013)
CMC	2	Padalino et al. (2013)
Cowpea	Up to 30	Bergman et al. (2004)
Defatted Soy	Up to 35	Shogren et al. (2006)
Durum bran	10	Kordonowy et al. 1985
Full fat soy	17.9	Nasehi et al. (2007)
Full fat soy	25% + 7% gluten	Nasehi et al. (2011)
Inulin	Up to 15	Aravind et al. (2012)
Lentil or green pea	UP to 15	Zhao et al. (2005)
Lupin	Up to 15	Rayas-Duarte et al. (1996)
Mango peel	Up to 5	Ajila et al. (2010)
Onion	10	Rajeswari et al. (2013)
Resistant starch	Up to 20	Aravind et al. (2013)
Spinach	25	Borneo et al. (2008)
Tomato	2.5	Pasqualone et al., (2016)
Unripe banana	45	Agama-Acevedo et al. (2009)
Yellow pea	Up to 20	Zhao et al. (2005)

Table 2. Summary of the effect of different fiber resources on the properties of the pasta product.

Group	Type	Overall Acceptance	Cooking Weight	Cooking Loss	Cooking time	Firmness	Comment
Cereal	Wheat, Oat, Buckwheat, Barley	Decrease	Ineffective	Increase	Ineffective	Decrease	Increase Fe, Zn, Mg
Legume	Broad bean	Decrease	-	Increase	Decrease	Increase	Increase Protein, oil, Ash
	Pea		Increase	Increase	Increase	Increase	
	Pinto beans		Ineffective	Decrease	Decrease	Decrease	
	Chickpea		Decrease	Decrease	Ineffective	Decrease	
	White beans		Decrease	Increase	Decrease	Increase	
	Lentils		-	Decrease	Increase	Increase	
	Soya		Decrease	Increase	Decrease	Decrease	
Fruit	Potato	Decrease	-	Increase	-	-	Increase fiber
	Carrot		-			-	
	Orange		-			-	
	Mango		-			Decrease	
	Garlic		Increase			Increase	
	Tomato		Ineffective			Increase	
Soluble fiber	Xanthan	Ineffective	Ineffective	Ineffective	Ineffective	Increase	Decreased glycemic index
	Guar		Increase	Decrease		Decrease	
	Inulin		Decrease	Increase		Decrease	
	B glucan		Ineffective	Increase		Decrease	
	Locust		Ineffective	Decrease		Increase	
	CMC		Increase	Increase		Ineffective	
Resistance starch	Second and third	Increase	Decrease	Decrease	Decrease	Increase	Decreased cooking loss

Other vegetables have been also applied to modulate the techno-functional and nutritional properties of pasta products. The study of Lu et al. (2018) about enrichment pasta products whit mushroom indicated that incorporation of mushroom powder significantly decreased the extent of starch degradation and the area under the curve of reducing sugars released during digestion, while the total phenolic content and antioxidant capacities of samples increased. A mutual inhibition system between the degree of starch gelatinization and antioxidant capacity of the pasta samples was observed. These results suggest that mushroom powder could be incorporated into fresh semolina pasta, conferring healthier characteristics, namely lowering the potential glycemic response and improving antioxidant capacity of the pasta.

5. Resistant starch enriched pasta products

The addition of resistant starch type II at amount of 10–20% to pasta product reduced the digestibility of starch compared to control (Gelencsér et al., 2008). Also, the cooking loss and cooking time, stickiness and water absorption decreased and better textural properties were obtained than control (Bustos et al., 2011; Vernaza et al., 2012). The starch increased the farinograph water absorption and decreased the dough development time (Aravind et al., 2013). In addition, the fortified product had lower diameter and higher firmness than control sample. And sensory analysis did not display any significant difference between the enriched and control samples in terms of sensory attributes (Hernandez-Nava et al., 2009).

Incorporation of resistant starch type III into pasta product had a little effect on the sensory quality and textural properties of the product. The water absorption was slightly higher in enriched pasta product, while cooking loss was lower than the control sample at optimum cooking time (Sozer et al., 2007). The dough containing resistant starch type III had higher farinograph water absorption and lower dough development time. However, the cooking loss of all the samples containing resistant starch type III was higher than that of resistant starch type II at the same level of enrichment. Also, the cooking time declined as resistance starch levels increased, and the firmness of the pasta product containing resistant starch type III was slightly higher than that of the control sample. Additionally, sensory analysis also did not show any significant differences between the flavor and textural properties of the enriched pasta product and the control sample (Aravind et al., 2013). It is also noteworthy that the addition of resistant starch type IV to the pasta product, despite a decrease in water absorption and an increase in hardness and stickiness, had no significant effect on sensory properties of the product (Bustos et al., 2011). In summary, the use of resistant starches is a straightforward strategy to increase the fiber content in pasta products without negative effects on the final product (Table 2).

6. Hydrocolloids enriched pasta products

Non-starch polysaccharides or gums could be used to produce some pasta products such as canned and frozen ones (Table 2). Gums are used as texture stabilizers against freezing and thawing. Initial studies are based on the role of gums as thickening agents and glycemic index reducers. However, the use of gum as a source of soluble dietary fibers is of great interest to researchers, because a small amount of gum is sufficient to obtain a product with appropriate properties (Nasehi et al., 2011). In this context, the firmness of the pasta product containing up to 2% xanthan gum increased during optimum and over cooking times. There were also no differences between the cooked weight, cooking loss, swelling degree or moisture content of the samples. The samples containing xanthan gum have less iodine binding power than other samples, since xanthan gum forms a network around the starch granules and in turn restricts their high swelling degree and diffusion of their compounds (Edwards et al., 1995). In another research, it was demonstrated that although the addition of guar gum to the pasta formulation increased the stickiness of the product, the cooking loss and water absorption of the enriched pasta were less influenced by guar gum incorporation. Sensory analysis also showed that the quality of the product contained up to 15% guar gum was similar to the control, but the textural indices were reduced (Aravind et al., 2012). The swelling degree, stickiness and cohesiveness increased as gum levels increased; however, dry weight, cooking loss and elasticity of the treatments were significantly reduced at high levels of gum.

Although the Arabic gum-enriched pasta product did not show any significant differences between cooked weight, swelling degree, moisture content and cooking loss of the samples during conventional cooking compared to the control sample (Edwards et al., 1995), it was reported that the incorporation of locust gum into pasta product decreased the cooking loss and increased the firmness and stickiness of the product (Brennan & Tudorica, 2007). On the other hand, the addition of carboxylmethyl cellulose to pasta product lowered the stickiness and slightly increased the cooking loss and water absorption. Also, there were no significant effects on sensory properties, firmness, stickiness or cooking loss. Briefly, many nutritional effects have been observed in low levels of high viscous soluble fibers, such as carboxymethyl cellulose, without affecting the technological and sensory properties (Aravind et al., 2012).

Similar results have been reported in the literature. The addition of inulin to spaghetti formulation increased the amount of dry matter and cooking loss and decreased the water absorption capacity, swelling degree and stickiness of the product. It also reduced the digestibility of the spaghetti, since inulin forms a network around the starch granules and protects them from enzymatic digestion (Brennan et al., 2004). On the other hand, the addition of inulin decreased the firmness, stickiness, taste and appearance scores of the pasta product (Negro et al., 2007; Aravind et al., 2012). In addition, inulin incorporation lowered the dough development time, dough stability and farinograph quality number of dough macaroni, and water absorption and softening degree of the dough increased as a function of inulin level. Furthermore, in extensograph, energy, resistance to extension, extensibility and relative resistance were decreased (Azarpazhooh et al., 2011).

7. Conclusion

In conclusion, a major barrier to accept the consumption of fiber-contained pasta products is the destruction of their properties, such as hardness, stickiness, and so forth. Fibers have different water absorption and water holding capacity due to their various sources and particle sizes. Fiber particles are somewhat larger than starch granules and they are not mixed thoroughly and uniformly, which result in a paste with a weaker and softer structure. Fiber hydrates more rapid than the starch. As a result, the overall structure is softer and optimum cooking time is less than the control sample. The hydrophobicity of fibers also increases the stickiness of the pasta product and cause an unacceptable appearance, especially when fibers did not mix well and accumulate on the surface of the pasta products. All of these effects change the shape and other features of pasta products. While some fiber sources are colorless and tasteless, they are more commonly used in the pasta products than natural and dark color ones and therefore reduce the acceptance of pasta products. It is also noteworthy that unpleasant tastes and odors are produced due to the oxidation of lipid-rich legumes indicating that the thermal deactivation of lipoxygenases is a necessary process. The addition of proteinaceous compounds weakens the gluten network, which provides solid out from spaghetti. Application of gums or high drying temperatures is a solution to this problem.

The addition of fruit and vegetable increases fiber content of the product, followed by an increase in cooking loss and a reduction in the firmness of the final product. On the other hand, soluble fibers do not affect overall acceptability, but increase the cooked weight and improve the product's texture. Many nutritional effects have been observed in low amounts of high viscous soluble fibers, without affecting the quality and sensory properties. Addition of resistant starch improves the properties of pasta products, reducing the cooking loss and increasing firmness and does not affect overall acceptability. In other words, the use of resistant starches is an easy way to increase the amount of fiber content in the pasta products without any adverse effects on the product.

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Conflict of interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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