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Nutritional Value, Antioxidant Activity, Cooking Quality, and Sensory Attributes of Pasta Enriched with Cornsilk

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CORNSILK is one of the agricultural wastes of great nutritional and therapeutic benefit. This research aimed to study the chemical composition, antioxidant activity, phenolic content, and phenolic compounds profile of cornsilk powder (CSP) and the effect of adding it on the nutritional value, color, textural properties, cooking quality, and sensory attributes of pasta. The results showed a higher content of mineral elements in CSP compared to durum wheat semolina (DWS). The total phenolic content in CSP (10.68±0.1 mg GAE/g) was significantly ($p<0.05$) higher compared to DWS (0.478±0.07 mg GAE/g). The ethanolic extract of CSP recorded a significantly higher DPPH radical scavenging activity (9.786±0.09 mg TE/g dry matter) than the ethanolic extract of DWS (4.108±0.1 mg TE/g dry matter) ($p<0.05$). Likewise, for the FRAP assay, which was 12.494 ± 0.19 and 2.624 ± 0.14 µmol Fe^{+2}/g dry matter in CSP and DWS, respectively. The most five abundant phenolic compounds in CSP dry samples were gallic, rosmarinic, rutin, catechin, and kaempferol. The addition of CSP into DWS-pasta caused a significant gradual increase in protein, ash, and fiber, while the addition of CSP caused a significant decrease in the carbohydrate content and the energy value ($p<0.05$). DWS was lighter than the CSP, while CSP was higher in both redness (a* value) and yellowness (b* value) than the DWS. The redness and yellowness values increased significantly in both uncooked and cooked pasta by increasing the enriching with CSP. The cooking properties and firmness of the 2.5-CSP enriched pasta were not affected much compared to the control, while some effect was shown in these parameters by increasing the enrichment percentage. Sensory evaluation indicated that CSP can be incorporated into pasta ingredients in 10%, without any significant effect on consumers' sensory acceptability. Shortly, these results reflect a nutritional and distinct health value of corn silk as an additive to DWS pasta.

Keywords: Cornsilk, phenolic profile, Pasta.

Introduction

Corn (*Zea mays* L.) is one of the most popular and widely distributed cereal crops as human food and as animal feed around the world (da Hora et al., 2021). Cornsilk is part that is left behind in abundance after corn grains are consumed. Cornsilk - also known as Stigma maydis- grows in female flowers after pollination during the reproductive stage of the corn plant, and it consists of fine fibers that resemble threads, corn silk at this stage is characterized by its green color, soft texture, and high moisture content, and soon becomes dry brown during the following stages of plant growth (Cárcova et al., 2003).

Cornsilk has been known as a medicine in folk medicine in East Asian countries since a long time ago, and more recently, the health benefits and biological activities of corn silk which include antioxidant, antimicrobial, and anti-glioma activities (da Hora et al., 2021), anti-diabetic activity (Zhao et al., 2012), anti-tumor activity (Habtemariam, 1998), anticancer activity (Abirami et al., 2021), anti-obesity, various

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urinary system diseases (Velazquez et al., 2005), curb hyperpigmentation (Choi et al., 2014)), and anti-fatigue (Hu et al., 2010) have been reported in many scientific pieces of literature. Cornsilk powder is taken as a dietary supplement or as a capsule.

Pasta is one of the most important foods consumed around the world due to its relatively low cost and desirable organoleptic properties. (Oyeyinka et al., 2021). Its components, manufacturing and presentation methods vary within the same country, as well as the diversity in that among different countries of the world. The pasta is mainly made of durum wheat semolina (DWS), which is characterized by an appropriate amount and characteristics of strong gluten that gives the pasta dough its distinctive rheological properties (Vignola, et al., 2018). Pasta is a rich source of carbohydrates and an acceptable source of vegetable protein, but it is relatively poor in minerals, vitamins, and antioxidants, which are removed with the bran during the wheat milling process (Oyeyinka et al., 2021). This deficiency may be compensated for by adding some ingredients to the pasta recipe such as eggs or some other vegetable additives but bearing in mind that an increased amount of these ingredients may negatively affect the cooking qualities of the resulting pasta (Rosell, 2008; Bolarinwa & Oyesiji, 2021).

Recently, the trend has grown to provide non-traditional food additives that meet the need to fill the deficit in the quantities of food available for human consumption, and provide more diversity to the prevailing food dishes, and, on the other hand, contribute to maximizing the use of agricultural production residues (Rozan & Boriy, 2022).

There is no research - within the limits of our reading - on the study of the effect of adding corn silk powder to cereal foods. Therefore, our current study aimed to evaluate corn silk as an abundantly available secondary source in terms of chemical composition, antioxidant activity, phenolics profile, and the effect of adding corn silk to DWS at different levels on nutritional value, antioxidant activity, textural properties, cooking quality, and sensory attributes of pasta.

Materials and Methods

Materials

Cornsilk *(Zea mays)* was collected from a single hybrid yellow Giza 168 cultivar, grown at Sakha Agricultural Research Station (latitude of 31.100 N and longitude 30.930 E, at an elevation of 14m above sea level), Kafr El-Sheikh Governorate, Egypt, in the season 2021. Corn silk was collected at the physiological maturity stage (30 days after anthesis, August 15), the sample was washed lightly with distilled water, and then immediately spread out with a thickness of 0.5 cm for ventilation in a dry, sunny location away from dust and dirt tracks on a water-resistant plastic tarpaulin throughout the day (approximately 13 h), then the sample was placed in a vacuum drying oven (Apex AX Model, Carbolite Gero, UK) at 40°C for four days, after which the sample was ground using a multi-speed electric grinder (MB-355 Model, China) at speed 1 to allow the corn silk powder to pass through a 50-mesh size sieve to obtain corn silk powder (CSP). The dried CSP was kept in sealed polyethylene bags at -20±2 º C until use and analysis.

Durum wheat semolina (Triticum turgidum ssp. durum) was obtained from the Rogina Pasta Factory in Sadat City, Menoufia Governorate, Egypt.

All chemicals and solvents used for spectral and HPLC analyses were of HPLC grade and were purchased from Sigma Chemical Company, USA.

Pasta preparation

Based on the results of the preliminary experiments, four levels were chosen to replace CSP with DWS for the production of the enriched pasta, which is: 2.5, 5, 7.5, and 10% (w/w). DWS was mixed with CSP at the four levels to obtain a homogeneous flour. Five blends were used, four contain CSP at the levels listed above, and the fifth for comparison does not contain CSP (control). In all five treatments (including control, 2.5-CSP, 5-CSP, 7.5-CSP, and 10-CSP) 50g of distilled water and 2g of salt are added to 100g of sample, then the ingredients are mixed using a mixer until dough is of good consistency, and left to rest for 15 min. Then, the dough was put into a pasta forming machine (Design 150mm-DELUXE, Italy) and pressed, cut into identical pieces 2mm thick in trays lined with aluminium foil, then the samples were dried in a hot air oven (PRESTO, PSO – 451 digital models, India) at 82±3 ºC for 2 h, the dried pasta was packed into Ziploc bags and stored at room temperature (25±1 ºC) until use in the tests.

Chemical composition and energy value

The proximate composition (moisture, fat, ash, and fiber) of the samples was determined according to AOAC (2007) methods. Nitrogen content was estimated using the Kjeldahl method, then protein was calculated with convert factor (6.25 × N), while the total carbohydrate was estimated using the following formula: [100 - (%protein + %moisture + %fat +%ash +%fiber)]. The caloric value of cooked pasta (Kcal/ 100g) was calculated mathematically by multiplying the amount of carbohydrate and protein (g/100g) by 4 and multiplying the amount of fat (g/100g) by 9.

Estimation of mineral elements

Mineral elements including sodium, potassium, magnesium, calcium, iron, zinc, copper, manganese and phosphorous were determined according to the methods of AOAC (2007).

Total phenolics content

The total phenolic contents in DWS and CSP were determined following the Folin-Ciocalteu procedure. Briefly, 100 µL of the ethanolic extract was transferred into a test tube, and 250 µL of Folin-Ciocalteau reagent was added. After 5 min, the mixture was neutralized with 1.25 ml of 20% aqueous Na_2CO_3 solution. After 40 min, the absorbance was spectrophotometrically measured (T80 x UVNIS model Spectrometer PG Instruments Ltd) at 725 nm against the solvent blank. The total phenolic content was determined using a calibration curve prepared with gallic acid and expressed as mg of gallic acid equivalent (GAE) per gram of sample (Zilić et al., 2012).

Antioxidant activity

Antioxidant activity in DWS and CSP extracts was determined using DPPH Free Radical-Scavenging assay according to the method of Teh et al. (2014), while antioxidant activity using ferric reducing antioxidant power (FRAP) Assay was estimated according to the method of Benzie and Strain (1996).

Determination of phenolic compounds

Extraction of phenolic compounds: to extract the phenolic compounds the following procedure was followed: one gram of each of DWS and CSP was put into a conical flask with 20 mL of NaOH (2M), the flask was rinsed with nitrogen gas, and shaken for 3 h (1200 rpm, 24±1 ºC), pH was adjusted to 2 with HCl (N), then the output was centrifuged for 10 min (5000 rpm, 24±1 ºC). To obtain the phenolic compounds, 50 mL of an equal mixture of ethyl acetate and ethyl ether was used to wash the filtrate twice. The formed organic face was separated and evaporated at 45°C and the samples redissolved in 1ml methanol.

HPLC analysis of phenolic compounds: HPLC analysis was carried out using Agilent Technologies 1100 series liquid chromatograph equipped with an autosampler and a diode-array detector. The analytical column was an Eclipse XDB-C18 (150 X 4.6 µm, 5 µm) with a C18 guard column (Phenomenex, Torrance, CA). The mobile phase consisted of acetonitrile (solvent A) and 2% acetic acid in water (v/v) (solvent B). The flow rate was kept at 0.8 ml/min for a total run time of 70 min and the gradient program was as follows: 100% B to 85% B in 30 min, 85% B to 50% B in 20 min, 50% B to 0% B in 5 min and 0% B to 100% B in 5 min. The injection volume was 50 µl and peaks were monitored simultaneously at 280 and 320 nm for the benzoic acid and cinnamic acid derivatives, respectively. All samples were filtered through a 0.45 µm syringe filter before injection. Peaks were identified by congruent retention times and UV spectra and compared with those of the standards.

Color measurements

Color parameters (Lightness (L): L=0 for darkness, L*=100 for lightness; a*: chromaticity on a scale of green (–) to red (+); b*: chromaticity on a scale of blue (–) to yellow (+), 90˚= yellow; 180˚ = bluish to green and 270˚ = blue scale) were measured in semolina, corn silk, and pasta samples according to the method of Tong et al., (2010) using Konica Minolta CR-410 Chroma meter (Konica Minolta, Sensing, INC., Japan). The following formula was used for calculating the total color difference (ΔE):

$$\Delta E = (\Delta L^{*2}+\Delta a^{*2}+\Delta b^{*2})\ 0.5$$

Where ΔL* = L* sample – L* standard, Δa* = a* sample – a* standard, and Δb* = b* sample – b* standard.

Cooking properties of pasta

The cooking properties of pasta have been evaluated including optimum cooking time, weight increase, swelling index and solid loss after cooking.

Optimum cooking time (OCT) was determined using the method of (Sobota et al. (2015), OCT is indicated by the disappearance of the white core of the pasta when pressed between two glass plates.

Weight increase was estimated as follows: approximately 10 g of each sample was cooked for the pre-set optimal cooking time, the weight after cooking was recorded, and the percentage of weight increase was calculated from the following formula:

% Weight increase = [(weight of cooked pasta - weight of raw pasta)/ weight of raw pasta] × 100.

The swelling index (g water/g dry pasta) was estimated using the method of Tudorică et al. (2002), as follows: About 5 g of cooked pasta (Wc) was dried at 105 °C until the weight was constant, and the dried pasta weight was accurately recorded (Wd). The swelling index (SI) was calculated using the following equation:

$$SI= (Wc- Wd)/ Wd$$

The solid loss after cooking pasta according to Sun-Waterhouse et al. (2013) method has been estimated with slight modifications. Approximately 5g of pasta was weighed and the weight was accurately recorded (W1), the weighted pasta was cooked in 200ml of boiling water for the pre-set optimum cooking time. The cooked pasta was removed from the cooking water taking care to drain the water completely and the drained water was collected in a standard 250 ml beaker, the volume in the beaker was supplemented to 250 ml using distilled deionized water, with shaking to homogenize the cooking water, 10 mL of the homogeneous liquid was taken, evaporated in a vacuum drying oven (Apex AX Model, Carbolite Gero, UK) at 80 °C, and the weight of the solid residue after evaporation (Wr) was recorded. The solid residue was calculated from the following equation:

% Solid loss = Wr (g) × 250 ×100/ [10 ×W1 (g)].

Firmness

To measure the firmness of the pasta samples, the samples were cooked for the predetermined OCT for each sample individually, then drained from the cooking water well and left to rest for 10 min (Gull et al, 2015). Texture analyzer (Spaghetti/Noodle Tensile Rig, Stable Micro Systems, UK) was used under the following settings: the load cell was 50 kg, equipped with pressure plates, with a cylindrical penetration probe of 25 mm diameter, the speed of the pre-test was set at 2 mm/s, while the speed of the post-test was set at 10 mm/s, and test speed 2.0 mm/s. The pasta slices were cut into 4 cm squares and the sample was placed on the base and pressed twice to obtain a complete stress-relaxation-tension curve. Firmness (N) was obtained from the force-distance curve. The measurements were repeated five times for each sample.

Sensory evaluation

Sensory evaluation of cooked pasta samples was conducted by forty-five semi-trained panelists from staff members of the Food Science and Technology Department, Faculty of Agriculture, Damanhour University (26 males, 19 females, between the ages of 22 and 48 years). The written consent of the members was obtained to conduct the test after informing them of its nature and the potential allergic risks for people with gluten sensitivity. The approval of the Scientific Research Ethics Committee at the Faculty of Agriculture, Damanhour University were also obtained.

The pasta samples were cooked by boiling in distilled water to reach the optimum cooking time, then dried for 2 minutes and presented to the members in coded dishes. The members were instructed to rinse their mouths before commencing the assessment and between samples.

Sensory properties of coded pasta samples including color, taste, aroma, texture (mouth feel), and overall acceptability were evaluated using a 9-point hedonic scale where 1 represents 'dislike extremely' and 9 represent 'like extremely'. Pasta is considered acceptable if its mean score for overall acceptability was higher than 5 (Wójtowicz et al., 2020).

Statistical analysis

The results are expressed by taking the average value for five replicates (M ± SD), using SPSS 16 software by one-way ANOVA. The results were considered significant at $p<0.05$. The correlation matrix diagram was produced using the R corrplot package.

Results and Discussions

Mineral elements

Table 1 displays the content of mineral elements in CSP and DWS. The results show that the content of all the mineral elements estimated in CSP is significantly more than in DWS. Potassium and phosphorous are the two most abundant elements in CSP and DWS, with their content reaching 1652.4±11.3, 605±6.7 mg/100g (DW) in CSP, and 274.5±6.3, 243±7.4 mg/100g, dw in DWS, respectively. Mineral elements are mainly concentrated in the outer layers of the wheat grain, which leads to a marked decrease in its content when milling the wheat and removing the layers of bran (Cubadda et al., 2009). These results make CSP a rich additive to pasta that recoups a great number of minerals lost during wheat milling. Looking at data on the FDA's recommended daily values (DV) for estimated minerals, 100 grams of

TABLE 1. The content of mineral elements in CSP and DWS compared to FDA-recommended daily value.

Element	DWS (mg/ 100g, dw)	CSP (mg/100g, dw)	FDA recommended daily value (mg)*	% DV of CSP**
Sodium	0.23±0.07[b]	11.25±0.15[a]	2300	0.49
Potassium	274.5±6.3[b]	1652.4±11.3[a]	4700	35.16
Magnesium	78.3±1.36[b]	95.9±1.2[a]	420	22.83
Calcium	27.6±0.23[b]	63.48±1.05[a]	1300	4.88
Iron	3.66±0.1[b]	8.94±0.1[a]	18	49.67
Zinc	2.01±0.1[b]	5.36±0.1[a]	11	48.73
Copper	0.35±0.05[b]	2.34±0.06[a]	0.9	260
Phosphorous	243±7.4[b]	605±6.7[a]	1250	48.4
Manganese	0.52±0.04[b]	3.57±0.1[a]	2.3	155.22

Values: Mean ± standard deviation, five replicates. Values followed by different letters in the same row are significantly different (LSD) at p<0.05.
* As available at this link: https://www.fda.gov/media/135301/download, last accessed 10/ 2022. ** % daily requirement covered by 100g of corn silk.

corn silk covers 260% of DV for copper, 155.22% of manganese, and nearly 50% percent of DV for iron, zinc, and phosphorous.

Total phenolic content, and antioxidant activity

The total phenolic content (Table 2) in CSP (10.68±0.1 mg GAE/g) was significantly ($p<0.05$) higher compared to DWS (0.478±0.07 mg GAE/g), which reflects a nutritional and distinct health value of CSP as an additive to DWS pasta. Refining flour and semolina leads to the loss of many phenolic compounds because it is concentrated in the outer layer of the whole wheat grain, therefore, food products made from refined flour and semolina, such as pasta, are characterized by a low content of these compounds (Wójtowicz et al., 2020).

Phenolics are antioxidants that can scavenge free radicals, so the antioxidant activity of extracts is positively related to their total phenolic content of them (Ardestani & Yazdanparast, 2007; žilić et al., 2016). Previous studies have reported that the high content of phenols in the outer layers of wheat grain corresponded with the high antioxidant activity in the brain, while the low antioxidant activity for semolina was associated with its low content of total phenols (Liyana-Pathirana & Shahidi, 2007; Fu et al., 2017)

Table 1 shows the results of antioxidants activity conducted via the DPPH and FRAP assays. The ethanolic extract of CSP recorded a significantly higher DPPH radical scavenging activity (9.786±0.09 mg TE/g dry matter) than the ethanolic extract of DWS (4.108±0.1 mg TE/g dry matter) ($p<0.05$). Likewise, for the FRAP assay, which was 12.494 ± 0.19 and 2.624 ± 0.14 µmol Fe^{+2}/g dry matter in CSP and DWS, respectively. Sarepoua et al. (2015) found that the total phenolic content of corn silk ranged between 26.5 and 206.8 µg GAE/g (dried sample) in the purple waxy, white waxy and super sweet corn varieties evaluated across silking, milky, and physiological maturity stages. The silk samples obtained from the purple waxy corn had the highest content of total phenolic content, while the lowest content was found in the white waxy corn. The highest total phenolic content was followed by silking stage and physiological maturity stage. For DPPH radical scavenging activity, the silk harvested at the silking stage was the best source especially for the purple waxy corn, followed by the milky phase, and finally the physiological maturity phase. žilić et al. (2016) found that the total phenolics content in corn silk collected 5 days after its growth, was higher by about 2- to 4-fold than in the mature corn silk (collected 25 days after its growth), also, they reported wide differences between cultivars in their total phenolic content, which ranged in silks collected after 5 days from its growth between 8101.6 ± 73.5 and 10160.8 ± 250 mg CGAE/100 g) and ranged in mature silks from 2093.9 ± 215.7 to 4347.2 ± 49.0 mg CGAE/100 g. Maksimović et al. (2005) found that FRAP values for mature silks of fifteen maize hybrids ranged from 79.8±0.5 to 160.8±1.7 ascorbic acid equivalents/mg of dry plant material, and total polyphenols content ranged from 758.8±63.8 to 2937.5±152.5 mg catechin/100g dry plant material, while Nurhanan et al. (2012) reported that the total polyphenol content of water and methanolic extracts of corn silk were 256.36 mg GAE/100 mg, and 272.81mg GAE/100 g dry plant, respectively, and the water extract scavenged at 63.5% of free radicals at 1000 µg/mL while the methanolic extract showed 81.7% of inhibition. The difference between these results can be attributed to several factors; The most important are the extraction conditions, the variety of corn, the country from which the samples were collected, and the growth stage of corn silk (Sarepoua et al., 2015; žilić et al., 2016).

Phenolics profile

Phenolic compounds are natural antioxidants that are found naturally in various parts of the plant, particularly medicinal plants, fruits, and vegetables. Phenolic compounds show broad therapeutic properties. A large part of the importance of their presence in diets, in addition to their role as dyes and flavorings, lies in their ability to provide natural antioxidants as an alternative to artificial antioxidants that can have a toxic effect (Khojasteh et al., 2020; de Araújo et al., 2021). Accordingly, it is essential to know the phenolic compounds profile in corn silk as a nutritional supplement and potential food additive. Under the conditions of our current study, 11 and 16 phenolic compounds were detected in DWS and CSP extracts, respectively as shown in Table 3. DWS was distinguished by the presence of two phenolic acids that were not detected in the CSP sample including syringic and vanillic, while CSP was distinguished by seven phenolic acids that were not detected in the DWS sample, including catechin, rutin, apigenin-7-glucoside, rosmarinic, quercetin, apigenin, and kaempferol. The most five abundant phenolic compounds in CSP dry samples were gallic (333.67±2.45 µg/g), rosmarinic (262.462±3.47 µg/g), rutin (70.1±0.3 µg/g), catechin (42.658±0.15 µg/g), and kaempferol (33.636±0.19 µg/g), while the most five abundant phenolic compounds in DWS were ferulic (407.67±3.78 µg/g), caffeic (83.052±0.28 µg/g), chlorogenic (72.453±0.3 µg/g), cinnamic (54.18±0.5 µg/g), and sinapic (41.171±0.22 µg/g). Except for gallic and p-coumaric, the content of phenolic compounds detected in both DWS and CSP was significantly higher in DWS than in CSP ($p<0.05$).

Chemical composition of pasta samples

Table 4 shows the chemical composition of corn silk compared to DWS, the results indicate that CSP had a higher content of protein, oil, ash and fiber, and a lower total carbohydrate and energy value compared to DWS, while no significant differences were recorded between CSP and DWS in moisture content ($p<0.05$). The incorporation of CSP into the pasta formula caused a significant difference in some components of control treatment and CSP- pasta including protein, ash, and fiber contents. The addition of CSP caused a significant gradual increase in these three components ($p<0.05$). Protein content was 11.974 ± 0.23, and 12.266±0.1 in control and 10-CSP pasta samples, respectively, while ash content was 1.652±0.07, 2.072±0.05 in control and 10-CSP pasta samples, respectively, and fiber content was 0.864±0.03, 3.068±0.1 in control and 10-CSP pasta samples, respectively. In contrast, the addition of CSP caused a significant decrease in the carbohydrate content and the energy value ($p<0.05$), this decrease was inversely proportional to the increase in the percentage of CSP addition. There were no significant differences between the control and CSP-pasta samples in the content of both moisture and oil contents ($p<0.05$). These results are logical due to the difference in chemical composition between CSP and DWS.

The proximate chemical composition of corn silk differed somewhat from the results reported by Aukkanit et al. (2015), which were as follows: 9.06 Moisture, 17.94% protein, 0.91% fat, 4.60%

TABLE 2. Total phenolic content and antioxidant activity, of DWS and CSP .

Parameter	Component	Durum Wheat Semolina	Corn silk
Total phenolic content (mg GAE/g dw)		0.478±0.07^{b}	10.68±0.1^{a}
Antioxidant activity	**DPPH (mg TE/g dw)**	4.108±0.1^{b}	9.786±0.0^{9}a
	FRAP assay (µmol Fe^{+2}/g dw)	2.624±0.14^{b}	12.494±0.19^{a}

Values: Mean ± standard deviation, five replicates. Values followed by different letters in the same row are significantly different (LSD) at $p<0.05$.

TABLE 3. Phenolic compounds profile in corn silk.

Compound	DWS (μg/g, dw)	CSP (μg/g, dw)
Gallic	5.4±0.1[b]	333.67±2.45[a]
Protocatechuic	25.12±0.25[a]	18.012±0.2[b]
p-hydroxybenzoic	60.421±0.29[a]	8.958±0.1[b]
Catechin	ND	42.658±0.15
Chlorogenic	72.453±0.3[a]	29.445±0.12[b]
Caffeic	83.052±0.28[a]	1.273±0.05[b]
Ferulic	407.67±3.78[a]	23.169±0.1[b]
Sinapic	41.171±0.22[a]	10.863±0.1[b]
p-coumaric	2.53±0.09[b]	7.405±0.09[a]
Rutin	ND	70.1±0.3
Apigenin-7-glucoside	ND	11.693±0.14
Rosmarinic	ND	262.462±3.47
Cinnamic	54.18±0.5[a]	17.033±0.15[b]
Qurecetin	ND	20.479±0.27
Apigenin	ND	13.146±0.23
Kaempferol	ND	33.636±0.19
syringic acid	16.801±0.21	ND
vanillic	14.6±0.18	ND

Values: Mean ± standard deviation, three replicates. Values followed by different letters in the same row are significantly different (LSD) at p<0.05.

TABLE 4. Chemical composition of durum wheat semolina, corn silk, and pasta enriched with corn silk powder.

Treatment	Component (g/ 100g)						Energy (Kcal/ 100g)
	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate	
DWS	11.35±0.31[b]	12.062±0.1[b]	1.822±0.1[c]	0.638±0.07[c]	0.77±0.01[cd]	73.358±0.61[a]	358.08±1.26[a]
CSP	11.204±0.27[b]	14.86±0.45[a]	1.918±0.1[bc]	4.49±0.24[a]	22.62±0.24[a]	44.92±0.19[d]	252.38±1.14[e]
0-CSP pasta	12.46±0.17[a]	11.974±0.23[b]	1.93±0.06[bc]	1.652±0.07[b]	0.864±0.03[cd]	71.12±0.042[ab]	349.75±1.23[b]
2.5-CSP pasta	12.324±0.11[a]	12.088±0.13[b]	1.97±0.05[ab]	1.76±0.04[b]	1.45±0.046[c]	70.4±0.39[ab]	347.69±1.36[bc]
5-CSP pasta	12.362±0.35[a]	12.106±0.24[b]	2.014±0.07[a]	1.834±0.04[b]	2.058±0.08[bc]	69.626±0.4[bc]	345.05±1.17[c]
7.5-CSP pasta	12.426±0.25[a]	12.198±0.2[ab]	2.036±0.09[a]	1.97±0.04[b]	2.618±0.08[b]	68.752±0.35[bc]	342.12±1.3[cd]
10-CSP pasta	12.49±0.22[a]	12.266±0.1[b]	2.06±0.05[a]	2.072±0.05[b]	3.068±0.1[b]	68.044±0.37[c]	339.78±1.39[d]

Values: Mean ± standard deviation, five replicates. Values followed by different letters in the same column are significantly different (LSD) at p<0.05.DWS: durum wheat semolina, CSP: corn silk powder.

ash, 16.11% crude fiber and 51.37% carbohydrate. These differences can be attributed to a variety, of environmental and agricultural factors.

Color parameters of pasta

Color is one of the most important characteristics that determine the quality, suitability, and acceptability of food. The pigments that cause the natural coloring of pasta belong to carotenoids (Ohm et al., 2008).

The color properties results (Table 5) showed that DWS was lighter than the CSP, where it reached 74.42±0.58 in DWS, and 43.26±0.12 in CSP, while CSP was higher in both redness (a* value) and yellowness (b* value) than the DWS, where a* and b* values were 5.692±0.18 and 17.152±0.1 in CSP, 2.076±0.1 and 14.216±0.16 in DWS, respectively. These results can be attributed to the difference in pigment composition between corn silk and durum wheat semolina. The distinctive yellow color of semolina and pasta is due to the accumulation of carotene pigments in the grains. The carotene pigments are natural antioxidants and vitamin A generators, in addition to their commercial value in pasta products, consumers prefer the light-yellow color in semolina and pasta products (Colasuonno et al., 2019). Unlike other kinds of wheat, the durum wheat used to make pasta is characterized by its relatively high content of carotenoids (Trono, 2019).

The color characteristics of both uncooked and cooked pasta were studied in the control and CSP- pasta samples. The addition of CSP caused a significant difference in all color characteristics, as the results show (Table 5) that the L* value, which indicates lightness-darkness, was significantly higher (p) in both the uncooked and cooked control samples compared to the CSP-pasta samples, and the increase in the added percentage of CSP also caused a significant decrease in the lightness in both uncooked and cooked samples. These results may be attributed to the difference in pigment composition between wheat durum semolina and corn silk. On the other hand, cooking led to a decrease in lightness in all treatments, including the control. This observation can be attributed to the fact that the cooking heat caused the degradation of some carotenoid pigments, which resulted in increased lightness in cooked samples compared to their uncooked counterparts.

In addition to the effect of additives on pasta, the final color of the cooked pasta represents the sum of the effect of heat on the pigments and coloring enzymes on the one hand and its effect on the formation of the products of the Maillard reaction between reducing sugars and protein on the other hand. So, previous studies showed a discrepancy in the results of the effect of cooking on the lightness (L*) of pasta, for example, it decreased in cooked pasta fortified with millet flours and carrot pomace (Gull, et al., 2015), and increased in cooked pasta fortified with carob fiber (Biernacka et al., 2017) and cooked pasta supplemented with protein isolate from pangas processing waste (Surasani et al., 2019).

The redness and yellowness values increased significantly in both uncooked and cooked pasta by increasing the percentage of CSP incorporation, where the value of redness and yellowness in the control was 3.29±0.08 and 14.11±0.15, respectively, while those values were in 2.5-CSP 4.17±0.1 and 14.78±0.2, respectively, then redness and yellowness values increased by increasing the percentage of incorporation of CSP gradually and significantly until it became in 10-CSP treatment 8.03±0.11 and 16.82±0.1, respectively. This result can be explained by the fact that corn silk contains a relatively greater amount of yellow and red pigments than that wheat durum semolina. The value of redness and yellowness in all samples was affected by cooking, as these values decreased in cooked samples compared to their uncooked counterparts, which can be attributed to the effect of heat on the decomposition of some red and yellow pigments.

In total, naked-eye discrimination between samples was possible, as differences in total color difference values between samples were greater than 2. Theoretically, if ΔE between two samples is less than 1, the human eye is unable to perceive the color difference between them, but if ΔE value is equal to 1, the human eye can perceive the color difference between them provided that the lighting is perfect. If the lighting is not perfect, it may not be possible to distinguish the color between two samples unless ΔE between them is 2 or more depending on the quality and intensity of the lighting (Rozan, 2017).

Cooking properties

The cooking characteristics of the pasta fortified with different levels of CSP are tabulated in Table 6, the obtained data show that OCT for the control treatment was 6.52±0.1 min, which is insignificantly more than the OCT for the 2.5- CSP pasta ($p<0.05$). The results also show that increasing the level of CSP incorporation significantly decreased the OCT of the resulting pasta, OCT ranged from 6.008 ± 0.12 in 10-CSp pasta to 6.48 ± 0.12 in 2.5-CSP. pasta. Pasta containing more wheat starch takes a longer cooking time, so replacing wheat durum semolina in pasta with non-starchy ingredients can lead to a shorter cooking time. These results agree with those reported by Bayomy & Alamri (2022) in pasta containing graded levels of chickpea or lentil flour.

The weight increase during cooking is mainly related to the ability of the pasta ingredients to absorb water, where there is a positive correlation between them. Simple sugars, fiber and protein can absorb water. Also, starch by cooking heat absorbs water, and the absorbed amount depends on several factors including the ratio of ingredients content to each other, the method of manufacturing pasta by pressing or extrusion, cooking temperature, and the presence of salts. In general, high-quality pasta will gain at least twice its weight during cooking (Gulia et al., 2014). The results showed significant differences in the weight increase, the samples can be arranged in descending order as follows: 2.5-CSP (134.91±0.68%), control (132.84±0.72), 5-CSP (130.06±0.54), 7.5-CSP (129.06±0.4), and 10-CSP (127.02±0.52).

The swelling index is one of the quality criteria for pasta, and it expresses the absorption of water by the solid components, especially starch and protein, during cooking pasta (Foschia et al., 2015). The swelling index (Table 6) of the control was 2.03 ± 0.07 g water/g dried pasta, which is significantly higher than the other treatments, while a gradual decrease in the value of the swelling index was observed with the increase in the CSP content in the pasta samples, where it was recorded as 1.98 ± 0.05, 1.95 ± 0.07, 1.9 ± 0.04, and 1.84 ± 0.06 g water/g dried pasta in 2.5, 5, 7.5, and 10-CSP pasta samples, respectively. Although CSP contains more fiber than semolina, which means more hydration, in theory, gluten competes with fiber for water during mixing which reduces its impact on the amount of water absorbed, delaying starch swelling and gelatinization (Aravind et al., 2012; Monteiro, et al., 2019). Furthermore, the high fiber content of CSP comes at the expense of the low starch content, which may lead to a different way of absorbing and retaining water.

Solid weight loss after cooking is an important indicator of pasta quality, the higher the solid loss after cooking, the lower the pasta quality (Gull et al., 2015). Solid loss is associated with an undesirable sticky texture in pasta due to amylose leaching from the starch granules during cooking (Mercier et al., 2016). The solid loss in the control treatment was 5.25 ± 0.25, and it decreased insignificantly in 2.5-CSP pasta recording 5.222 ± 0.21, but increased significantly in 5, 7.5, 10-CSP pasta samples, it scored 5.39 ± 0.2, 5.838 ± 0.22, and 6.24 ± 0.26%, respectively. These results may be attributed to the increase of water-soluble components in the samples to which CSP was added, especially the mineral elements. moreover, the low gluten content weakens the gluten network responsible for maintaining the structure of the pasta, which leads to the leakage of the solid ingredients into the cooking water (Khan et al., 2013). A similar effect on solid loss after cooking was observed in pasta containing graded levels of sorghum flour (Khan et al., 2013), and pasta containing graded levels of tilapia waste flour (Monteiro et al., 2019).

Firmness

Firmness can be considered the most important criterion for judging the quality of cooked pasta. The higher the firmness value, the higher the quality of the pasta (Gull et al., 2015). Table (6) shows the firmness values for cooked pasta, no significant difference was observed between control and 2.5-CSP pasta samples. The firmness value decreased, but was not completely significant in the treatments 5 and 7.5-CSp, while increasing the level of incorporation of corn silk to 10% caused a significant decrease in the firmness of the cooked pasta compared to the control and 2.5-CSp samples. These observations can be attributed to the dilution of gluten by an increase in the level of addition of CSP, which leads to a weakening of the resulting gluten network structure, which is consistent with the results of swelling index and solid loss. Moreover, the interaction of fibers with starch limits the agglomeration necessary to form the dough structure, and the formation of the starch/ protein matrix (Biernacka et al., 2017). Similar

TABLE 5. Color properties of corn silk, durum wheat semolina, raw and cooked pasta.

Samples	L*	a*	b*	ΔE	L*	a*	b*	ΔE
DWS	74.42±0.58	2.076±0.1	14.216±0.16	-				
CSP	43.26±0.12	5.692±0.18	17.152±0.1	-				
Pasta	**Raw pasta**				**Cooked pasta**			
Control	71.63±0.24a	3.29±0.08e	14.11±0.15e	0±0e	75.17±0.11a	0.49±0.01e	9.65±0.1e	0±0e
2.5-CSP	57.1±0.17b	4.17±0.1d	14.78±0.2d	14.57±0.18d	66.14±0.1b	1.32±0.07d	10.24±0.1d	9.09±0.1d
5-CSP	55.56±0.14c	5.36±0.1c	15.53±0.21c	16.27±0.09c	64.57±0.24c	2.18±0.05c	10.87±0.14c	10.8±0.1c
7.5-CSP	54.06±0.19d	6.8±0.07b	16.17±0.17b	18.04±0.1b	62.84±0.27d	3.25±0.07b	11.5±0.15b	12.77±0.14b
10-CSP	52.92±0.21e	8.03±0.11a	16.82±0.1a	19.49±0.14a	60.69±0.15e	4.2±0.1a	12.08±0.1a	15.14±0.11a

Values: Mean ± standard deviation, five replicates. Values followed by different letters in the same column are significantly different (LSD) at p<0.05. DWS: durum wheat semolina, CSP: corn silk powder.

TABLE 6. Cooking properties and firmness of cooked pasta enriched with different levels of corn silk powder.

Treatments	OCT (min)	Weight increasing (%)	Swelling index (g water/g dried pasta)	Solid loss (%)	Firmness (N)
Control	6.52±0.1^{a}	132.84±0.72^{ab}	2.03±0.0^{7}a	5.25±0.25^{a}	5.14±0.05^{a}
2.5-CSP	6.48±0.12^{a}	134.91±0.68^{a}	1.98±0.0^{5a}b	5.222±0.21^{a}	5.06±0.07^{a}
5-CSP	6.326±0.1^{b}	130.06±0.54^{b}	1.95±0.0^{7a}b	5.39±0.2^{b}	4.82±0.05^{ab}
7.5-CSP	6.216±0.1^{c}	129.06±0.4^{bc}	1.9±0.0^{4}b	5.838±0.22^{c}	4.75±0.03^{ab}
10-CSP	6.008±0.12^{d}	127.02±0.52^{c}	1.84±0.0^{6b}c	6.24±0.26^{d}	4.59±0.07^{b}

The data are expressed as the mean ± standard deviation (n = 5). CSP: corn silk powder, where 2.5, 5, 7.5 and 10-CSP express the amount of corn silk powder replacement (W/W). Values followed by different letters in the same column are significantly different (LSD) at p<0.05.

results have been reported, adding some gluten-free ingredients, such as millet flour or carrot pomace (Gull et al., 2015), and carob (Biernacka et al., 2017) reduced the firmness of the resulting pasta compared to WDS- pasta.

Sensory evaluation

Systematic sensory evaluation is an important step in predicting consumer behavior towards a particular product, whether that is innovative wholesale products or products which manufacturers want to make a change in one of its components. The sensory evaluation score of pasta made from WDS (Control) and pasta made from WDS with different percentages of CSP are shown in Table 7. The results show that there were no significant differences in odor, and overall acceptability between the samples, while there are some significant differences between the samples in the values of color, taste, and texture. The absence of significant differences in the sensory evaluation of the odor of the products can be attributed to the lack of influence of the components on the volatile flavor compounds in the different samples. Compared to the control, sensory evaluation traits did not differ significantly between control and treatment 2.5, except for a slight decrease in texture. Color, taste, and texture were relatively negatively affected by increasing the incorporation level of CSP in 5, 7.5, 10-CSP pasta samples, but they are still within the overall acceptability range. At the 10% level of incorporation of CSP into the WDS pasta, the color of the resulting pasta was relatively dark, which led to a significant decrease in the sensory evaluation of the color, as well, the effect of texture was clear, which is consistent with the results of cooking and rheological characteristics, while the significant effect of taste in 10-CSP pasta sample can be attributed to the leakage of some components dissolved in the water, which have a direct effect on stimulating the taste buds, resulting in a weak sense of the usual taste of pasta. These results indicate that CSP can be incorporated into pasta ingredients in 10%, without any significant effect on consumers' sensory acceptability.

Cross- Correlation analysis between estimated pasta traits

Pearson's correlation coefficients were determined among the estimated nineteen traits in different pasta samples (Fig 1). They were categorized into three subgroups as follows: (1) chemical traits including moisture, protein, fat, ash, fiber, and carbohydrate (carb) contents; (2) color traits such as lightness (L), redness (a), yellowness (b); (3) cooking properties including optimal cooking time (OCT), weight increasing (WI), swelling index (SI), solid loss (SL), and firmness (Fir), and finally (4) sensory traits including color, taste, odor, texture (Tex) and overall acceptability (OA). Interestingly, the estimated traits were divided into two groups based on the pattern of association. In general, carbohydrate content, lightness, sensory traits, OCT, WI, SI, and firmness were mainly negatively correlated with moisture, protein, fat, ash, fiber, solid loss, a* value (redness) and b* (yellowness). Overall, the blue color in the upper left quadrant of the chart shows a positive correlation between sensory traits, and between sensory traits and some other traits including carbohydrate content, lightness, optimal cooking time, weight increasing, swelling index, and firmness. However, the positive correlation between the traits was significant among some of them and not significant among others. Odor was significantly associated ($p<0.05$) with color ($r = 0.92$), and color was significantly associated with odor in addition to OCT ($r = 0.98$), SI ($r = 0.96$), carbohydrate content ($r = 0.95$) and firmness ($r = 0.93$). Taste was significantly associated ($p<0.05$) with overall acceptability ($r = 0.99$), firmness ($r = 0.98$), WI ($r = 0.95$), carbohydrate content ($r = 0.94$), OCT ($r= 0.93$) and SI ($r = 0.9$). Texture was significantly associated ($p<0.05$) with L value ($r = 0.99$), carbohydrate content ($r= 0.94$), SI ($r= 0.94$), firmness ($r= 0.89$) and overall acceptability ($r= 0.89$). WI was also significantly associated ($p<0.05$) with OCT ($r= 0.93$), firmness ($r= 0.93$) and carbohydrate content ($r= 0.89$). OCT was also significantly associated ($r= 0.98$, $p<0.05$) with SI, firmness, and carbohydrate content. SI was also significantly associated ($p<0.05$) with carbohydrate content ($r= 0.99$), firmness ($r= 0.97$) and L value ($r= 0.9$). firmness was also significantly associated ($p<0.05$) with carbohydrate content ($r= 0.98$) and L value ($r= 0.88$).

Also, the blue color in the lower right quadrant of the chart shows a positive correlation between a set of traits including moisture, protein, fat, ash, fiber, solid loss, a* value (redness) and b* (yellowness). Other than the correlation value between protein and solid loss ($r= 0.87$), all values of the correlations between these traits were significant ($p<0.05$), with r values ranging between 0.91 and 1.0.

The cross- correlation was significantly negative ($p<0.05$) among the traits of chemical composition (protein, fat, fiber, and minerals) on the one hand, and between each of the carbohydrate content ($r = -0.98: -1.0$), L value ($r= -0.9: -0.94$), color ($r= -0.89: -0.96$), OCT ($r= -0.95: -0.98$), firmness ($r= -0.94: -0.99$), and texture ($r= -0.94: -0.97$). Also, there was a significant negative correlation ($p<0.05$) between fat, ash, and fiber on the one hand, and taste on the other ($r= -0.91: -0.96$). The values of the negative correlation were also significant ($p<0.05$) between redness and yellowness traits on the one hand and the carbohydrate content ($r= -1.0$), lightness ($r= -0.9, -0.91$, respectively), OCT ($r= -0.98$), WI ($r= -.089$), SI ($r= -1.0, -0.99$, respectively), color ($r= -0.96, -0.94$, respectively), taste ($r= -0.93, -0.94$, respectively), texture ($r= -0.93, -0.94$, respectively), and overall acceptability ($r= -0.95, -0.96$, respectively). Finally, the values of the negative correlation were significant ($p<0.05$) between SL and color ($r= -1.0$), OCT ($r= -0.97$), SI ($r= -0.95$), carbohydrate content ($r= -0.94$), odor ($r= -0.92$), firmness ($r= -0.91$), and WI ($r= -0.9$).

Conclusion

The central objective of this work was to evaluate corn silk as a potential food additive in terms of its nutritional value, and its effect on the physical and sensory properties of pasta as an example of cereal products. The results showed a higher content of mineral elements, protein, ash, fiber, total phenolic substances, antioxidant activity and protein in corn silk compared to semolina. The cooking properties and firmness of the 2.5-CSP enriched pasta were not affected much compared to the control, while some effect was shown in these parameters by increasing the enrichment percentage. CSP can be incorporated into pasta ingredients in 10%, without any significant effect on consumers' sensory acceptability. These results support the classification of corn silk as a promising food additive and recommend the study of its effect in further food applications.

TABLE 7. Sensory evaluation of pasta containing different levels of corn silk powder.

Treatments	Color	Odor	Taste	Texture	Overall acceptability
Control	7.74±0.12[a]	8.12±0.17[a]	8.05±0.14[a]	8.15±0.1[a]	8.07±0.1[a]
2.5-CSP	7.75±0.16[a]	8.14±0.2[a]	8.03±0.12[a]	7.97±0.12[ab]	8.02±0.12[a]
5-CSP	7.58±0.19[ab]	8.14±0.18[a]	7.65±0.11[ab]	7.96±0.1[ab]	7.88±0.2[a]
7.5-CSP	7.26±0.1[ab]	8.1±0.2[a]	7.63±0.18[ab]	7.88±0.15[ab]	7.85±0.18[a]
10-CSP	6.91±0.25[b]	8.09±0.15[a]	7.52±0.15[b]	7.84±0.17[b]	7.82±0.11[a]

The data are expressed as the mean ± standard deviation (n = 45). CSP: corn silk powder, where 2.5, 5, 7.5 and 10-CSP express the amount of corn silk powder replacement (W/W). Values followed by different letters in the same column are significantly different (LSD) at $p<0.05$.

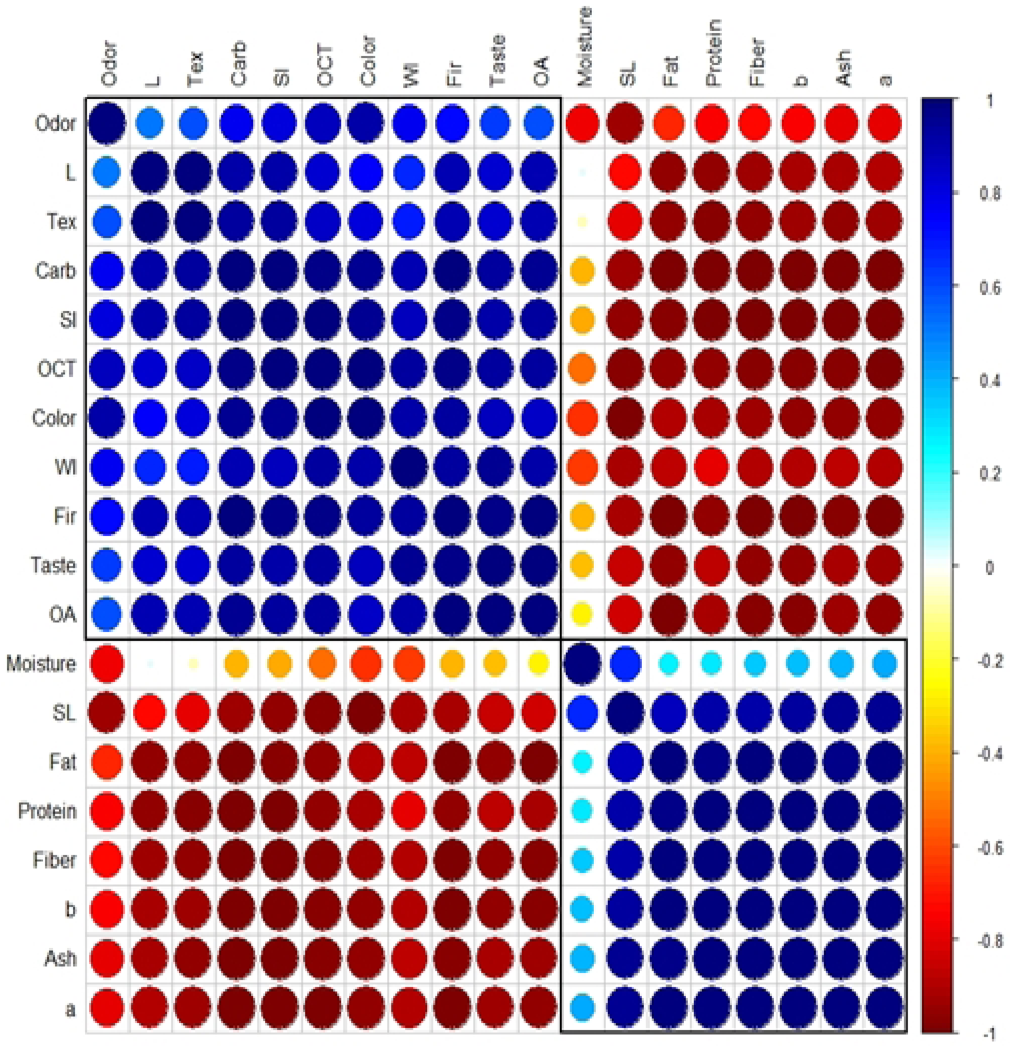

Fig 1. Pearson's correlation Matrix of chemical, physical, cooking, and sensory traits of pasta enriched with corn silk powder. L= lightness, Tex = texture, Carb= carbohydrate, SI= swelling index, OCT = optimal cooking time, WI = weight increasing, Fir = firmness, OA= overall acceptability, SL= solid loss, b= b* value (redness), a= a* (yellowness). The positive correlation is displayed in cyan and blue, and the negative correlation is in yellow and red.

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