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Gluten-Free Pasta Based on Corn, Rice, and Quinoa Flours Plus Hydrocolloids

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ABSTRACT: The new gluten-free pasta formulations based on the ratio of corn: rice: quinoa flours (20:60:20) enriched with the different percentages (0.5, 1, 1.5, and 2%) of β-glucan and xanthan (XG) were produced to reduce the gluten-related diseases and glycemic responses. These were then compared with each other and the control (wheat flour) in terms of texture, chemical composition, rheology, color, cooking quality, sensory analysis, prebiotic activity, glucose release, rapidly and slowly digested starch (RDS and SDS), and resistant starch (RS). The highest and lowest values of loss and storage moduli were for the control and sample 1 (2% β-glucan and 0.5% XG), respectively. The control and sample 1 were also comparable in terms of textural and sensorial characteristics. The L* (brightness) of cooked and raw sample 3 reached maximum level, and the highest values of b* and a* were associated with the cooked and raw control. The superior cooking quality was related to the sample 3 (1.5% β-glucan and 1% XG) while sample with 0.5% β-glucan and 2% XG had the minimum value. Regarding functional properties, the sample 3 was the superior sample in terms of prebiotic activity, glucose release, RSD, and RS while the control showed the maximum glucose release in all digestion intervals.

Keywords: Functional Properties, Gluten Free Pasta, Glycemic Responses, Hydrocolloids, Physicochemical Properties.

Introduction

Baking products containing gluten, one of the most abundant proteins in grains (wheat, oat, and barley) may result in celiac disease and gluten sensitivity (Susanna & Prabhasankar, 2013). That is why attention to gluten-free products (GF) has prominently increased in recent years. GF products naturally contain 20 mg of gluten per liter, and acceptable dose is 10 mg of prolamin per day for those who suffer from celiac disease (Susanna & Prabhasankar, 2013). The GF products are more expensive than gluten-containing counterparts in many countries. As a result, it is highly likely to affect patients 'adherence to non-gluten diets (Lambert and Ficken, 2016). Despite the 1% prevalence of celiac disease in Iran, there is a lack of production of GF products probably because of their cost (Gholam Mostafaei *et al.*, 2019). Furthermore,

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gluten-rich baking products including pasta have high popularity among various groups, as their alternatives should be produced the same way as the conventional do in terms of the technical, sensorial, and functional properties. It has been found that starch gelatinization and protein coagulation are two main structural changes during cooking (Tazrart *et al.*, 2018). In recent years, the addition of functional compounds and additives (e.g. starches, proteins, and hydrocolloids) to wheat flour replacers (e.g. corn, rice, and quinoa flours) is an efficient procedure to improve GF pasta structure (Sanchez *et al*., 2006; Jankovic *et al*., 2015; Rocha Parra *et al*., 2015; Culetu *et al*., 2021). Wheat flour replacers are capable of providing a rigid network from their pre-gelatinized and retrograded starch (Larrosa *et al*., 2013). Among all alternatives, rice and corn flour have widely used, and quinoa flour (*Chenopodium quinoa*) is of high importance, with acceptable technical characteristics such as high viscosity, freeze ability, and water-holding capacity. Likewise, this flour is rich in nutritive proteins, minerals, folate, tocopherol, and flavonoids (Gao *et al*., 2017; Makdoud & Rosentrater, 2017). Also, hydrocolloids, a group of hydrophilic polysaccharides, can improve the structure, flavor, and shelf life of GF pasta (Culetu *et al*., 2021). Adding some hydrocolloids to pasta dough promotes its textural properties by preventing other ingredients like starch granules from mechanical damage such as mixing. Moreover, these compounds increase the rehydration rate during cooking and soaking due to their high water-holding capacity and gelling ability. Xanthan gum (XG) is a commonly used non-starch hydrocolloid in the food industry with increasing viscosity and firmness. It also provides the mouthfeel and body of the final products (Larrosa *et al*., 2013; Linares-Garcia *et al*., 2017; Srikaeo *et al*., 2018).

On the other hand, new low-glycemic formulations have recently drawn much more attention. Conventional pasta provides low or medium glycemic responses (Agama-Acevedo *et al*., 2009), as an increase in blood sugar levels is a gradual process, and insulin release also occurs slowly (Garbetta *et al*., 2020). Therefore, the formulation of GF pasta should also reduce the glycemic responses and consequently prevent diabetes and overweight (Agama-Acevedo *et al*., 2009; Kan *et al*., 2020; Sardabi *et al*., 2021). Applying dietary interventions like food-grade fibers to starch-rich food can decrease starch uptake and control blood sugar levels (Kan *et al*., 2020; Sardabi *et al*., 2021). According to AACC (2000), fiber is an edible part of plants with non-digestive properties in the small intestine and fermentative characteristics by colon microflora. Among all used fibers, β-glucan extracted from the oat cell wall is of high importance (Garbetta *et al*., 2020). It has been proved that β-glucan also has prebiotic activity in promoting colon microbiota viability, particularly for *Lactic acid bacteria* and *Bifidobacterium* (Madhukumar & Muralikrishna, 2010). In addition to the functional properties of β-glucan, it has been introduced as a viscous, stabilizing, emulsifying, and gelling agent (Ahmad *et al*., 2009). Besides, XG employed in the formulation can interact with starch and affect the accessibility of gastrointestinal enzymes to starch and subsequently starch digestion (Srikaeo *et al*., 2018).

After cooking, the rigid network containing gelatinized amylose and/or amylopectin and denatured protein provides texture integrity and compact structure and increases the firmness of GF pasta (Foschia *et al*., 2017; Gao *et al*.,

2017). Hence, GF pasta formulation can efficiently affect cooking quality. As a result, the appropriate percentages of wheat flour substitutes and hydrocolloids should be used in order to obtain suitable technological and functional properties at the same time.

In conclusion, the aim of this study was to add the different proportions of XG and β-glucan to a constant rate of rice, corn, and quinoa flour mixture and to evaluate their physicochemical, rheological, nutritional properties and cooking quality. These formulations were finally compared with the conventional one made of durum wheat.

Methods and Materials

- *Materials*

Corn and rice flour were purchased from North Powderiran company while quinoa flour was provided from Farsine company. Xanthan gum and B-glucan were also supplied from Pishgaman and Soren Tak Toos companies, respectively. All the chemicals were provided from Merk (Germany) and Sigma-Aldrich (USA) chemical companies with analytical grade.

- *Preparation of pasta formulations*

Different percentages of XG and B-glucan were added to a constant ratio of corn, rice, and quinoa flour mixture (20: 60: 20), as shown in Table 1. The conventional pasta was prepared with durum wheat as well.

Table 1. The proportion of raw materials used for GF pasta samples and the control

Samples	Corn: rice: quinoa	XG (g/100g flour mixture)	B-glucan (g/100g flour mixture)
1	20:60:20	0.5	2
2		1	1.5
3		1.5	1
4		2	0.5
Control	Durum wheat flour		

- *Processing of pasta*

The pasta samples were processed based on the method of Kamali Rousta *et al*. (2020). Briefly, 70 ml of water was added to 165 g of flour mixture enriched with the used hydrocolloids or durum wheat flour, and the mixture was mixed for 10 min in a pasta extruder (Anselmo Bene Vagienna, Italy) belonged to the Zar Makaron Company. The rigatoni pasta samples were produced at 25ºC and then dried at 75 ºC for 5 hours in a cabinet drier.

- *Measurement of chemical compositions*

The contents of pH, protein, fat, fiber, moisture, and ash in the samples were determined based on AOAC methods (AOAC, 2005). Water activity was evaluated according to the method stated by Demarchi *et al*. (2013) and was measured using a water activity meter (AquaLab Dew Point Water Activity Meter 4TE, Decagon).

- *Cooking quality*

- *Cooking loss*

It was evaluated according to the method described by Makdoud and Rosentrater (2017). Briefly, the remaining solid particles in cooking water were weighed after drying in an oven at 50 ºC for 48 hours. The cooking loss percentage was calculated with equation 1: ((DPW - OPW) /DPW) × 100), where DPW and OPW are the weights of raw and dried pasta, respectively.

- *Optimal cooking time*

It was determined according to the method of AACC 66-50 (AACC, 2000). Briefly, 5 g of dried pasta sample was boiled in 200 ml of water and squeezed between two pieces of glass until disappearing the white center core.

- ***Water absorption of cooked pasta***

It was measured according to the method stated by Agama-Acevedo *et al*. (2009). 12.5 g of pasta samples were boiled in 200 ml of distilled water before draining and rinsing with 50 ml of the distilled water for 1 min and then weighing. This factor was calculated with equation 2: ((CPW-DPW)/DPW) × 100, where CPW and DPW are the weights of the cooked drained pasta and the raw pasta, respectively.

- ***Weight after cooking***

It was evaluated base on the procedure 66-50 of AACC (AACC, 2000). Briefly, the cooked pasta samples were drained and weighed when 12 g of raw pasta sample was boiled in 500 ml of water for OCT. The cooking weight was calculated based on equation 3: ((Wc-Wd)/Wd)×100, where Wc and Wd were weights of cooked and dry pasta, respectively.

- ***Rheological analysis of pasta dough samples***

The procedure of Larrosa *et al*. (2013) was used to measure the rheological properties of pasta dough samples using an Anton Paar Rheometer (MCR301 Rotational Rheometer, Austria). It was equipped with a plate-and-plate geometry system (35 mm diameter, 1.6 mm gap). A frequency sweep test (0.01-10 Hz) was applied to evaluate the storage and loss modulus of dough samples vs. frequency (w) at 20ºC after 10 min of loading the dough on the plate.

- ***Color analysis of raw and cooked pasta samples***

The color of raw and cooked samples was measured by applying a HunterLab Colorimeter (DP-9000, US), possessing the L* (brightness (0 to 100)), a* (redness (120 to -120)), and b* (yellowness (120 to -120)) system (Milde *et al*., 2020).

- ***Texture analysis of raw and cooked pasta samples***
- ***Warner-Bratzler test***

Warner-Bratzler test was applied to measure the firmness of raw and cooked samples using a Texture Analyzer (Hounsfield, H5KS, England). According to Brochard *et al*. (2021) with some modifications, pasta firmness (maximum force peak) was measured in raw or cooked form at OCT using a blade probe with different programs (speed rate (1 mm/s for raw pasta and 60 mm/min for cooked pasta), load cell (500 N), and distance or endpoint (3 mm for raw pasta and 10 mm for cooked pasta)).

- ***Texture profile analysis (TPA)***

Hardness, adhesiveness, cohesiveness, elasticity, and chewiness were measured using Texture Analyzer (6025, Instron co. England) based on the procedure of Tazrart *et al*. (2018).

- ***Measurement of digested starch percentage***

The digestion process and the determination of released glucose were performed according to the procedures of Kan *et al*. (2020) and Rovalino-Cordova *et al*. (2018), respectively. The percentage of digested starch was determined at 0, 20, 40, 60, 80, 100, and 120 min. Also rapidly digested starch (RSD), slowly digested starch (SDS), and resistant starch (RS) were obtained based on the methods described by Goni *et al*. (1997) and Menon *et al*. (2015).

- ***Prebiotic activity of pasta samples***

A co-culture of *Bacillus adolescentis* and *Lactobacillus casei* was employed to evaluate the prebiotic property of samples according to Madhukumar and

Muralikrishna, (2010).

- ***Sensory analysis***

The 5-point hedonic test was used to measure firmness, stickiness, color, and flavor of cooked pasta samples by 10 trained panelists. Scores of 1, 3, and 5 were considered extremely dislike, neither like nor dislike, and extremely like, respectively (Garbetta *et al*., 2020).

- ***Statistical analysis***

All experiments were conducted at least in triple. The means, standard deviation of means, and the significant difference of mean values ($p<0.05$) for all the properties were evaluated with the one-way analysis of variance (ANOVA) and Duncan test using the SPSS.22 software.

Results and Discussion

- ***Analysis of chemical composition***

Table 2 shows the chemical analysis of pasta samples. There were significant differences among the moisture content (MC) and water activity (aw) of pasta samples ($p<0.05$). The control had the highest MC and aw while the lowest MC and aw was related to sample 4. it is related to the high-water holding capacity of hydrocolloids, especially XG (Larrosa *et al*., 2013; Linares-Garcia *et al*., 2017). In general, increasing percentages of B-glucan and XG reduced MC and aw. The standard and safe values of MC and aw for pasta products account for $\leq 12.5\%$ and ≤ 0.6, respectively (Makdoud and Rosentrater, 2017). It was similar to a report in which the addition of quinoa to the pasta provided lower MC than its counterpart made of wheat flour (Torres *et al*., 2021). Therefore, GF pasta samples could remain relatively safe and unchanged during storage. The table also indicates that the values of crude protein, crude fiber and ash of various samples had a significant difference one another ($p<0.05$). As the greatest amount of crude protein and fiber was associated with sample 3 (1% b-glucan and 1.5% XG), and sample 2 (1.5% b-glucan and 1% XG) had the highest level of Ash. The crude fiber in GF samples was more than that of the control, and sample 2 and 3 showed the highest values of crude fiber. pH also ranged from 5.30 (sample 3) to 6.01 (sample 1). It demonstrated that different percentage of hydrocolloids present in pasta sample can affect the chemical analysis (De Paula *et al*., 2017).

Table 2. Chemical composition and pH of pasta samples

Samples	Moisture content (% w/w)	Aw	Crude protein (%)	Crude fiber (%)	Ash (%)	pH
Control	11.75±0.06^{a}	65.61±0.27^{a}	11.48±0.07^{f}	1.82±0.06^{c}	0.78±0.02^{c}	5.40±0.01^{c}
1	10.63±0.06^{d}	64.15±0.27^{c}	11.72±0.07^{d}	1.87±0.06^{c}	0.39±0.02^{d}	6.01±0.01^{a}
2	11.02±0.06^{b}	65.32±0.27^{ab}	12.30±0.07^{b}	2.24±0.06^{b}	0.91±0.02^{a}	5.34±0.01^{c}
3	10.84±0.06^{c}	64.51±0.27^{bc}	12.53±0.07^{a}	2.85±0.06^{a}	0.84±0.02^{b}	5.30±0.01^{d}
4	9.64±0.06^{e}	64.28±0.27^{c}	11.97±0.07^{c}	1.89±0.06c	0.40±0.02^{d}	5.92±0.01^{b}

Each value is the mean ± standard deviation of three replicates. In each column, different superscript letters mean significant differences ($P<0.05$).

- ***Cooking quality***

As shown in Table 3, there were significant differences among cooking quality of pasta samples ($p<0.05$). OCT values of samples had no significant differences except for samples 2 and 3, which were higher. It showed that the medium percentages of XG and B-glucan (1, 1.5%) increased OTC value. Also, cooking loss percentage of the control was in the lowest level while sample 3 (1% B-glucan, 1.5% XG) showed the highest percentage. XG and B-glucan have been proven to limit excessive swelling of starch granules due to the formation of a polymer network between them and protein chains (Milde *et al*., 2020; Krawecka *et al*., 2020). Thus, this phenomenon makes water absorption of pasta samples hard. It showed that XG was more effective than B-glucan in this regard. GF samples with medium levels of XG and B-glucan (1%, 1.5%) had the same water adsorption capacity as the control did. Cooking weight depends on the quantity of water adsorption after cooking and subsequently quality and quantity of the used starch, protein, and fiber (Yahyavi *et al*., 2020). Also, hydrocolloids can interact with accessible amylopectin chains and elevate the water-holding capacity and viscosity. This can increase the sample mass (Srikaeo *et al*., 2016; Makdouk and Rosentrater, 2017). As a result, samples 2 and 3 had the highest values of cooking weight while the lowest values were related to the control and sample 4.

- ***Rheological analysis***

The rheological properties (storage and loss moduli) of pasta samples have been shown in Figure 1. There were significant differences among storage and loss moduli of the samples ($p<0.05$). the storage modulus of all the samples was higher than the loss modulus, showing the elastic behavior of pasta samples. Furthermore, the control had the highest storage and loss modulus, followed by sample 1. It means that increased and decreased levels of b-glucan and XG, respectively, positively affected on two moduli. However, sample 4 with the minimum B-glucan and maximum XG values showed the lowest values of storage and loss moduli in all the studied frequencies. As a result, the high amount of XG can act as a lubricant agent and affect two moduli (Larrosa *et al*., 2013; Linares-Garcia *et al*., 2017). Also, B glucan is a viscous and gelling agent (Ahmad *et al*., 2009), and rheological properties of pasta samples can be influenced by its quantity.

Moreover, all pasta samples indicated the elevated values of elastic and viscose moduli with an increase in frequency (Fig 1), indicating their pseudo-elastic behavior (Javaid *et al*., 2018).

Table 3. Cooking quality of the control and GF pasta samples

Samples	Optimum cooking time	Weight after cooking	Cooking loss	Water adsorption capacity
Control	9.05 ± 0.19^{b}	49.35 ± 0.34^{c}	30.48 ± 0.14^{d}	23.61 ± 0.21^{b}
1	8.47 ± 0.19^{b}	50.87 ± 0.34^{b}	32.22 ± 0.14^{c}	16.93 ± 0.21^{c}
2	10.21 ± 0.19^{a}	53.12 ± 0.34^{a}	32.31 ± 0.14^{c}	23.94 ± 0.21^{ab}
3	10.34 ± 0.19^{a}	54.03 ± 0.34^{a}	34.48 ± 0.14^{a}	24.56 ± 0.21^{a}
4	8.73 ± 0.19^{b}	49.75 ± 0.34^{c}	33.59 ± 0.14^{b}	15.94 ± 0.21^{d}

Each value is the mean ± standard deviation of three replicates. In each column, different superscript letters mean significant differences ($P<0.05$).

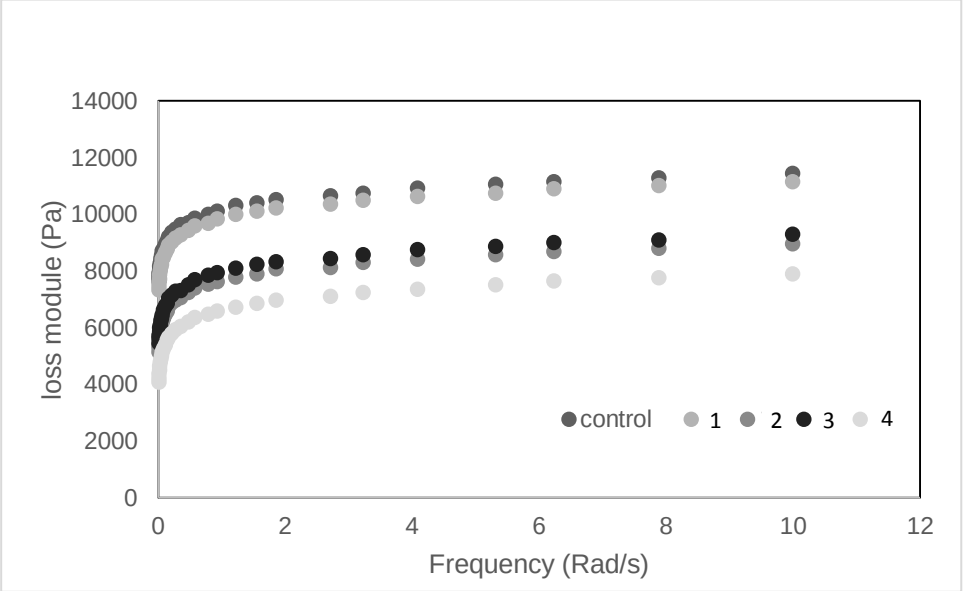

Fig. 1. Rheological analysis of the control and GF pasta samples (Storage and loss modulus vs frequency)

- ***Color analysis***

The color factors (L*, a*, and b*) of raw and cooked pasta samples have been shown in Figure 2. The color of samples was significantly different one another ($p<0.05$). Among cooked pasta samples, sample 3 had the highest brightness (L*) while the control and sample 4 had the lowest one. Also, the highest amount of redness (a*) and yellowness (b*) was related to the control.

For raw pasta samples, the highest brightness was associated with sample 2 and 3, and redness and yellowness of the control (like the cooked) were in the maximum values. The percentages of XG and B-glucan added to GF pasta samples affected color factors, as GF samples enriched with a medium level of hydrocolloids (1, 1.5%) showed higher brightness and yellowness as well as lower redness values. It was in line with the report of Milde *et al*., (2020). Also, the starch content has been proven to provide higher whiteness and transparency for the samples (Torres *et al*., 2021). Quinoa decreased the brightness and yellowness due to its low starch value (50-60%) (Gupta *et al*., 2021). Likewise, cooking and processing can affect all the color factors due to the oxidation of carotenoids present in the pasta samples (Krawecka *et al*., 2020).

- ***Texture analysis***

- ***Warner-Bratzler test***

The firmness values of pasta sample have been shown in Figure 3. There were significant differences among samples (cooked or raw) ($p<0.05$). In general, firmness of raw pasta was higher than that of cooked pasta (no shown statistically). It is related to greater water absorption of the cooked pasta samples (Brochard *et al*., 2021) and weaker protein network during cooking (Makdouk & Rosentrater, 2017). Moreover, the control needed higher strain force to be cut than the GF samples. It was because of the formation of more rigid network by gluten (Brochard *et al*., 2021). In cooked pasta samples, the highest level of B-glucan and the lowest level of XG provided higher firmness than the opposite levels of B-glucan and XG in the sample. Therefore, B-glucan had higher effect on firmness than XG. The results showed that

the used quantity of hydrocolloids is considered the main factor of physicochemical changes of samples (Nasehi, 2020). B-glucan can increase water absorption index, water solubility capacity, and dough viscosity (Krawecka *et al*., 2020). There can be a synergistic interaction between hydrocolloids, depending on their quantity as well.

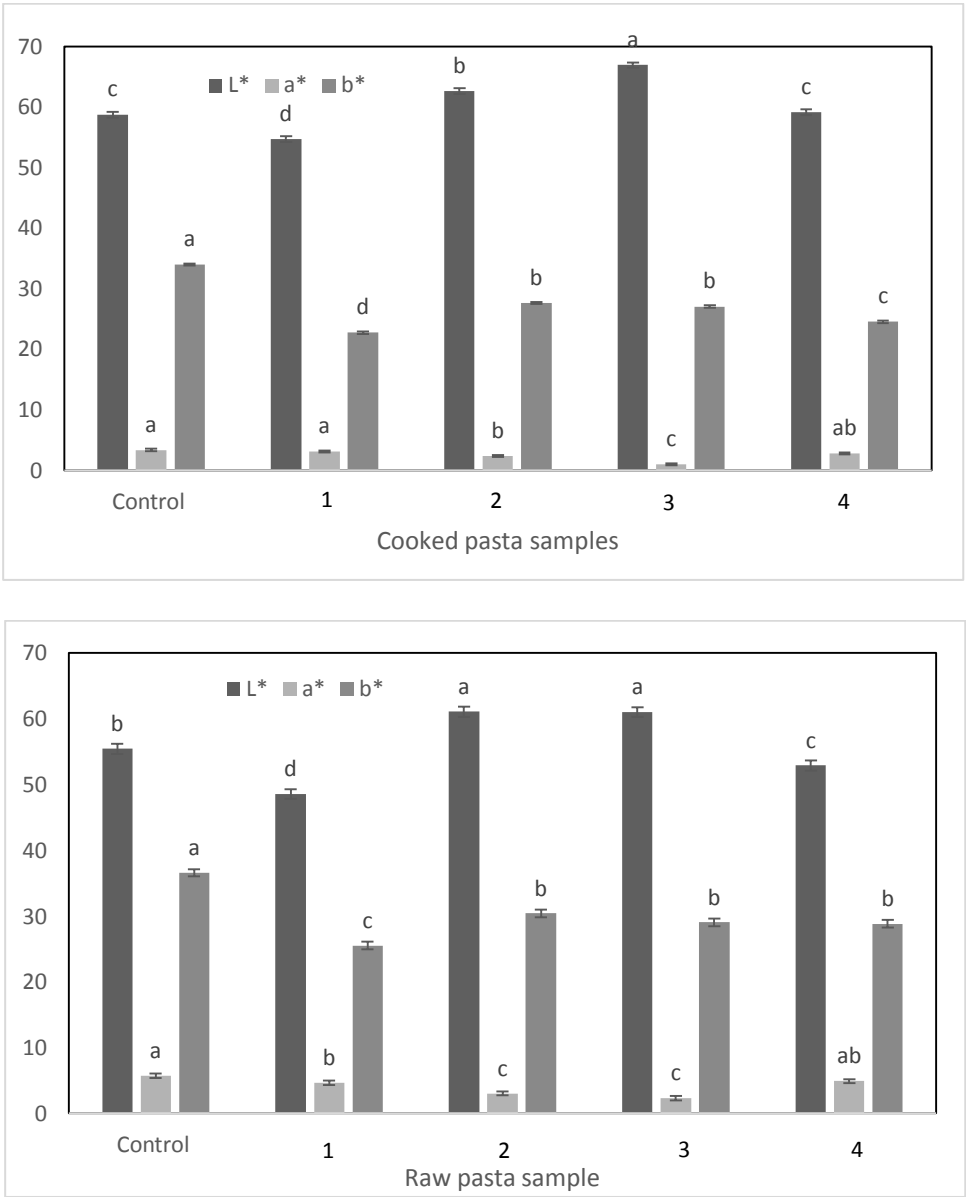

Fig. 2. The color factor of cooked and raw pasta samples.

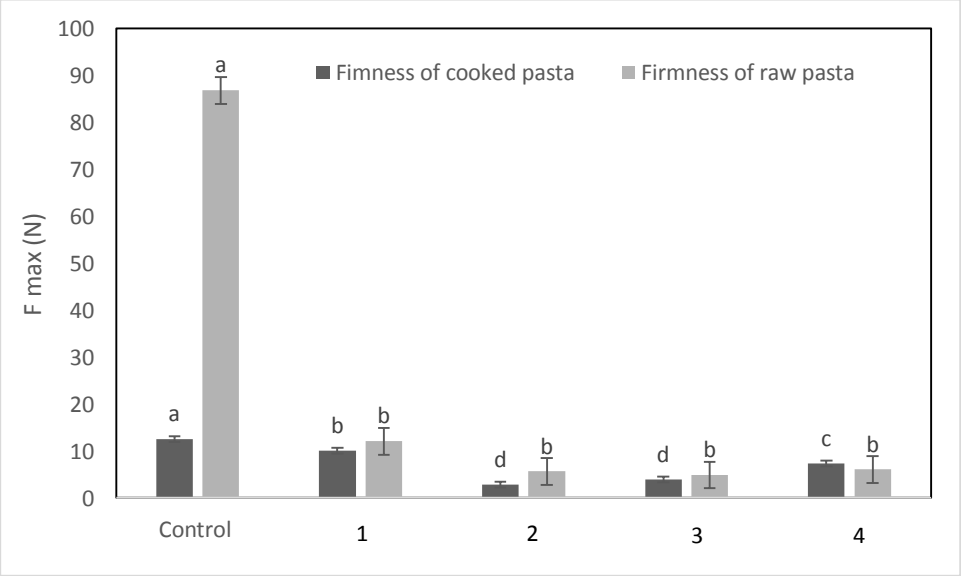

Fig. 3. Firmness (Fmax) of cooked and raw pasta samples.

- *TPA test*

The results of TPA test has been shown in Table 4. There were significant differences among samples in terms of the studied parameters ($p<0.05$). As shown in Table 4, the control and sample 1 had the highest hardness (force peak), cohesiveness (integrity or mouthfeel), elasticity, and chewiness. Also, the maximum adhesiveness (the least stickiness) was related to the control, followed by sample 1. However, the most cases with minimum values of parameters were the samples containing the medium levels of hydrocolloids. The more rigid protein network and more powerful interaction between protein and starch could result in higher values of hardness during experiment (Torres *et al*., 2021). Sample 1 was comparable with the control in this regard. Moreover, less amount of adhesiveness also causes higher stickiness in pasta because of releasing starch granules in cooking water and then covering the surface of pasta (Milde *et al*., 2020). Further, leaching starch in cooking water reduced the chewiness (El-Sohaimy *et al*., 2020; Milde *et al*., 2020). The highest levels of B-glucan or XG in pasta samples increased cohesiveness, elasticity, and chewiness, and B-glucan was more effective than XG in this regard. However, the medium levels of B-glucan and XG in pasta provided lower values of almost all parameters. It was found that XG decreased the cohesiveness of pasta samples while it increased the chewiness of the samples (Milde *et al*., 2020). Therefore, the proportion of hydrocolloids in pasta formulation affect textural parameters.

- *Analysis of prebiotic activity and starch digestion in pasta samples*

The values of the glucose release at different time intervals during the digestion, RDS, SDS, RS, and prebiotic activity of pasta samples have been shown in Table 5. There were also significant differences in the rate of starch digestion during the *in-vitro* experiment ($p<0.05$) (Figure 3). The amount of digested starch during *in-vitro* digestion time intervals in the control was higher than that of the GF. As shown in Table 4, the glucose release values at 20 and 120 min in the control

were higher than those of GF samples. It resulted from lack of fiber in the control formulation because the fibers can encapsulate starch molecules and then decrease the gastrointestinal enzyme effect on these molecules (Susanna and Prabhasankar, 2013). This result was similar to the reports of Menon *et al*., (2015) and Chillo *et al*. (2011). Among GF pasta samples, sample 3 (1% B-glucan and 1.5% XG) containing the medium levels of XG and b-glucan had the lowest glucose release at 20- and 120-min intervals. B-glucan limits starch gelatinization by a decrease in granule swelling, especially at lower concentrations (Chillo *et al*. 2011). Moreover, high viscosity of B-glucan can reduce starch digestibility (Krawecka *et al*., 2020). Also, 1.5% of xanthan added to the sample provided the lowest starch digestion as well (Menon *et al*., 2015).

Also, RDS of the control was in the highest percentage, followed by sample 1. However, sample 3 had the lowest RDS. Interestingly, sample 4 containing 2% xanthan and 0.5% B-glucan had the minimum SDS. Samples 3 and 4 also showed the highest values of RS. It showed that higher levels of XG had more significantly effects on SDS and RS.

There were also significant differences among samples in terms of prebiotic activity ($p<0.05$). Obviously, sample 3 containing the medium levels of XG (1.5%) and B-glucan (1%) had higher prebiotic activity than other samples. The maximum levels of these hydrocolloids had the minimum prebiotic activity. It has been proven that XG and B-glucan have certain beneficial activity on probiotics' viability (Badri and Alizadeh, 2016; Ziaolhagh and Jalali, 2017); however, the quantity of these hydrocolloids used in samples is of high importance as well.

- ***Sensory analysis***

The sensory evaluation has been shown in Figure 4. Sample 1 obtained the best scores in terms of stickiness, firmness, flavor, and color (around or more than 4). Other samples, particularly remaining GF samples, had no acceptable scores for firmness and stickiness. It was because of using non-gluten proteins and inappropriate proportions of hydrocolloids that provides different water-holding capacity and rehydration ratio during cooking (Sozer, 2009).

Table 4. The textural parameters of pasta samples with TPA test

Samples	Hardness	Adhesiveness	Cohesiveness	Elasticity	Chewiness
Control	42.20±1.34^{a}	1.11±0.00^{a}	0.66±0.02^{a}	0.69±0.18^{a}	17.44±0.87^{a}
1	40.56±1.51^{a}	0.97±0.03^{b}	0.66±0.02^{a}	0.62±0.07^{ab}	16.69±2.74^{a}
2	30.44±0.36^{c}	0.82±0.00^{c}	0.45±0.01^{c}	0.51±0.02^{b}	7.08±0.06^{c}
3	32.29±0.26^{b}	0.84±0.01^{c}	0.47±0.02^{c}	0.45±0.01^{b}	6.94±0.15^{c}
4	33.24±0.56^{b}	0.82±0.03^{c}	0.57±0.02^{b}	0.62±0.05^{ab}	11.66±1.12^{b}

Each value is the mean ± standard deviation of three replicates. In each column, different superscript letters mean significant differences ($P<0.05$).

Table 5. Prebiotic activity and glucose release and different starch fractions of pasta samples

Samples	Prebiotic activity Log cfu/ml	Glucose release at 20 min	Glucose release at 120 min	RDS	SDS	RS
Control	7.47±0.08^{b}	55.60±2.55^{a}	93.65±0.61^{a}	52.74±0.87^{a}	31.55±0.78^{b}	15.72±0.55^{c}
1	7.20±0.08^{c}	55.57±2.55^{a}	91.69±0.61^{a}	50.01±0.87^{a}	32.52±0.78^{ab}	17.48±0.55^{c}
2	7.50±0.08^{b}	36.39±2.55^{b}	77.41±0.61^{b}	34.44±0.87^{b}	35.23±0.78^{a}	30.34±0.55^{b}
3	7.92±0.08^{a}	26.77±2.55^{c}	65.32±0.61^{c}	25.26±0.87^{c}	33.53±0.78^{ab}	41.21±0.55^{a}
4	7.20±0.08^{c}	36.88±2.55^{b}	65.32±0.61^{c}	34.94±0.87^{b}	24.26±0.78^{c}	40.80±0.55^{a}

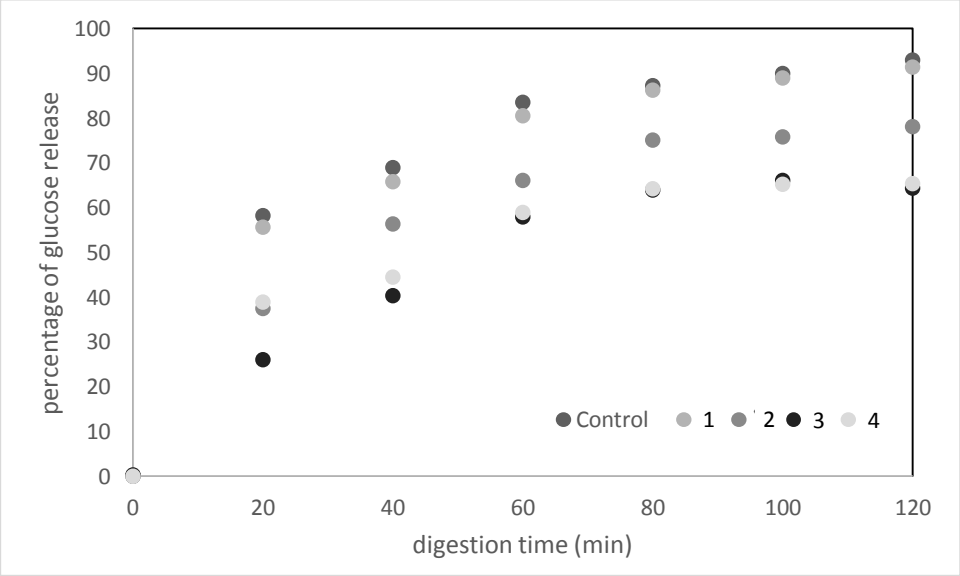

Fig. 4. Glucose release process in *in-vitro* Starch digestion.

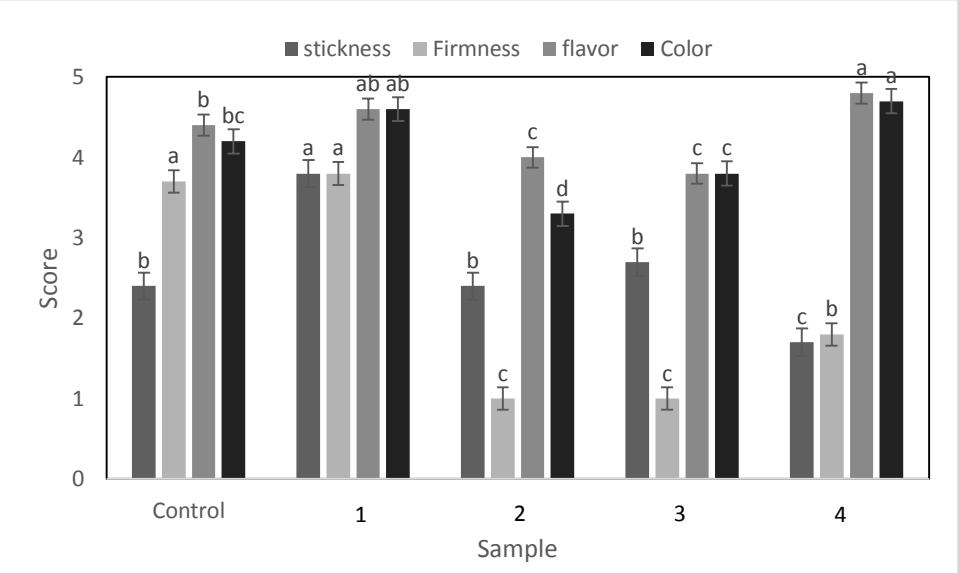

Fig. 5. Sensory evaluation of GF pasta and the control.

Conclusion

It is absolutely essential that new GF formulation be replaced with gluten-containing products due to gluten's side effects. Moreover, attention to glycemic responses of new formulation is a key factor to control other modern health conditions in recent year, as the production of food with low or medium glycemic responses is of high importance. On the other hand, the technical and physicochemical properties of these formulations play an important role in general acceptance as well. Regarding these matters, the precise and appropriate proportions of wheat flour replacers plus hydrocolloids is necessary in terms of both quality and functional properties. As sample 1 containing 2% B-glucan and 0.5% XG had the superior sensorial and textural properties while sample 3 (1% B-glucan and 1.5% XG) had the lowest

glycemic response, and the highest prebiotic activity.

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