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EFFECTS OF LENTIL POWDER OR WHEY PROTEIN CONCENTRATE ADDITION ON THE QUALITY OF SORGHUM FLOUR-BASED GLUTEN-FREE PASTA

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ABSTRACT

The current study aims to evaluate the impact of replacing sorghum flour (variety Shandweel-1) in gluten-free blends with hulled lentil or whey protein concentrate (WPC) in the presence of yellow corn (variety 178) and sweet potato powder on the quality attributes of gluten-free pasta (included color parameters, cooking quality, and sensory attributes) to fill the gap in gluten-free products. Six gluten-free formulas were prepared with a different level of sorghum flour substitution with lentil or WPC powder. Besides, physical and chemical analyses of sorghum and yellow corn varieties were investigated. Results revealed that weight of 1000 grains, density, and hectoliter values were significantly different between Shandweel-1 and yellow corn grains, the lightness of Shandweel-1 grain was higher than yellow corn. Shandweel-1 contains a higher value in protein and ash compared to yellow corn, and there was no significant difference between them in fat value. Substitution of sorghum flour with lentil or WPC powder increased cooking time with increasing substitution level. While, water absorption and cooking loss increased of sorghum pasta with the addition of lentil powder, whereas it decreased with the addition of WPC. Lightness values decreased with increasing the substitution of lentil or whey protein concentrate powder. Redness and yellowness values

decreased with the substitution of WPC, while they increased with increasing levels of lentil powder substitution. In terms of sensory attribute parameters, the best acceptable ratio was sorghum pasta substituted with lentil powder at 20%. Sorghum pasta enriched with lentil powder is promising as a consumer-acceptable product and a practical and attractive option to provide the market with various gluten-free products that meet the diversity of consumers' desires.

Keywords: Sorghum, Lentil, Whey protein concentrate, Gluten-free pasta, Quality characteristics.

INTRODUCTION

Pasta is one of the most popular and widely used cereal products in the world because of its palatable taste, cooking convenience, long shelf life, and affordability, and it is mainly processed from wheat flour. Gluten contains gliadin and glutenin proteins, which are responsible for the chewability, elasticity, and cooking qualities of pasta (**Rozan *et al.*, 2022**). The low stickiness, low cooking loss, and firm structure of pasta are the main factors contributing to its high quality. However, people with celiac disease (CD) must adhere to a gluten-free diet and avoid foodstuffs that contain gluten. Gluten can cause small intestine damage and that may affect the absorption of vital nutrients such as vitamins and minerals. Consequently, market demand for gluten-free pasta has increased, commonly from people with CD (**Cardo *et al.*, 2021**).

Besides, the increasing prevalence of CD promotes awareness worldwide (around 1% of the world's population has celiac disease) (**Green and Cellier, 2007; Palavecino *et al.*, 2017; Bradauskiene *et al.*, 2023**). The usage of gluten-free grains like millet, maize, sorghum, and pseudocereals like amaranth, and quinoa can be a significant challenge for both commercial processing operations and food research and development. Utilizing such raw materials has the benefit of potentially enhancing the nutritional value of gluten-free foods.

(**Schoenlechner *et al.*, 2010; Paux and Rosentrater, 2018**). Gluten-free pasta has issues with quality due to the absence of gluten, such as high cooking loss, high stickiness, and low firmness. (**Detchewa *et al.*, 2012; Detchewa *et al.*, 2022**). In particular, to counterbalance any changes in the rheological qualities brought on by the addition of these new constituents, balanced formulations and appropriate technological methods must be employed. (**Padalino *et al.*, 2015**). For gluten-free pasta making, additional proteins and gums may well in part substitute for gluten to make sure low cooking loss (even after long cooking), high absorption, and good final texture (**Martínez *et al.*, 2017**).

The most commonly used grains flour for gluten-free pasta manufacture are rice or corn, but there are a lot of cereals and tubers capable of performing useful functions. Among the gluten-free cereals used in food, sorghum [*Sorghum bicolor* (L.) Moench] has been described as a staple diet for more than half a billion people in at least thirty countries (**Ferreira *et al.*, 2016; Palavecino *et al.*, 2017**). Besides, it is the fifth most significant cereal in the world after maize, rice, wheat, and barley. The area of sorghum grain cultivation in Egypt is about 155,509 hectares, with an annual production of 764,880.14 tons in the year 2021 (**FAOSTAT, 2021**). The studies are being conducted to develop substitutions that meet the sensory and technological standards of regular pasta, while also providing economic benefits and meeting the needs of a segment of the population with food restrictions (**Giménez-Bastida *et al.*, 2015; Ribeiro *et al.*, 2018**).

Moreover, sorghum flour may be substituted for wheat flour in gluten-free products such as breakfast cereals, cakes, bread, biscuits, and pasta (**Ferreira *et al.*, 2016; Palavecino *et al.*, 2017**). In addition, it is becoming increasingly important to use sorghum as a gluten-free ingredient, either alone or in blends with other gluten-free cereal flour (**Asif *et al.*, 2010; Marengo *et al.*, 2015**). Sorghum grain has intriguing properties from the nutritional aspect, such as protein, thiamin, niacin, vitamin B6, and numerous dietary minerals, such as manganese and iron. It contains 4-15% protein, 55-75% starch, 2-

7.6% fat, and 1-3.4% fiber (**Abah *et al*., 2020; Hussnain *et al*., 2022**). This is why there may be a new application for sorghum. could be the manufacturing of pasta products, as well as with or as a substitute for rice or corn flour in the production of gluten-free food (**Suhendro *et al*., 2000**).

Pulses pasta-especially from lentils (*Lens culinaris*), are becoming more and more popular with customers and the food sector, essentially due to the high protein, crude fiber, and lower fat content **(Laleg *et al*., 2016; Bresciani *et al*., 2021)**. It is the second main consumed pulse after chickpeas. It originated in several colors such as, yellow, red, orange, green, black, and brown **(Rozan *et al*., 2018)**. Among them, yellow lentil is the best raw material for pasta processing, due to the cotyledon color that is similar to durum wheat semolina **(Marti and Pagani, 2013; Bresciani *et al*., 2021)**.

Whey protein is generally appreciated for its efficient usefulness and high nutritional value; therefore, they are most preferred due to its functional qualities, calcium content, and balanced amino acid profile. Protein enhancement may increase the quality of protein and nutritional value by improving the texture and other quality parameters of pasta. Though, denaturation of whey proteins has a detrimental effect on pasta quality **(Kumar *et al*., 2019)**.

Yellow corn flour (*Zea mays* L.) contains 7–13 % of proteins, is high in dietary fiber and magnesium, and has very low fats, phenolics, and carotenoid content **(El-Bialee *et al*., 2017)**. Yellow corn pasta is one of the most popular gluten-free food products. Moreover, amylose in corn pasta has been identified as the component accounting for their textural integrity after cooking. Lower amylose content in corn blends leads to lower pasta cooking quality. Corn starch has about 26-28% of amylose and is well-used for bichon-type pasta production (**Tam *et al*., 2004; Vetrani *et al*., 2019**). There is an increasing need for a wide variety of suitable products for CD patients, and the development of gluten-free products is critical. Therefore, the present study aimed to design a gluten-free pasta formula for celiac persons using sorghum flour and different protein sources and evaluate the quality of gluten-free pasta, including its physicochemical, technological, and sensory characteristics.

MATERIALS AND METHODS

Materials

Sorghum [*Sorghum bicolor* (L.) Moench, Shandweel-1 variety, season 2019] and yellow corn (corn-178 variety, season 2019) were obtained from the Field Crops Research Institute, Agricultural Research Center, Egypt. Hulled yellow lentil, whey protein concentrate, sweet potato, corn starch, and salt were obtained from local markets in Alexandria, Egypt. All other chemicals were of analytical grades.

Methods

Milling

Sorghum and yellow corn grains and hulled yellow lentils were milled using a laboratory mill (IKA-laboratechnic, Janke and Kunkel Type: MFC, Germany), followed by sieving to obtain a fine flour (around 250 microns) and then kept at -18^{o}C until further analysis.

Sweet potato powder

The sweet potato roots were washed, peeled, and cut into thin slices according to the method of **Shih *et al*. (2009)**. The slices were soaked in 0.05% (w/v) sodium meta-bisulfite for around 20 minutes, to prevent browning. The slices were drained, dried at 50^{o}C±5 for 18-20 h, milled, and packaged at -18^{o}C until analysis.

Flour blends

Yellow corn flour (control) and six blends were prepared from sorghum flour, lentil, whey protein concentrate, sweet potato powder, and corn starch (Table 1).

Table 1. Different sorghum gluten-free blends (%)

Blends	Sorghum flour	yellow corn	lentil powder	Whey protein concentrate powder	sweet potato powder	corn starch	Gums**
Control	-	91	-	-	5	4	4
SL10	71	10	10	-	5	4	4
SL15	66	10	15	-	5	4	4
SL20	61	10	20	-	5	4	4
SW10	71	10	-	10	5	4	4
SW15	66	10	-	15	5	4	4
SW20	61	10	-	20	5	4	4

*Control = yellow corn 178 variety, S= Shandaweel-1, L= hulled lentil powder, W= whey protein concentrate powder, SL10= 10% lentil powder, SL15= 15% lentil powder, SL20= 20% lentil powder, SW10= 10% whey protein concentrate powder, SW15= 15% whey protein concentrate powder and SW20= 20% whey protein concentrate powder. ** Gums consisted of Arabic gum, carboxy methyl cellulose, and psyllium husk with a ratio of 1.5:0.5:2.

Physical properties of sorghum and yellow corn grains.

Sorghum grains (Shandweel-1) and yellow corn (variety 178) were carefully cleaned, as well as broken grains and extraneous matter were discarded. A thousand kernels weight, hectoliter, and density were measured **(Almeida-Dominguez and Rooney, 1997)**.

Color measurements of sorghum, corn grains, and cooked pasta

External color of sorghum grains (Shandweel-1), yellow corn (178), and cooked pasta samples were measured using a handheld Tristimulus reflectance colorimeter (Chroma meter, model CR-400, Konica Minolta, Japan). The equipment provided L^* [lightness with L = 100 for lightness, and L = zero for darkness], a^* [chromaticity on a green (-) to red (+)], b^* [chromaticity on a blue (-) to yellow (+)]. The obtained values are presented as the results of triplicate determinations.

Chemical analysis

Moisture, fat, crude fiber, and ash content of samples were determined according to the AOAC method **(AOAC, 2019)**. Protein content (N x 6.25) (Kjeldahl method, AOAC method 978.04), fat (AOAC method 920.85), and ash were determined by incineration at 600°C until a constant mass weight was achieved (AOAC method 923.03). Total carbohydrate was calculated by difference, [TC = 100 - (Protein+ fat + ash+ crude fiber)].

Quality of cooking

Cooking quality analysis of pasta include the measurements of optimum cooking time (OCT), cooking loss (CL), and water absorption capacity (WAC) of pasta samples were determined using the AACC (2000), method 66-50).

Optimum cooking time (OCT)

The optimal cooking time of pasta samples is determined by cooking 10g of pasta in 250 ml boiling distilled water, removing one piece of pasta from the cooking water every 30 s, and then squeezing the pasta piece between two glass slides. The OCT of pasta is corresponding to the time taken for the disappearance of the center starch core of the cooked pasta **(AACC, 2000 method No 66-50)**.

Cooking loss and water absorption

Ten grams of pasta were weighed and cooked in 250 ml of boiling distilled water for about 9 min., and the optimum cooking time (OCT) was recorded for each blend **(AACC, 2000, method 66-50)**. The cooked pasta was immediately drained using a Buchner funnel held directly above the cooking pan to retain the cooking water. The drained pasta was patted dry with a paper towel and weighed. The cooking pan containing water from cooking and rinsing was dried at 105°C in a drying oven for 16 h until constant weight was achieved, and the increase in weight was recorded. Three measurements were taken for each sample. The cooking loss (%) and water absorption (%) were calculated using the following equations:

$$\text{Cooking loss (\%)} = \left[\frac{Weight\ of\ cooking\ water\ after\ drying}{Weight\ of\ dried\ pasta}\right] x\ 100$$

$$\text{Water absorption(\%)} = \left[\frac{Weight\ of\ cooked\ pasta - Weight\ of\ dried\ pasta}{Weight\ of\ dried\ pasta}\right] x\ 100$$

Sensory evaluation

Sensory evaluation was conducted by 10 panelists from the Food Technology Research Institute **(Bashir *et al.*, 2012)**. The pasta samples were cooked in boiled distilled water until it reached the optimal cooking time obtained, and were drained for 2 minutes, and then served to the panelists. A 9-point descriptive scorecard that included color, taste, flavor, texture, and overall acceptability, and were evaluated using a 9-point hedonic scale test with 9 = likely extremely, 5 = neither like nor dislike, and 1 = dislike extremely.

Statistical analysis

Costat statistical software version 6.400 was used to analyze the data. The collected data were analyzed from three repetitions of any experiment and were statistically analyzed for means and standard deviations in triplicate. The data were subjected to one-way analysis of variance (ANOVA) at $p<0.05$ followed by Duncan's new multiple range tests, to assess differences between the sample means **(Snedecor, 1994).**

RESULTS AND DISCUSSIONS

Physical characteristics and color grains.

Table (2) shows the weight of 1000 kernels, density, hectoliter, and color of sorghum variety and yellow corn grains. The data indicate that the weight of 1000 kernels in sorghum and corn varieties were 28.54 and 337.69 g, respectively. **Belay (2017)** found that the weight of 1000 kernels of sorghum varieties varied and ranged between 22.26 and 42.63g.

Sorghum hectoliter recorded 82.36 Kg/hl, while yellow corn hectoliter recorded 78.40 Kg/hl. The results are close to **Chavan *et al.* (2016)** and **Cabrera-Ramírez *et al.* (2020)** who found that the hectoliter weight of sorghum grain ranged between 78.86 and 82.41kg/hl and between 79 and 88.7kg/hl, respectively. **Ponce-García *et al.* (2020)** found that the hectoliter weight of yellow corn varied from 78.30 to 85.70 kg/hl.

The color of the kernels is important because the data it provides helps predict the color quality of the final product color. Data in the same Table showed that the sorghum lightness was 73.23. These results agree with **Lopez-Contreras *et al.* (2015)** who found that the lightness values of ten sorghum genotypes ranged between 64 and 83, indicating that all samples were more white than black. The L^* scale for yellow corn grain was 60.65, this result was close to that of **Thakur *et al.* (2015)** who reported that the L^* scale for three genotypes of yellow corn ranged between 57.97 and 69.70.

The data indicated that the a^* and b^* scales for the whole meal sorghum variety (Shandweel-1) were 3.75 and 28.65 respectively. The results are in line with **Ebadi *et al.* (2019)** who found that a^* scales varied from 6.45 to 18.90 and b^* scales varied from 10.29 to 36.48 in different sorghum varieties. While a^* and b^* scales for yellow corn grain recorded 16.28 and 47.78, respectively. These results are close to **Hwang *et al.* (2016)** who reported that the b^* scale was 40.67.

Table (2). Physical characteristics and color of whole meal sorghum variety and yellow corn.

Constituents	**Shandaweel-1**	**Corn-178**
1000 Kernel weight (g)	$28.54^{b}\pm0.33$	$337.69^{a}\pm1.69$
Density (g/cm^3)	$0.74^{b}\pm0.02$	$1.66^{a}\pm0.03$
Hectoliter (kg/hl)*	$82.36^{a}\pm0.24$	$78.40^{b}\pm0.40$
L*	$73.23^{a}\pm0.26$	$60.65^{b}\pm1.12$
a*	$3.75^{b}\pm0.47$	$16.28^{a}\pm0.34$
b*	$28.65^{b}\pm0.32$	$47.78^{a}\pm0.26$

*Kilogram per hectoliter or 100 liters, $L*$ (lightness with $L = 100$ for lightness, and L = zero for darkness), $a*$ [(chromaticity on a green (-) to red (+)], $b*$ [(chromaticity on a blue (-) to yellow (+)]. Data are presented as means of three replicates ±SD and the number in the same row followed by the same superscript are not significantly different at $p < 0.05$.

Chemical composition of whole meal sorghum variety and yellow corn

Table (3) displays the chemical analysis of sorghum grain (Shandweel-1) and yellow corn. Moisture content was recorded at 8.32% in the sorghum variety. These results are in line with **Udachan *et al.* (2012)** and ***Ndimba et al. (2015)*** who found that moisture content in sorghum whole meal varied from 8.90 to 11.02% and from 8.95 to 11.16%, respectively. While yellow corn moisture content was recorded at 10.49%. The results are close to **Nelson (2002)** who found that the moisture content in yellow corn was 10.60%.

Protein content in sorghum was 12.50%. The results agree with **Awadelkareem *et al.* (2015)** and **Jimoh and Abdullahi (2017)** who found that protein content in sorghum (whole meal) ranged between 6.23 and 13.81 and between 10.21 and 13.45%, respectively. However, protein content in yellow corn (variety 178) was recorded at 9.87% and this result agrees with **Ponce-García *et al.* (2020)** who reported that protein content in whole yellow corn grain ranged between 10.50 and 12.00%.

Concerning ash content, it was 2.77% in Shandweel-1. **Serna-Saldivar and Espinosa-Ramírez (2019)** mentioned that the ash content in different sorghum varieties ranged between 1.10 and 4.50%. While ash content in yellow corn was 2.00%. Fageer and **El Tinay (2004)** observed that ash content in twelve corn genotypes ranged between 1.00 and 2.00%.

The same Table showed the fat content recorded at 3.78% in Shandweel-1. **Gebreyes (2017)** reported that the fat content in sorghum varieties ranged between 2.60 and 4.63%. Data indicated that yellow corn recorded 4.01%. **Naves *et al.* (2011)** reported that the fat content in corn was 4.85%.

The crude fiber content of whole meal sorghum and yellow corn was 1.95% and 2.23%, respectively. The results are in line with Wu *et al.* (2007) who revealed that crude fiber content in sorghum varieties ranged between 1.41 and 2.55%. **Ullah *et al.* (2010)** found that crude fiber varied from 0.80 to 2.32%.

Total carbohydrate content in sorghum and yellow corn was 79.00% and 81.89%, respectively. The results agree with **Okoh *et al.* (1982)** who reported that the total carbohydrate of sixteen sorghum genotypes ranged between 71.80 and 85.20%. **Fageer and El Tinay (2004)** found that carbohydrates in twelve corn genotypes ranged between 74.70 and 81.10%.

Table (3). Chemical composition of whole meal sorghum variety and yellow corn (%)

Varieties	**Moisture**	**Protein**	**Ash**	**Fat**	**Crude fiber**	**TC****
Shandweel-1	$8.32^{b}\pm0.12$	$12.50^{a}\pm0.24$	$2.77^{a}\pm0.19$	$3.78^{a}\pm0.33$	$1.95^{b}\pm0.04$	$79.00^{b}\pm0.45$
Corn-178	$10.43^{a}\pm0.02$	$9.87^{b}\pm0.56$	$2.00^{b}\pm0.25$	$4.01^{a}\pm0.11$	$2.23^{a}\pm0.08$	$81.89^{a}\pm0.49$

*Chemical composition was calculated as (%) on dry weight basis except for moisture, **TC Total carbohydrate. Data are presented as means of three replicates ±SD and the number in the same column followed by the same superscript is not significantly different at $p < 0.05$.

Cooking quality

The cooking process is an important factor in evaluating the quality of gluten-free pasta. Table (4) presents the cooking quality parameters of gluten-free pasta assessed for sorghum flour substituted with lentil or WPC powder were optimum cooking time (OCT), cooking loss (CL), and water absorption (WA). Optimum cooking time is the time in minutes needed to cook the entire core of the pasta and becomes soft. The cooking time of different sorghum gluten-free pasta ranged between 9.40 and 11.35 min. The data indicated that the cooking time of sorghum pasta substituted with whey protein concentrate was higher than that of pasta substituted with lentil powder. The high cooking time observed in Shandweel-1 substituted with 20% WPC and the lowest cooking time was in control pasta (9.15). The differences in cooking time may be attributed to the higher protein content, resulting in a firmer texture of the product **(Giri and Sakhale, 2022).** The results are in line with **Giuberti *et al.* (2015)** who found that both OCT and WA increased with the addition of 20 and 30% of bean powder in gluten-free rice pasta. Besides, **Savita *et al.* (2013)** found that fortification of pasta with different protein sources (*e.g.,* legumes, egg protein, and milk protein) increased OCT.

Cooking loss is a critical factor of pasta quality; it can be defined as the amount of solid materials that leach from the pasta surface and are lost to the cooking water. High cooking loss is undesirable, because it represents high solubility of starch, resulting in the turbidity of the cooking water; a low amount of cooking loss indicates a high quality of the cooked pasta. Generally, up to 6.0% solid cooking losses are considered quite well, from 7.0 to 8.0% are acceptable, and above 10% are considered to be poor. However, the cooking loss of gluten-free pasta cannot be compared to that of durum wheat pasta, which has a cooking loss of only 3% **(Susanna and Prabhasankar, 2013)**. The cooking loss percentage ranged from 4.86 to 7.55 %, and control pasta had the highest cooking loss, and Shandweel-1 pasta substituted with 20% WPC significantly decreased the cooking loss ($p<0.05$).

From the data shown in Table (4), it could be noticed that the cooking loss percentage for Shandweel-1 pasta substitution with lentil powder increased with the addition of lentil powder, and this may be due to the fact that the presence of fiber weakens the starch network **(Bouasla *et al*., 2017)**. In contrast, the cooking loss percentage of Shandweel-1 pasta substituted with WPC powder decreased by increasing the addition of WPC powder. This might be due to the strong starch-protein network in gluten-free pasta fortified with WPC which leads to lower leaching of solids in the cooking water, or it might be due to the fact that WPC forms a gel after denaturation and caused a decrease in cooking loss **(Phongthai *et al*., 2017; Kumar *et al*., 2019)**. These results are close to **Giuberti *et al*. (2015)** and **Phongthai *et al*. (2017)** who found that the addition of legume powder to gluten-free rice pasta from 20 to 40% increased the pasta cooking loss. Besides, the addition of whey protein concentrates or egg albumen decreases the cooking loss by up to 9%.

Pasta water absorption is based on the weakness of starch granules and is related to the amount of starch damage **(Lucisano *et al*., 2012)**. The amount of water absorption of pasta samples ranged between 89.72 and 119.26%. Shandweel-1 substituted with 20% lentil powder significantly ($p<0.05$) increased the water absorption, while the lowest value of water absorption was recorded in Shandweel-1 pasta substituted with 20% WPC.

The water absorption values for Shandweel-1 pasta substitution with lentil powder increased as the amount of lentil powder increased, which could be due to the protein denaturation of legumes during hot water hydration, which caused an increase in the availability of polar amino acids in proteins that could increase the water affinity **(Bouasla *et al*., 2017).** The water absorption values for Shandweel-1 pasta substituted with WPC powder decreased by increasing the addition of WPC powder. This may be due to that milk protein competitively decreases the water amount necessary for starch swelling in gelatinization **(Kumar *et al*., 2019)**. These results are close to **Ungureanu-Iuga *et al*. (2020)** who reported that the water absorption of corn gluten-free pasta decreased with the addition of WPC.

Table (4). Quality of cooking pasta

Pasta samples	OCT* (min)	CL (%)	WA (%)
Control	9.40^{d}±0.17	7.55^{a}±0.07	110.77^{c}±0.94
SL10	9.45^{cd}±0.29	5.93^{c}±0.18	115.21^{b}±0.33
SL15	10.10^{bcd}±0.10	6.22^{c}±0.27	117.91^{a}±1.78
SL20	10.40^{b}±0.10	6.66^{b}±0.29	119.26^{a}±1.13
SW10	10.15^{bc}±0.76	5.94^{c}±0.05	100.84^{d}±1.18
SW15	10.50^{b}±0.50	5.37^{d}±0.45	94.63^{e}±0.93
SW20	11.35^{a}±0.23	4.86^{e}±0.11	89.72^{f}±1.11

*Optimum cooking time (OCT), cooking loss (CL), and water absorption (WA). Control pasta= yellow corn 178 variety, S= Shandaweel-1, L= hulled lentil powder, W= whey protein concentrate powder, SL10= 10% lentil powder, SL15= 15% lentil powder, SL20= 20% lentil powder, SW10= 10% whey protein concentrate powder, SW15= 15% whey protein concentrate powder and SW20= 20% whey protein concentrate powder. Data are presented as means of three replicates ±SD and the number in the same column followed by the same superscript is not significantly different at $p<0.05$.

Color of gluten-free pasta

The color of pasta depends on the ingredients used in pasta preparation and the processing technique. The color parameters of cooked pasta samples are presented in Table 5. Regarding color values, the data showed that the lightness (L*) values of gluten-free pasta prepared from sorghum flour were significantly different compared with the control (yellow corn) pasta sample. The L* values were decreased with increasing levels of substitution of both lentil or whey protein concentrate (WPC) powder for cooked pasta samples. L* values of pasta decreased with increasing the level of legumes powder in rice gluten-free pasta from 10% to 30% **(Bolarinwa and Oyesiji, 2021)**. **Zhao *et al*. (2005)** observed that the L* of all spaghetti samples containing legumes powder decreased, and spaghetti containing lentil powder became much darker than spaghetti prepared from other legumes. The addition of 10 to 20% of WPC to gluten-free pasta decreases the L* values **(Kumar *et al*. (2019)**.

Cooked pasta samples substituted with hulled lentil powder increase redness and yellowness values with increasing levels of substitution. However, the yellowness values of cooked gluten-free sorghum pasta for both lentil and WPC samples were lower compared with control pasta. The results are close to those of **Bouasla *et al*. (2017)** who indicated that enriched gluten-free pasta with 30% of lentil powder significantly increase the red color of gluten-free pasta, and this was attributed to the color of the lentil powder. **Zhao *et al*. (2005)** found that increasing the level of legume powder from 5% to 30% in spaghetti increases the redness of lentil spaghetti. **Kumar *et al*. (2019)** reported that the addition of WPC decreased a* values in pasta. **Bolarinwa and Oyesiji (2021)** and **Bouasla *et al*. (2017)** mentioned that the yellowness values increased with increasing legume powder in gluten-free pasta. **Prabhasankar *et al*. (2007)** revealed that yellowness (b*) values decreased with increasing levels of WPC in vermicelli samples.

Table (5): Color parameters of cooked gluten-free pasta

Pasta samples	Cooked pasta		
	L*	***a****	***b****
Control	78.74^{a}±0.81	0.46^{d}±0.08	24.29^{a}±0.54
SL10	71.68^{c}±0.17	1.97^{bc}±0.07	14.80^{cd}±0.35
SL15	70.26^{d}±0.36	2.25^{b}±0.48	15.25^{bc}±0.39
SL20	68.18^{e}±0.31	3.30^{a}±0.51	15.67^{b}±0.30
SW10	72.92^{b}±0.12	2.04^{bc}±0.02	14.55^{cde}±0.17
SW15	71.93^{c}±0.27	1.78^{bc}±0.09	14.24^{de}±0.35
SW20	69.63^{d}±0.44	1.57^{c}±0.15	13.84^{e}±0.24

Control pasta= Yellow corn (178 variety), S= Shandaweel-1 variety, L= hulled lentil powder, W= whey protein concentrate powder, SL10= 10% hulled lentil powder, SL15= 15 % hulled lentil powder, SL20= 20% hulled lentil powder, SW10= 10% whey protein concentrate powder, SW15= 15% whey protein concentrate powder and SW20= 20% whey protein concentrate powder. Data are presented as means of three replicates ±SD and the number in the same column followed by the same superscript is not significantly different at $p < 0.05$.

Sensory evaluation of cooked pasta

The sensory parameters (*e.g.* color, taste, odor, texture, and overall acceptability) were assessed for gluten-free pasta of sorghum flour (Shandweel-1 variety) substituted with lentil or WPC powder. Color scores increased in the gluten-free pasta with increasing proportion of lentil powder, while the color score decreased by increasing the level of WPC. The data revealed that the control sample and Shandweel-1 substituted with lentil powder (10 - 20%) had the highest color scores and non-significantly different ($p< 0.05$), followed by Shandweel-1 substituted with 10% WPC powder and the lowest score was in Shandweel-1 pasta substituted with 20% WPC. Thus, pasta samples substituted with 20% lentil powder were the most preferred by the panelists in terms of color, and this may be due to the yellowness of the hulled lentil. These results are in line with **Bolarinwa and Oyesiji (2021)** who observed that the color scores for pasta improved with increasing the level of legume powder. The same Table showed the taste scores, the highest sensory score of taste was in Shandweel-1 with 10 to 30% lentil powder and 10% WPC followed by 20% WPC.

Regarding odor scores, Shandweel-1 pasta substituted with 15% lentil was highly evaluated in terms of odor, and while there were non-significant differences ($p<0.05$) compared with control pasta, except for pasta with 20% WPC. Concerning texture scores, the texture values increased in the substituted pasta with increasing proportion of lentil or WPC powder in the pasta. Shandweel-1 substituted with 20% lentil powder had the highest score and this may be due to the high protein content of pasta substituted with lentil or WPC powder. Concerning overall acceptability, pasta products presented scores (values >7), which increase by increasing the level of legume powder, while it decreased with increasing WPC. **Menon *et al.* (2016)** reported that noodles prepared from sweet potato with 20% WPC had higher overall acceptability. Thus, lentil powder could be used for gluten-free pasta fortification up to 20% for better consumer acceptability; however, WPC could be used for gluten-free pasta fortification up to 10% of Shandaweel-1 flour formula. Overall, Shandweel-1 substituted with lentil powder, was the most preferred in terms of all the parameters evaluated where the best ratio was 20%. These results are in line with those of **Teterycz *et al.* (2020),** who reported that pasta formulated with lentil powder was the most acceptable product among different legumes flour.

Table (6). Sensory evaluation of cooked pasta

Pasta samples	**Color**	**Taste**	**Odor**	**Texture**	**Overall acceptability**
Control	$8.30^{a}\pm0.26$	$8.00^{a}\pm0.33$	$8.10^{a}\pm0.21$	$7.90^{ab}\pm0.28$	$8.05^{a}\pm0.16$
SL10	$8.10^{a}\pm0.21$	$7.90^{a}\pm0.46$	$7.90^{ab}\pm0.39$	$7.85^{ab}\pm0.24$	$7.95^{ab}\pm0.16$
SL15	$8.10^{a}\pm0.24$	$7.90^{a}\pm0.21$	$8.15^{a}\pm0.34$	$7.95^{a}\pm0.16$	$8.00^{a}\pm0.00$
SL20	$8.25^{a}\pm0.26$	$8.00^{a}\pm0.24$	$7.85^{ab}\pm0.34$	$8.00^{a}\pm0.00$	$8.05^{a}\pm0.16$
SW10	$7.50^{b}\pm0.33$	$7.80^{a}\pm0.35$	$7.90^{ab}\pm0.61$	$7.65^{b}\pm0.41$	$7.80^{b}\pm0.26$
SW15	$7.40^{bc}\pm0.39$	$7.50^{b}\pm0.24$	$7.80^{ab}\pm0.48$	$7.80^{ab}\pm0.35$	$7.55^{c}\pm0.16$
SW20	$7.20^{c}\pm0.26$	$7.15^{c}\pm0.24$	$7.65^{b}\pm0.47$	$7.75^{ab}\pm0.26$	$7.35^{d}\pm0.24$

Control pasta= yellow corn 178 variety, S= Shandaweel-1, L= lentil, W= whey protein concentrate powder, SL10= 10% lentil powder, SL15= 15% lentil powder, SL20= 20% lentil powder, SW10= 10% whey protein concentrate powder, SW15= 15% whey protein concentrate powder and SW20= 20% whey protein concentrate powder. Data are presented as means of three replicates ±SD and the number in the same column followed by the same superscript is not significantly different at $p < 0.05$.

CONCLUSIONS

Lentil powder or whey protein concentrate (WPC) was added to sorghum flour in the gluten-free pasta formulation to enhance the quality of the pasta. WPC powder addition provides minimal cooking loss compared with lentil powder. Substituting sorghum flour with lentil or WPC powder affected the sensory evaluation of gluten-free pasta. Besides, the substitution levels of lentil powder up to 20% and WPC powder up to 10% were the highest acceptable levels for sensory attributes. Generally, the current research indicates that sorghum pasta enriched with lentil powder is promising as a consumer-acceptable product, a practical and attractive option to increase the acceptance of gluten-free pasta. In addition to that, it will provide markets and industries with new, diversified gluten-free products that meet the diversification of consumers' desires.

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الملخص العربي

تأثير إضافة مسحوق العدس أو بروتين مصل اللبن على جودة مكرونة دقيق الذرة الخالية من الجلوتين

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تهدف الدراسة إلى تقييم تأثير استبدال دقيق الذرة الرفيعة (صنف شندويل 1) في الخلطات الخالية من الجلوتين بالعدس أو مسحوق بروتين شرش اللبن المركز، في وجود الذرة الصفراء (صنف 178) ومسحوق البطاطا على صفات الجودة للمكرونة الخالية من الجلوتين (تشمل صفات اللون، جودة الطهي، والتقييم الحسي) لسد الفجوة فى المنتجات الخالية من الجلوتين. تم تحضير ست خلطات خالية من الجلوتين بمستويات استبدال مختلفة لدقيق الذرة الرفيعة مع دقيق العدس المقشور أو مسحوق بروتين شرش اللبن المركز. تم عمل التقييم الفيزيائي والكيميائي لحبوب الذرة الرفيعة والذرة الصفراء. وقد أشارت النتائج إلى أن وجود اختلاف معنوي في قيم وزن الألف حبة، والوزن النوعي بين الذرة الرفيعة وحبوب الذرة الصفراء، وكانت قيم البريق لحبوب شندويل-1 أعلى من الذرة الصفراء. ارتفع محتوى الذرة الرفيعة من البروتين والرماد مقارنة بالذرة الصفراء ولم يكن هناك فروق معنوية بينهما في محتوى الزيت. أدى استبدال دقيق الذرة مع العدس أو مسحوق بروتين شرش اللبن المركز إلى زيادة طرديّة فى مدة الطهي للمكرونة الناتجة بزيادة نسب الاستبدال. بينما زاد الفقد بعد الطهي وامتصاص الماء لمكرونة الذرة الرفيعة بإضافة مسحوق العدس، وأيضًا انخفض بإضافة بروتين شرش اللبن المركز. انخفضت قيم البريق بزيادة الاستبدال بمسحوق العدس أو بروتين شرش اللبن المركز، كما انخفضت قيم الاحمرار والاصفرار باستخدام بروتين شرش اللبن المركز، بينما زادت بزيادة نسب الاستبدال بمسحوق العدس المقشور. بالنسبة للقبول الحسي للمنتجات؛ كانت أفضل الخلطات والأكثر تقبلًا هي مكرونة الذرة الرفيعة المعدة من مسحوق العدس بنسبة 20٪. تشير الدراسة إلى أن مكرونة الذرة الرفيعة المعدة من مسحوق العدس قد لاقت قبولًا لدى المحكمين، وهي خيار عملي وجذّاب لتحسين جودة المكرونة الخالية من الجلوتين، وإمداد السوق بمنتجات متنوعة خالية من الجلوتين تناسب رغبات المستهلكين.