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# DEVELOPMENT OF GLUTEN-FREE PASTA WITH CHICKPEAS AS A WHEAT FLOUR SUBSTITUTE AND FORTIFIED WITH CAROB, BEETROOT, AND SPINACH

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*KEY WORDS:*
*gluten-free pasta, celiac disease, chickpea, carob, beetroot and spinach*

ABSTRACT

The study aimed to develop pasta dough using chickpeas as a substitute for wheat flour and fortified with carob, beetroot, and spinach. Three formulations of gluten-free pasta were prepared: F1 (chickpea flour 97% + carob powder 2% + CMC1%), F2 (chickpea flour 87% + carob powder 2% + beetroot powder 10% + CMC1%) and F3 (chickpea flour 87% + carob powder 2% + spinach powder 10% + CMC1%). Physical, chemical, rheological, and sensory characteristics of chickpea pasta were evaluated and compared to semolina flour (CS) as a control. In comparison with conventional wheat pasta, chickpea pasta has a higher content of protein, fiber, and polyphenolic compounds. The results indicated that the incorporation of chickpea as a main ingredient significantly increased the content of protein in the formulations of gluten-free pasta (17.50, 15.05 and 14.88% in F1, F3, and F2, respectively) compared to CS (12.10%). A similar trend was observed for the fiber content (0.45, 1.89, 2.16, and 2.29 in CS, F1, F2, and F3, respectively) and polyphenolic compounds (109.14, 112.14, 141.89, and 178.96 in CS, F1, F2, and F3, respectively). Chickpea pasta demonstrated strong acceptance across all sensory criteria, including texture, odor, shape, and taste. Therefore, this study suggests that chickpeas can serve as an effective substitute for wheat, thereby increasing the availability of healthy options for everyone, particularly for those with celiac disease, obesity, or diabetes.

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# РАЗРАБОТКА БЕЗГЛЮТЕНОВЫХ МАКАРОННЫХ ИЗДЕЛИЙ С НУТОМ КАК ЗАМЕНИТЕЛЕМ ПШЕНИЧНОЙ МУКИ И ФОРТИФИЦИРОВАННЫХ РОЖКОВЫМ ДЕРЕВОМ, СВЕКЛОЙ И ШПИНАТОМ

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*КЛЮЧЕВЫЕ СЛОВА:*
*безглютеновые макаронные изделия, целиакия, нут, рожковое дерево, свекла и шпинат*

АННОТАЦИЯ

Целью исследования была разработка макаронных изделий, используя нут как заменитель пшеничной муки и фортификацию рожковым деревом, свеклой и шпинатом. Было приготовлено три рецептуры безглютеновых макаронных изделий: F1 (нутовая мука 97% + порошок рожкового дерева 2% + карбоксиметилцеллюлоза (КМЦ) 1%), F2 (нутовая мука 87% + порошок рожкового дерева 2% + порошок свеклы 10% + КМЦ 1%) и F3 (нутовая мука 87% + порошок рожкового дерева 2% + порошок шпината 10% + КМЦ 1%). Оценивали физические, химические, реологические и сенсорные показатели макаронных изделий с нутом по сравнению с образцом из муки из твёрдой пшеницы (CS) в качестве контроля. По сравнению с обычными пшеничными макаронными изделиями, макаронные изделия с нутом имели более высокое содержание белка, клетчатки и полифенольных соединений. Результаты показали, что введение нута как основного ингредиента существенно увеличивало содержание белка в различных рецептурах безглютеновых макаронных изделий (17,50; 15,05 и 14,88% в F1, F3 и F2, соответственно) по сравнению с CS (12,10%). Аналогичная тенденция наблюдалась и для содержания клетчатки (0,45; 1,89; 2,16 и 2,29 в CS, F1, F2, и F3, соответственно) и полифенольных соединений (109,14; 112,14; 141,89 и 178,96 в CS, F1, F2, и F3, соответственно). Макаронные изделия с нутом также показали хорошую приемлемость для всех сенсорных показателей, включая текстуру, запах, форму и вкус. Таким образом, данное исследование говорит о том, что нут может быть использован как эффективная замена пшеницы, повышая доступность полезных вариантов для каждого и особенно для тех, кто имеет целиакию, ожирение или диабет.

## 1. Introduction

Pasta is widely consumed worldwide and is considered a vital component of human nutrition since it is affordable, easily stored, palatable, and manageable [1].

Traditionally, durum wheat semolina is used to make pasta. However, a number of studies have been done to improve the nutritional content of pasta by partially or entirely substituting durum wheat flour with flour from other sources, such as cereal or pulses [2]. It has gluten, which is a kind of protein present in rye, barley, and wheat. Gluten is generally well tolerated and causes no issues for most individuals. But for those with celiac disease, consuming gluten-containing foods can set off an immunological reaction that damages tiny intestinal cells [3]. Glyadin is one of the two proteins that make up wheat gluten, and its consumption can lead to celiac disease. It has been discovered that gliadin triggers mucosal injury, an immune reaction, in those who are genetically predisposed. Its withdrawal has resolved the issue [4]. The typical form of celiac disease, which is caused by proteins found in wheat, rye, and barley, is characterized in children by malabsorption and stunted growth. It is an autoimmune kind of gastrointestinal illness that affects those who are genetically predisposed [5].

Pasta is made mostly of wheat semolina and is a very popular cuisine throughout the globe. Pasta that is made commercially has a high protein and carbohydrate content. The nutritional profile of pasta was improved

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with the inclusion of chickpea, carob, beetroot, and spinach compared to the control pasta. The stringent gluten-free diet poses a major issue due to the poor nutritional content and several nutrient deficiencies, such as the decreased absorption of iron, calcium, vitamins A, D, E, and K, and folate [6].

Additionally, it is well known that gluten-free food items are more expensive than gluten-containing ones. For these reasons, it is imperative to create gluten-free foods that are both nutritious and capable of supporting a full diet [7,8].

Achieving identical product attributes and quality to ordinary gluten-containing pasta is the true objective of crafting high-grade gluten-free items. Thus, it would be beneficial to compare the properties of the produced gluten-free "dough" and pasta with those of a real, comparable gluten-containing system [9].

Substances rich in protein and dietary fiber, such as pulse flours, can serve as substitutes for gluten in pasta production. Chickpeas (*Cicer arietinum*) are a great source of protein because they are high in unsaturated fatty acids and complex carbohydrates, abundant in vitamins and minerals, and generally free of antinutritional elements [10]. Additionally, pasta with chickpea flour has been shown to have a significantly lower glycemic index (GI) compared with traditional durum.

During the development of gluten-free products, it was suggested to use hydrocolloids as a soluble fiber, joining starch granules together and achieving high water absorption capacity. The use of xanthan gum (XG) is very widespread among gluten-free technologies.

Carob is rich in dietary fiber (30–40%) and phytochemical compounds (i. e., polyphenols, flavonoids, and tannins). It is an excellent reservoir of potassium and calcium and contains the seven essential amino acids. It has anti-tumor, anti-proliferative and apoptotic activities, anti-diarrheal and anti-hyperlipidemic effects, and low glycemic index [11,12].

In the same line, beetroot is rich in potassium, phenolic compounds, sugars and natural colorants (Betalain). It exhibits chemopreventive effects as well as antioxidant and anti-inflammatory activities. It also possesses nutritional agents for the prevention and treatment of hypertension and cardiovascular diseases, and increased resistance to the oxidation of low-density lipoprotein [13].

Spinach is a great source of iron, magnesium and protein. It has antioxidants that help in diabetes management, cancer prevention, asthma prevention, blood pressure reduction, and promotion of digestive regularity [14].

Therefore, the present study aims to develop gluten-free pasta using chickpeas as a flour substitute, fortified with carob, beetroot, and spinach.

## 2. Materials and methods

*2.1. Sample preparation*

Chickpea pulses (*Cicer arietinum*), carob (*Ceratoniasiliqua linn*), beetroot (*Beta vulgaris*) and spinach (*Spinacia oleracea*) were purchased from a local market, then washed with tap water, dried using a laboratory tray dryer at 60 °C for 24 hrs. The dried samples were ground into a powder using a hammer mill and then passed through a 0.5 mm sieve to obtain flour. The flour samples were stored until analysis and use. Pasta samples were prepared according to the addition ratios shown in Table 1.

Table 1. **Development of pasta ingredient formula (%)**

Таблица 1. **Разработка состава ингредиентов макаронных изделий (%)**

| Ingredients (%) | Control and chickpea pasta | | | |
|---|---|---|---|---|
| | CS | F1 | F2 | F3 |
| Semolina flour | 100 | — | — | — |
| Chickpea flour | — | 97 | 87 | 87 |
| Carob powder | — | 2 | 2 | 2 |
| Beetroot powder | — | — | 10 | — |
| Spinach powder | — | — | — | 10 |
| CMC | | 1 | 1 | 1 |

CMC: Carboxymethylcellulose, CS: semolina control, F1: gluten-free pasta (chickpea flour 97% + carob powder 2% + CMC1%), F2: gluten-free pasta (chickpea flour 87% + carob powder 2% + beetroot powder 10% + CMC1%), F3: gluten-free pasta (chickpea flour 87% + carob powder 2% + spinach powder 10% + CMC1%).

*2.2. Chickpea pasta processing*

Chickpea pasta formulas were prepared using various mixtures and manufactured into macaroni with an Imperia Trading S. R.I. 10098 RIVOLI (TO) machine, located at C.so Susa, 242. The pasta samples were then dried at 45–50 °C for 24 hours. Additionally, a control batch of pasta made solely with semolina was also prepared.

*2.3. Quality characteristics of pasta samples*

*2.3.1. Rheological characteristics of pasta dough using Mixolab*

The dough rheological behavior of pasta samples was investigated using Mixolab (Chopin, Tripette et Renaud, Paris, France). This simultaneously establishes the properties of the dough while it is being mixed at a steady temperature and while it is being heated and cooled.

Using the input values for both flour moisture and water absorption, the Mixolab software calculated the amount of flour required for analysis. The usual Mixolab Chopin methodology was used for all measurements, as stated by Mohsen et al. [15] and Tlay et al. [16].

*2.3.2. Sensory evaluation of pasta samples*

The Food Sciences Department Faculty of Agriculture Cairo University, Giza, Egypt, provided ten qualified judges to assist in the evaluation of the pasta's sensory qualities (color, texture, odor, and taste) based on a nine-point hedonic scale [17].

*2.3.3. Cooking quality of pasta samples*

Optimal cooking time is the shortest amount of time required for the starch to gelatinize, and it was determined by timing the disappearance of the pasta's starchy white center [18]. Pasta cooking experiments were conducted in triplicate, with weight gain and cooking loss measurements taken as well. The pasta's cooking loss and weight gain were computed using the methodology described by Gull et al. [19].

$$\text{Weight gain (\%)} = [(\text{weight of cooked pasta} - 10)/10] \times 100$$

$$\text{Cooking loss (\%)} = [(\text{weight of dried residue in cooking water}/10)] \times 100$$

*2.3.4. Chemical composition of pasta samples*

The moisture, crude protein, lipid, crude fiber, and ash contents in the samples of dry pasta were assessed using the AOAC [18] procedures. The amount of carbohydrates was computed via difference.

*2.3.5. Phytochemical profiles of pasta samples*

The total phenol content of pasta samples was measured calorimetrically using the Folin–Ciocalteu reagent in accordance with Abedelmaksoud et al. [20]. The absorbance of the mixture was measured spectrophotometrically at 725 nm against a blank on a spectrophotometer (Uv-Vis spectrophotometer, Labomed Inc., USA). The standard utilized was gallic acid. On a dry weight basis, phenols were represented as mg gallic acid equivalent GAE/g sample.

The method for determining the total flavonoid content was based on Zhishen et al. [21]. Using catechin as a reference chemical, the calibration curve was created. On a dry weight basis, the total flavonoid concentration was determined as mg CE/g.

Quantitative determination of tannins was carried out as described by Price et al. [22] followed by minor modification by Osman [23]. The standard curve was prepared using catechin. Tannins were measured on a dry weight basis and expressed as mg of catechin equivalent (CE)/g.

According to Brand-Williams et al. [24], the radical scavenging capacity of pasta extracts in reaction with the stable 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical was used to measure their antioxidant activity. The following equation was used to determine the antioxidant activity as a percentage of radical scavenging:

$$\%\ \text{radical scavenging} = [(A_0 - A_1/A_0)] \times 100 \quad (1)$$

Where:

$A_0$ = the absorbance of the control reaction (containing all reagents except the test compounds);

$A_1$ = the absorbance in the presence of the tested extracts after 30 min.

*2.4. Statistical analysis*

Using XLSTAT software (Addinsoft, New York, USA), a statistical analysis of the results was performed with the use of Duncan's multiple range analyses, analysis of variance (ANOVA), and the least significant difference (LSD, 95%) test.

## 3. Results and Discussion

*3.1. Sensory evaluation*

Evaluation of sensory quality of gluten-free pasta can be a crucial first step in exploring the viability of an industrial and commercial strategy. In this study, sensory analysis was done using a 9-point hedonic scale. The results of sensory evaluation of gluten-free pasta made with chickpea flour as the main substitute for semolina flour with the three formulas are presented in Table 2 for color, taste, odor and chewiness of pasta. Based on color, formulas two and three showed higher acceptability because of their attractive colors. The other sensory indicators were similar in all formulas and significantly higher than those in the control, especially the chewiness and texture characteristics as the high fiber content of chickpea significantly enhanced these characteristics. Overall acceptability of formula two

**Table 2. Sensory scores of the gluten-free pasta samples and the control**

Таблица 2. **Сенсорные баллы для образцов безглютеновых макаронных изделий и контроля**

| Sample | Color (9) | Texture (9) | Odor (9) | Taste (9) | Overall acceptability (9) | Overall quality score (45) |
|---|---|---|---|---|---|---|
| CS | $7.3\pm0.0^{c}$ | $7.1\pm0.33^{c}$ | $7.0\pm0.45^{c}$ | $6.7\pm0.0^{c}$ | $7.0\pm0.25^{b}$ | $35.1\pm0.22^{b}$ |
| F1 | $7.2\pm0.84^{c}$ | $7.6\pm0.89^{b}$ | $7.5\pm0.45^{b}$ | $7.2\pm0.87^{bc}$ | $7.3\pm0.76^{b}$ | $36.8\pm3.54^{b}$ |
| F2 | $8.6\pm0.76^{a}$ | $8.7\pm0.19^{a}$ | $8.1\pm0.42^{a}$ | $8.4\pm1.04^{a}$ | $8.8\pm0.89^{a}$ | $42.6\pm0.28^{a}$ |
| F3 | $8.0\pm0.0^{b}$ | $8.1\pm0.32^{ab}$ | $8.3\pm0.35^{a}$ | $7.9\pm0.55^{b}$ | $8.5\pm0.61^{a}$ | $40.8\pm0.24^{a}$ |

CS: semolina control, F1: gluten-free pasta (chickpea flour 97% + carob powder 2% + CMC1%), F2: gluten-free pasta (chickpea flour 87% + carob powder 2% + beetroot powder 10% + CMC1%), F3: gluten-free pasta (chickpea flour 87% + carob powder 2% + spinach powder 10% + CMC1%). Values are means of three replicates ± SD. Means followed by different superscripts within the same column are significantly different at 0.05 level.

Table 3. **Chemical composition (% on dry weight basis) of gluten-free pasta compared to the control**

Таблица 3. **Химический состав (% на сухую массу) безглютеновых макаронных изделий по сравнению с контролем**

| Formulas | Parameters % | | | | | |
|---|---|---|---|---|---|---|
| | Moisture | Ash | Fiber | Protein | Fat | TC |
| CS | $6.24\pm0.67^{c}$ | $0.52\pm0.03^{c}$ | $0.45\pm0.07^{c}$ | $12.10\pm1.13^{c}$ | $1.16\pm0.09^{c}$ | $85.77\pm4.21^{a}$ |
| F1 | $7.32\pm0.72^{b}$ | $2.09\pm0.07^{b}$ | $1.89\pm0.03^{b}$ | $17.50\pm1.02^{a}$ | $5.58\pm0.14^{a}$ | $71.94\pm6.23^{c}$ |
| F2 | $8.77\pm0.23^{a}$ | $2.31\pm0.05^{a}$ | $2.16\pm0.21^{a}$ | $14.88\pm1.32^{b}$ | $4.75\pm0.17^{b}$ | $75.9\pm3.09^{b}$ |
| F3 | $8.41\pm3.10^{a}$ | $2.45\pm0.08^{a}$ | $2.29\pm0.12^{a}$ | $15.05\pm1.34^{b}$ | $4.58\pm0.15^{b}$ | $75.63\pm4.11^{b}$ |

CS: semolina control, F1: gluten-free pasta (chickpea flour 97% + carob powder 2% + CMC1%), F2: gluten-free pasta (chickpea flour 87% + carob powder 2% + beetroot powder 10% + CMC1%), F3: gluten-free pasta (chickpea flour 87% + carob powder 2% + spinach powder 10% + CMC1%), TC: total carbohydrates (%). Different letters (a, b, c) mean statistically significant difference ($p<0.05$); the results represent the mean ± standard deviation.

was the highest followed by formula three then one and all the formulas had a significant difference from the control as illustrated in Table 2.

It can be observed from data in Table 2 that the color score of pasta increased significantly with increasing beet root substitution levels (F2, 10% beet root). The semolina control (CS) and F1 pasta samples had the lowest color score (7.2 and 7.3, respectively).

In terms of texture appreciation, analysis of variance showed that there was no significant difference among different pasta samples except for the control pasta sample. In the same trend, there were no significant differences in odor characteristics between F2 and F3 pasta samples. On the other hand, the pasta control sample (CS) recorded the lowest score followed by the F1 pasta sample.

The results also indicated that the F3 and F1 pasta samples had no significant effect on the taste score (7.9 and 7.2, respectively) compared with CS pasta (6.7). Meanwhile, the taste score of the F2 pasta sample showed the highest value (8.4).

Gökçe et al. [25] studied the organoleptic attributes of some bakery products and concluded that the addition of xanthan gum, guar gum, locust bean, carob gum and their mixtures in gluten-free bakery products increases the emulsion stability and the nutritive value of bakery products.

*3.2. Chemical composition of prepared pasta samples*

The presented results in Table 3 show significant changes in the chemical profiles of gluten-free pasta compared to the control (semolina pasta). The incorporation of beetroot and spinach increased the moisture content in F2 and F3. This means that the free water is bound by nutrients and thus participates in increasing shelf life and the time needed for drying.

The chemical composition of the pasta samples presented in Table 3 indicated that the incorporation of chickpea as a main ingredient increased significantly the content of protein in the different pasta formulations (17.50, 15.05, and 14.88% in F1, F3 and F2, respectively) compared to CS (12.10%). This means that the protein content of the gluten-free pasta was higher than that of semolina pasta as a control. The highest protein content is reported for F1 followed by F3 then F2. The results also indicated a slight decrease in the fat content in all gluten-free pasta samples compared to CS. The fat content increased when semolina was replaced with chickpea flour. The lowest fat content was reported in CS followed by F2 then F3 and the highest one was in F1. The ash content increased in different formulations of gluten-free pasta relative to semolina wheat flour pasta as a control. Furthermore, significant differences in the crude fiber content were observed among all prepared pasta samples under study. Among pasta samples, the lowest value of fiber content (0.45%) was observed in the control pasta. On the other hand, the highest fiber percent was identified in F3 and F2 followed by F1. The high fiber content in gluten-free pasta improved the sensory characteristics. Furthermore, dietary fiber has beneficial health effects such as improvement of the digestion ability and treatment of colonic disorders [26]. In this respect, Mudgil et al. [27] reported that chickpea flour is predominantly composed of insoluble dietary fiber (IDF), which may enhance intestinal transit. The results for ash content, representing mineral content, indicated that F3, which consists of 87% chickpea, 2% carob, and 10% spinach, had the highest mineral content. This is attributed to the high mineral content found in spinach (Table 3).

Furthermore, the carbohydrate content of gluten-free pasta was significantly lower compared to the wheat flour pasta control. A similar finding was reported by El-Demery et al. [28].

*3.3. Phytochemical profiles*

The results presented in Table 4 indicate significant changes in the phytochemical profiles of gluten-free pasta compared to the control (semolina wheat pasta). The total phenolic content for the different formulas is expressed as milligrams of gallic acid equivalent per 100 g of sample. Formula F3 exhibited the highest phenolic content at 178.96 mg/100 g, followed by F2 at 141.89 mg/100 g. Formula F1's content was similar to that of the control. This suggests that the incorporation of spinach and beetroot increased the phenolic content by boosting the bioactive compounds. Similarly, Ahmad et al. [29] reported that adding spinach leaves to noodles enhanced antioxidant activity, as well as phenolic and flavonoid compounds.

Table 4. **Phytochemical profiles of gluten-free pasta compared to the control**

Таблица 4. **Фитохимические профили безглютеновых макаронных изделий по сравнению с контролем**

| Parameters | Total phenolic compounds (mg/100 g) | Total flavonoids (mg/100 g) | Tannins (mg/100 g) | Antioxidants (%) |
|---|---|---|---|---|
| CS | $109.14\pm2.22^{c}$ | $50.11\pm2.11^{d}$ | $17.62\pm0.85^{c}$ | $19.23\pm2.34^{d}$ |
| F1 | $112.14\pm3.34^{c}$ | $61.18\pm1.43^{c}$ | $19.95\pm0.72^{b}$ | $28.94\pm1.98^{c}$ |
| F2 | $141.89\pm1.90^{b}$ | $72.16\pm2.45^{b}$ | $17.87\pm1.94^{c}$ | $35.90\pm2.23^{b}$ |
| F3 | $178.96\pm4.66^{a}$ | $86.45\pm1.23^{a}$ | $26.54\pm1.54^{a}$ | $46.58\pm1.56^{a}$ |

CS: semolina control, F1: gluten-free pasta (chickpea flour 97% + carob powder 2% + CMC1%), F2: gluten-free pasta (chickpea flour 87% + carob powder 2% + beetroot powder 10% + CMC1%), F3: gluten-free pasta (chickpea flour 87% + carob powder 2% + spinach powder 10% + CMC1%). Values are means of three replicates ± SD. Means followed by different superscripts within the same column are significantly different at 0.05 level.

The results revealed that total flavonoids, which are reported as mg catechin equivalent (CE)/g on a dry weight basis were significantly different. The results also showed that F3 had the highest value of flavonoid content (86.45 mg/100 g sample) followed by F2 (72.16 mg/100 g sample), while the control sample had the lowest content of flavonoids (50.11 mg / 100 g sample). Tannins are reported as mg catechin equivalent (CE)/g on a dry weight basis. Fortification of the base formula with spinach increased the tannin content, which acts as a preservative and significantly increases the shelf life. The antioxidant activity expressed as inhibition percent of DPPH is illustrated in Table 4. The results showed significant differences between the gluten-free pasta and the control. The antioxidant activity significantly increased in F3, followed by F2 and F1, with all formulations showing higher activity than the control. Therefore, F3 is recommended for its potential anticancer and anti-inflammatory properties. The results indicate that fortifying gluten-free pasta made from chickpea flour with carob, beetroot, and spinach enhances both the quality characteristics and the nutritional value of the final product, as well as its phytochemical profile. The primary use of beetroot is as a food ingredient. The beetroot, in particular its betalains, or betanin, has been drawing more and more attention due to its potent biological activity that reduces LDL, scavenges DPPH, eliminates oxidative stress, and prevents DNA damage [30].

### *3.4. Cooking properties*

The presented results in Table 5 show significant changes in the cooking characteristics of the gluten-free pasta compared to the control (semolina pasta).

Table 5. **Cooking properties of gluten-free pasta compared to the control**

Таблица 5. **Свойства безглютеновых макаронных изделий при варке по сравнению с контролем**

| Parameters | OCT min. | Water absorption % | Cooking loss % |
|---|---|---|---|
| CS | $10 \pm 0.04^b$ | $146.92 \pm 3.34^a$ | $5.23 \pm 0.05^c$ |
| F1 | $14 \pm 0.05^a$ | $132.71 \pm 2.34^b$ | $8.44 \pm 0.04^a$ |
| F2 | $13 \pm 0.02^a$ | $121.23 \pm 3.09^c$ | $6.77 \pm 0.05^b$ |
| F3 | $13 \pm 0.05^a$ | $119.89 \pm 2.07^c$ | $6.23 \pm 0.02^b$ |

* CS: semolina control, F1: gluten-free pasta (chickpea flour 97% + carob powder 2% + CMC1%), F2: gluten-free pasta (chickpea flour 87% + carob powder 2% + beetroot powder 10% + CMC1%), F3: gluten-free pasta (chickpea flour 87% + carob powder 2% + spinach powder 10% + CMC1%). OCT = optimal cooking time (min). Values are means of three replicates ± SD. Means followed by different superscripts within the same column are significantly different at 0.05 level.

Cooking quality of pasta is the most important attribute from a consumer point of view. It is defined by the physical parameter along with the chemical and nutritional parameters. Pasta quality and cooking characteristics are dependent upon the protein starch matrix of a pasta product [31]. The results of the various cooking quality parameters for the pasta formulations including optimal cooking time (min), cooking loss (%) and weight gain (%) are given in Table 5.

The cooking time of the pasta samples ranged from 10 to 14 minutes. The optimal cooking time depends primarily on the rates of water penetration and starch gelatinization. Gluten-free pasta (F1, F2 and F3, respectively) exhibited higher optimal cooking time than the semolina pasta control (CS). It was observed that cooking time was shorter at relatively lower protein levels than at higher protein content, when it takes longer for water to penetrate the protein network. Therefore, the hydration levels were high in the samples containing higher levels of chickpea flour [32].

Cooking loss, which refers to the amount of residue left in the water after cooking pasta, is a key indicator of the overall quality of the pasta. It is primarily influenced by the dissolution and release of gelatinized starches from the pasta surface into the cooking water. The quality of pasta is indicated by the low amount of residue left in the cooking water [33]. The cooking loss increased significantly in all gluten-free pasta, while the semolina pasta control had the lowest cooking loss value (5.23%). These results were likely obtained because chickpeas could not form a strong network of starch and protein that holds the pasta together; thus, this led to more solids leaching into the cooking water. An increase in cooking losses in all gluten-free pasta samples might be related to the disruption of the protein matrix by the chickpea particles [34]. On the other hand, gluten-free pasta samples presented the weight gain percentage (from 119.89 to 132.71%) that was significantly lower than the semolina pasta control (146.92%).

### *3.5. Dough rheological characteristics of pasta dough samples using Mixolab*

Table 6 lists the rheological parameters of the dough pasta samples: water absorption percentage (the amount of water needed to achieve a consistency level sufficient to achieve an atorque of C1=1.1 ± 0.05 Nm using the standard Chopin + protocol), dough development time (DDT) (the amount of time needed to reach C1), dough weakening (C2), and starch gelatinization (C3). It explains the behavior of starch, which is seen as a rise in dough consistency with a degree of an increase depending on the starch quality. A drop in viscosity in the fourth stage is linked to amylase activity and the physical disintegration of the starch granules. The torque at (C4) provides information on the stability of the heated gel that is generated as well as the pace of enzymatic hydrolysis. The less stable starch gel has a lower value.

The torque (C5) suggests how shelf stable a flour product will be and is a sign of retrogradation or the rearranging of starch molecules during the chilling process.

Finally, dough stability is a measure of dough resistance to kneading. The long period is referred to stronger dough.

Table 6 shows that water absorption, DDT and C1 values of pasta dough samples were in a range from 53.90%, 5.69 min and 1.05 Nm (for F1) to 61.28%, 6.67 min and 1.09 Nm (for F3), respectively. The free-gluten formula F3 recorded the highest value of DDT and C1, while F1 recorded the lowest one. It takes longer to make stronger flour. The findings demonstrate that gluten characteristics, flour particle size, and protein all had a significant impact on DDT [35]. This means that an increase in protein incorporation in the pasta formula increased the DDT.

Table 6. **Rheological characteristics of gluten-free pasta compared to the control**

Таблица 6. **Реологические характеристики безглютеновых макаронных изделий по сравнению с контролем**

| Treatment | Water absorption (%) | DDT (min) | Torque (Nm) | | | | | Stability (min) |
|---|---|---|---|---|---|---|---|---|
| | | | C1 | C2 | C3 | C4 | C5 | |
| CS | 56.98 | 5.76 | 1.06 | 0.58 | 1.74 | 1.88 | 2.73 | 8.30 |
| F1 | 53.90 | 5.69 | 1.05 | 0.55 | 1.73 | 1.63 | 2.86 | 5.23 |
| F2 | 59.23 | 6.45 | 1.07 | 0.61 | 1.65 | 1.54 | 3.44 | 7.23 |
| F3 | 61.28 | 6.67 | 1.09 | 0.63 | 1.70 | 1.57 | 3.39 | 6.14 |

* CS: semolina control, F1: gluten-free pasta (chickpea flour 97% + carob powder 2% + CMC1%), F2: gluten-free pasta (chickpea flour 87% + carob powder 2% + beetroot powder 10% + CMC1%), F3: gluten-free pasta (chickpea flour 87% + carob powder 2% + spinach powder 10% + CMC1%). Values are means of three replicates ± SD. Means followed by different superscripts within the same column are significantly different at 0.05 level.

On the other hand, C2 of pasta dough samples ranged from 0.55 to 0.63 Nm, and C3 ranged from 1.65 to 1.74 Nm. Regarding C4, CS pasta dough had the highest value of 1.88 Nm, implying the most stable gel in the hot phase. CS and F1 pasta doughs had the lowest value of C5 (2.73 and 2.86 Nm, respectively). Concerning dough stability, it was observed that the control pasta dough had the highest dough stability (8.30 min).

The decreased water absorption in F1 dough appeared to have an impact on its development and stability. Protein quality and its capacity to withstand kneading pressures are the primary factors affecting dough stability. In this respect, Šimurina et al. [36] discovered that adding protein from legumes enhances the dough ability to combine when made with whole grain spelt flour. Its increased stability and improved water absorption are the main causes of this improvement.

## 4. Conclusion

The study successfully developed gluten-free pasta using chickpea flour, fortified with carob, beetroot, and spinach powders, offering a nutritious alternative to conventional wheat pasta. The results demonstrated that chickpea-based pasta formulations significantly increased protein, fiber, and polyphenolic compound content compared to the semolina control. Chickpea-based pasta formulations (F1, F2, and F3) showed higher protein, fiber, and polyphenolic content compared to conventional semolina pasta. Sensory evaluation indicated good acceptance across all criteria, including texture, odor, shape, and taste. These findings suggest that chickpea-based pasta is not only a viable alternative for those with celiac disease but also offers a healthier option for individuals seeking to manage obesity and diabetes. Overall, chickpea pasta presents a nutritious and well-accepted alternative to traditional wheat pasta.

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