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Utilization of Yellow Corn in Preparing High Nutritional Value Gluten-Free Noodles

Saad A. Mahgoub and Ghada A. Alfauomy*
Crops Technology Research Department, Food Technology Research Institute, Agricultural Research Center, Al-Giza, Egypt

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Abstract: The present study aimed to produce gluten-free noodles from yellow corn grits, rice flour and chickpea powder blends and then evaluate their sensory, nutritional and technological characteristics. Yellow corn grains were ground and sieved to obtain the grits at three particle size (< 200, 200–350 and 350–450 µm). The highest protein content was observed at particle size 200-350 and 350-450 µm and the particle size 200-350 µm had the highest value of water hydration index (WHI) which are needed for noodles making. Consequently, noodles were formulated using yellow corn grits (200-350µm), 10% chickpea powder and different substitutions of rice flour (10, 20, 30, 40 and 50%). Noodles contained 40% rice flour were closed to semolina noodles with respect to sensory characteristics. Noodles with 10% rice flour showed high values of protein, fat, Ca, Zn and β-carotene and low total carbohydrates content. The hardness and cohesiveness of noodles were increased by increasing the rice flour percentage. The gluten-free noodles made with 40% and 50% rice flour as yellow corn grits substitution possessed the highest cooking time. Increasing the rice flour percentages in the noodles formulation lead to increase cooking weight and swelling percentage and decreasing the cooking loss and protein loss percentages. Gluten-free noodles contained 50% yellow corn grits, 40% rice flour and 10% chickpeas powder showed the highest overall acceptability. It could be concluded that using of yellow corn grits, rice flour and chickpea powder in gluten-free noodles formulation are suitable for celiac disease individuals.

***Keywords*:** Corn grits, rice flour, chickpea powder, gluten-free, texture profile, sensory characteristics, cooking quality

INTRODUCTION

Corn is the third most important crop after wheat and rice. It is a source of a large number of industrial products besides its uses as a human food and animal feed (Sharma *et al*., 2012). It contains 7–13 g ⁄100 g of protein, very low fat, phenolics, ferulic acid, flavonoids, carotenoids, rich in dietary fiber, vitamin B_6 and magnesium (Niewinski, 2008; Liu and Lu, 2013). Corn is a good option as it is naturally gluten-free and a better choice than other grains to produce different gluten-free bakery products. One of the corn products that can be used for a variety of celiac disease foods is corn grits (Gwirtz and Garcia-Casal, 2014).

The particle size of cereal flour influenced on the various properties of noodle products and is regarded as a valuable indicator of their quality and performance. Specifically, particle size is known to play a critical role in developing an optimal and uniform gluten network during sheeting (Kruger *et al.,* 1996). Hence, explorations into the effect of particle size on noodle quality have been carried out in a number of studies whose primary attentions have been paid to wheat-based noodles such as yellow alkaline noodles (Hatcher *et al.,* 2009), white salted noodles (Hatcher *et al.,* 2002), and white Chinese noodles (Chen *et al*., 2011).

The production of traditional bakery products involves four steps: ingredient mixing, dough kneading, fermentation, and baking. Gluten plays an influencing role in all of these procedure steps (Zhou *et al.,* 2014). Gluten-free bakery products are often less desirable in terms of their appearance, taste, aroma, and texture. The simplest way to improve the structure of gluten-free products is by adding other functional ingredients and additives (*e.g.* starches, protein, gum, hydrocolloids, emulsifiers, dietary fiber) to the wheat flour substitutes (*e.g.* rice, maize, sorghum, buckwheat, amaranth, quinoa, corn, chickpea) as reported by (Rocha Parra *et al.,* 2015; Salem *et al*., 2019). The purpose of adding natural rich-protein ingredients such as legume powders is mainly for improving nutritional quality and maintaining a strong cohesive structure (Ribotta *et al.,* 2004). Legumes are, after cereals, the most cultivated plants in the world and represent an important source of gluten-free proteins (Berrios *et al.,* 2010). They are low in fat, high in resistant starch content, and excellent sources of dietary fiber and micronutrients, such as iron, zinc, potassium, and folate.

Chickpea is a good source of high quality protein (lysine and threonine), carbohydrates, vitamins (thiamine and niacin), minerals (phosphorous, iron, magnesium, and potassium) and its oil is rich in the essential fatty acid, linoleic (Malunga *et al.,* 2014).

Rice is a good source of a vitamin B group such as thiamine, riboflavin, and niacin. Besides, in consideration of the amino acid profile, while it has a high content of glutamic and aspartic acid, it is, also, has a low content of lysine that is a limiting amino acid. The combination of cereal and legume proteins would provide a better overall essential amino acid balance and a good nutritional value (Temba *et al.,* 2016).

Instant noodles are widely consumed throughout the world and it is a fast-growing sector of the noodle industry. Global consumption of the noodles is second only to bread. Noodles are a staple food in many cultures made from unleavened dough which is stretched, extruded, or rolled flat and cut into one of a variety of shapes (Okoye *et al.,* 2008).

This present study aimed to utilize yellow corn grits for producing gluten-free noodles and evaluating their technological and sensory characteristics.

*Corresponding author e-mail: ghadaelfauomy@yahoo.com

MATERIALS AND METHODS

Materials

Yellow corn was obtained from Al Anan Milling Company - Kafer EL-Sheikh Governorate, Egypt. Rice flour, chickpea seeds, wheat semolina, corn oil and salt were obtained from the local market at Giza, Egypt. Xanthan gum was obtained from Dove's Farm Foods Co., the UK. All chemicals were obtained from Sigma, Aldrich Chemical Co. (St. Louis, USA), and Algomhorya, Co., Giza, Egypt.

Methods

Preparation of flour

The yellow corn grains and chickpea seeds were dry-milled into grits using an attenzione Mill, type Hz 50, 220 volts, Italy. The yellow corn grits was passed through a series of sieves (Fritsch Laborgerätebau, Germany) to be fractionated into three different fractions depending on particle size (< 200, 200–350 and 350–450µm). The different fractions was then packed in plastic bags and stored at 4°C till analyze (Kim *et al*., 2019).

Preparation of noodles

Wheat noodles (traditional noodles) were made with semolina of durum wheat mixed with about 63 ml water with mixer (Kenwood, Major Premier UK) at 25±2 ºC for 20 min to obtain dough (Padalino *et al.,* 2013).

From preliminary trails, the optimum corn grits particle size used to produce gluten-free noodles dough was 200-350 µm, which is prepared by adding 0.1% xanthan gum, 1% salt and adding water at 70ºC, then mixing for 2 min.

The sample (90% yellow corn grits 200-350µm and 10% chickpea powder) was used as a gluten-free control sample. For preparing samples formulas: the yellow corn grits (200-350µm) was replaced with rice flour at 10, 20, 30, 40 and 50% as shown in Table (1) according to the method described by Ormenese and Chang (2004). The dough was sheeted on a laboratory noodle machine using Imperia Trading S.r.I. 10098 RIVOLI (TO)-C.so Susa, 242 device followed by cutting into noodles then dried at 60ºC for 1 hr. and noodles formulas were left over night at ambient temperature (30±2ºC). The dried noodles were packed in polyethylene pages and stored at ambient temperature till analyses.

Table (1): Ingredients of noodle formulas

Ingredients	Traditional wheat formula	Gluten-free formula					
		C	F1	F2	F3	F4	F5
Semolina	100	0.00	0.00	0.00	0.00	0.00	0.00
Yellow corn grits (200-350 µm)	0.00	90	80	70	60	50	40
Rice flour	0.00	00	10	20	30	40	50
Chickpea powder	0.00	10	10	10	10	10	10
Corn oil	1.00	1.0	1.0	1.0	1.0	1.0	1.0
Xanthan gum	0.00	0.1	0.1	0.1	0.1	0.1	0.1
Salt	1.00	1.0	1.0	1.0	1.0	1.0	1.0

Traditional wheat formula: 100% semolina (traditional noodles), C: 90% yellow corn grits + 10% chickpeas powder (control), F1:80% yellow corn grits+ 10% rice flour + 10% chickpeas powder (noodles $_1$), F2: 70 % yellow corn grits+ 20% rice flour + 10% chickpeas powder (noodles $_2$), F3:60 % yellow corn grits+ 30% rice flour + 10% chickpeas powder (noodles $_3$), F4: 50% yellow corn grits+ 40% rice flour + 10% chickpeas powder (noodles $_4$) and F5: 40% yellow corn grits+ 50% rice flour + 10% chickpeas powder (noodles $_5$).

Proximate analysis

Moisture, protein, fat, crude fiber and ash contents were determined according to the methods of AOAC (2012).Total carbohydrates were calculated by difference [100-(Protein + Fat + Ash + Crude fiber)]. Calcium (Ca), ferrous (Fe) and zinc (Zn) contents were determined using Microwave Plasma Atomic Emission Spectroscopy (MP-AES 4210). Total calories were calculated from the following equation as reported by James (1995).

$$\text{Energy value} = 4\,(\text{g protein} + \text{g carbohydrates}) + 9\,(\text{g fat})$$

Amylose content was determined using the method outline by Juliano (1971).

Determination of ß-carotene and vitamin A value calculation

The ß-carotene estimation was performed for noodles using HPLC according to the method of Pupin *et al.* (1999). Vitamin A value calculation was performed based on vitamin A activity of the ß-carotenes according to the conversion factor provided by the Food and Nutrition Board, Institute of Medicine (2001).Vitamin A value was expressed in retinol activity equivalents (RAE), which represents vitamin A activity as retinol. Where, 12 µg of ß-carotene from foods are required to provide the body with 1 µg of retinol.

Determination of water hydration

The water hydration properties of yellow corn fractions were determined according to the method of Kornblum and Stoopak (1973).

A 2g sample was placed in 15ml plastic centrifuge tube and 10ml distilled water was added. The contents were mixed on a vortex mixer for 2 min. The mixture was then allowed to stand for 10min and immediately centrifuged at 2240 RCF (Relative Centrifugal Force) for 30min. The supernatant was carefully decanted and the sediment weighed. The results obtained were used to calculate the hydration capacity and hydration index based on the following equations.

$$\text{Hydration capacity} = \frac{\text{Weight of sediment} - \text{Weight of tube}}{\text{Dry weight of sample}}$$

$$\text{Hydration index} = \frac{\text{Hydration capacity}}{\text{Dry weight. of sample}}$$

Color measurement of gluten-free noodles

The external color of gluten-free noodles was measured using a hand-held Chromameter (model CR-400, Konica Minolta, Japan).

Texture profile analysis (TPA) of gluten-free noodles

Hardness, cohesiveness, chewiness and springiness of the resultant noodles were measured according to AACC (2002).

Cooking quality of gluten-free noodles

Optimum cooking time: It is the minimum time necessary to gelatinize the starch. It was assessed by crushing cooked noodles between glass plates and by measuring the time taken for the starchy white core of the noodles to disappear (AOAC, 2000).

Cooking loss:

Cooking loss and cooking weight of noodles were calculated by the equations according to the method described by Lai (2002).

Cooking weight % = [(weight of cooked noodles – sample dry weight) /sample dry weight)] ×100

Cooking loss % = [(weight of dried residue in cooking water / sample dry weight)] × 100

Swelling: the volume increase % (swelling %) was determined by AOAC (2000).

Protein loss in water cooking was calculated according to the method described by Holliger (1963).

Sensory evaluation

The hedonic rating test was used to determine the acceptability. The panelists rated the products according to their acceptability on a 01-09-point hedonic scale (Taneya *et al.,* 2014). Noodles were organoleptically evaluated for its sensory characteristic (color, shininess, surface smoothness, firmness, chewiness, elasticity, taste and overall acceptability).The evaluation was carried out by ten well-trained experienced panelists from Food Technology Research Institute, Agricultural Research Center, Egypt. The semolina sample (traditional noodles) was sensory evaluated compared with other gluten-free noodles.

Statistical analysis

For the analytical data, mean values and standard deviation are reported using Costat statistical software according to Steel and Torrie (1980). The obtained data were subjected to one-way analysis of variance (ANOVA) at $P<0.05$ followed by Duncan's new multiple range test to assess differences between samples mean.

RESULTS AND DISCUSSIONS

Proximate composition of raw materials

The proximate composition of semolina, yellow corn grits, rice flour, and chickpea powder is shown in Table (2). Moisture content recorded high value for semolina (12.35 %). Protein content of chickpea powder was the highest value (20.3%) and the lower value for rice flour (6.83%). It could be noticed that rice flour contained the lowest value of fat and ash (0.82 and 0.75 %, respectively) followed by semolina (0.99 and 1.75%, respectively). Significant differences were found for crude fiber content where the highest value recorded in chickpeas. Total carbohydrates contents were 91.01, 84.65, 80.57 and 65.91 g/ 100g for rice flour, yellow corn grits, wheat semolina and chickpea powder, respectively. Abdel-Haleem and Hafez (2015) found that corn grits contained 7.3% protein, 2.17% fat, 1.24% ash and 1.0% fiber; also, found that rice flour contained 90.14% total carbohydrates.

These results were closed to which obtained by Saleh and Tarek (2006) who found that raw chickpea contained 23.64% protein, 6.48% fat, 3.72% ash, 3.42% fiber and 63.84% carbohydrates.

Physical and chemical properties of yellow corn grits at different particle size

Physical and chemical properties of yellow corn grits with different particle size are presented in Table (3). The protein content of corn grits obtained with particle size < 200µm was significantly lower than those of corn grits with particle size 200-350 and 350-450µm (7.29, 8.32 and 8.34%, respectively).

Table (2): Proximate composition (g $100g^{-1}$) of raw materials

Properties	Semolina	Yellow corn Grits	Rice Flour	Chickpeas Powder
Moisture	$12.35^{a}\pm 0.07$	$12.30^{a} \pm 0.31$	$8.51^{b} \pm 0.24$	$8.64^{b} \pm 0.27$
Protein *	$14.18^{b}\pm 0.04$	$8.45^{c} \pm 0.25$	$6.83^{d} \pm 0.31$	$20.3^{a} \pm 1.23$
Fats *	$0.99^{c}\pm 0.04$	$2.52^{b} \pm 0.02$	$0.82^{d} \pm 0.01$	$4.62^{a} \pm 0.31$
Ash*	$1.75^{c}\pm 0.01$	$1.97^{b} \pm 0.12$	$0.75^{d} \pm 0.02$	$3.52^{a} \pm 0.14$
Crude fiber*	$2.51^{b}\pm 0.03$	$2.41^{c} \pm 0.13$	$0.59^{d} \pm 0.02$	$5.65^{a} \pm 0.41$
Total carbohydrates*	$80.57^{c}\pm 0.11$	$84.65^{b} \pm 2.51$	$91.01^{a} \pm 2.34$	$65.91^{d} \pm 3.24$

*on dry weight basis
Values are the average of 3 experiments ± SD. Mean values (within the same row) followed by different superscripts are significantly different at the 5% level.

Table (3): Physical and chemical properties of yellow corn grits at different particle size

Parameters	< 200µm	200-350 µm	350-450 µm
Protein	$7.29^{b} \pm 0.06$	$8.32^{a}\pm 0.08$	$8.34^{a} \pm 0.05$
Amylose	$24.22^{a} \pm 0.02$	$22.83^{b}\pm 0.06$	$21.93^{c}\pm 0.04$
Hydration Index	$2.36^{b} \pm 0.01$	$2.73^{a} \pm 0.03$	$2.22^{c} \pm 0.02$
Color			
L^*	$96.54^{a} \pm 0.15$	$94.37^{b} \pm 0.09$	$90.74^{c} \pm 0.03$
a^*	$-2.38^{c} \pm 0.03$	$-2.01^{b} \pm 0.04$	$-0.87^{a} \pm 0.80$
b^*	$21.47^{c} \pm 0.01$	$26.35^{b} \pm 0.10$	$37.14^{a} \pm 0.33$

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].
Values are the average of 3 experiments ± SD. Mean values (within the same row) followed by different superscripts are significantly different at the 5% level

Some findings observed by Lawton and Wilson (2007) mentioned that cereals fractions had a higher protein content than finer fractions. Among amylose content grits with <200 µm had the highest value (24.22%) compared with the other two grits (22.83 and 21.93%) fractions (200-350 and 350-450 µm, respectively). Regarding to water hydration index (WHI) there were significant differences among samples. Grits with particle size (200-350µm) had the highest value (2.73) while the lower value was obtained in grits fraction of 350-450µm. These results could be probably due to greater surface areas of fine particle size. The factors that can be caused an enhanced water absorption capacity included high protein content (Celik *et al*., 2004) and high fiber content (Kethireddipalli *et al*., 2002).

Concerning color, L^* values data showed that L^* value decreased as particle size increased. It ranged from 90.74 to 96.54.Grits fraction with (350-450µm) had the lowest value (90.74) while the fraction <200µm had the highest value (96.54). It cleared that the* values were low for all samples while b^* values was higher in the grits with particle size 350-450 than the two other fractions. In general, the finer grits may have lighter and less yellow color. Another possible explanation could be the different distribution of carotenoids in the grain; the greater concentration in the pericarp (mainly coarse fraction) would cause yellowish color of the coarse fractions rather than the floury endosperm (which is mainly finer fractions) (Quackenbush, 1963). Based on the results of hydration index, amylose percentage, it could be found that, the best dough for making noodles were when particle size was 200-350µm. Therefore, it could be considered the best mixture for the manufacture of noodles.

Sensory evaluation of gluten-free noodles

Among all sensory attributes, yellow color, shininess, surface smoothness, firmness, chewiness, elasticity, and taste can be considered positive attributes; these indicated better noodle quality as high sample characteristic values (Walid, 2016). Important quality factors for instant noodles are color, flavor and texture, cooking quality, rehydration rates during final preparation (Gulia *et al.,* 2014).

Sensory evaluation of cooked noodles is showed in Table (4). Data showed that, there were significant differences in color between traditional noodles (8) followed by 7.75 for $noodles_3$ and 7.17 for noodles $_4$, while the lowest value was 5.33 for noodles $_5$. Noodles $_4$ nearly had the same scores in shininess and surface smoothness (8.17 and 7.83, respectively), in relative to traditional noodles (8.08 and 7.83, respectively), while control and $noodles_1$ had the lowest scores (5.67 and 5.92, respectively), for shininess and (5.25 and 5.58, respectively), the surface smoothness. Firmness data cleared that, no significant differences were obtained in $noodles_4$ and $noodles_5$ compared with traditional noodles (7.58, 7.67 and 8.17, respectively).

In chewiness and taste characters, data cleared that $noodles_3$ recorded 7.67 and 7.92, respectively, while noodles $_4$ recorded 8.00 and 8.25, respectively, with non-significant differences compared with traditional noodles (7.75 and 8.33, respectively). On the other hand, control had the lowest scores (5.83 and 6.33, respectively). Elasticity scores were significantly different in all resultant noodles except for noodles $_4$ (8.00) which had non-significant differences with traditional noodles (8.08). Noodles $_4$, also nearly had the same value of traditional noodles in overall acceptability (OAA) (8.67 and 8.83, respectively). At the same time data cleared that, noodles $_4$ had the highest score compared with the other gluten-free noodles. Hassan *et al.* (2007) found that, rice flour improved the sensory properties of noodles such as taste mouth feel and overall acceptability, this is due to the properties of rice starch.

According to the sensory evaluation data, it could be noticed that the traditional noodles, was slightly varied with some gluten-free noodles with respect to shininess, surface smoothness, firmness, chewiness, elasticity taste and overall acceptability, especially noodles $_4$.

Table (4): Sensory evaluation of gluten-free noodles compared with traditional noodles

Properties	Traditional noodles	Gluten-free noodles					
		C	1	2	3	4	5
Color	8.00^{a}±0.55	6.17^{d}±0.75	6.17^{d} ±0.41	7.00^{c} ±0.61	7.75^{ab}±0.42	7.17^{bc} ±0.52	5.33^{e} ±0.52
Shininess	8.08^{a}±0.66	5.67^{e}±0.82	5.92^{de}±0.49	6.46^{cd}±0.82	7.50^{ab}±0.55	8.17^{a}±0.41	7.17^{bc}±0.75
Surface smoothness	7.83^{a}±0.51	5.25^{d}±0.42	5.58^{cd}±0.49	6.25^{bc}±0.39	7.67^{a}±0.88	7.83^{a}±0.75	6.83^{ab}±0.75
Firmness	8.17^{a}±0.52	6.08^{d}±0.49	6.75^{c}±0.27	7.00^{bc}±0.63	7.25^{bc}±0.42	7.58^{ab}±0.80	7.67^{ab}±0.41
Chewiness	7.75^{a}±0.42	5.83^{d}±0.41	5.92^{cd}±0.49	6.51^{bc}±0.32	7.6 7^{a}±0.75	8.00^{a}±0.55	6.92^{b}±0.38
Elasticity	8.08^{a}±0.66	5.67^{d}±0.61	5.92^{d}±0.92	6.25^{cd}±0.88	7.58^{ab}±0.38	8.00^{a}±0.32	6.92^{bc}±0.49
Taste	8.33^{a}±0.61	6.33^{c}±0.41	6.42^{bc}±0.38	6.92^{bc}±0.20	7.92^{a}±0.66	8.25^{a}±0.42	7.00^{b}±0.71
OAA*	8.83^{a}±0.41	6.33^{c}±0.41	6.57^{c}± 0.42	7.17^{b}± 0.81	7.83^{b}±0.75	8.67^{a}± 0.41	7.75^{b}± 0.76

Traditional noodles:100% semolina, C: 90%yellow corn grits+10%chickpea powder (control), 1: 80% corn grits + 10% rice flour +10%chickpea powder ($noodles_1$), 2: 70% corn grits+ 20% rice flour +10% chickpea powder ($noodles_2$), 3: 60% corn grits+ 30% rice flour +10% chickpea powder ($noodles_3$), 4: 50% corn grits+ 40% rice flour +10% chickpea powder ($noodles_4$), 5: 40% corn grits+ 50% rice flour +10% chickpea powder ($noodles_5$).

*OAA: overall acceptability. Values are the average of 10 experiments± SD. Mean values (within the same row) followed by different superscripts are significantly different at the 5% level

Nutritional characteristics of gluten-free noodles

Proximate composition of gluten-free noodles is presented in Table (5). Moisture content showed a slight increase by increasing rice flour percent. The highest protein value of noodles was found in control (8.72%) while the lowest protein content was found in noodles $_5$ and noodles $_4$ (8.38 and 8.52%, respectively). These may be due to the increase in addition percentage of rice flour.

Fat and crude fiber contents significantly decreased by increasing the addition of rice flour in noodles formula and the highest content was found in control (1.28 and 2.88 g/100g) but the lowest content was found in $noodles_5$ (1.14 and 1.89 g/100g, respectively).

Also, the data showed an increase in total carbohydrates content at noodles 3, 4 and 5 (87.24, 87.51 and 87.79%). Control noodles contained 44.8 mg/100g calcium, and 1.83 mg/100g zinc, a significant decrease was found by increasing the rice flour percentage. In addition, no significant differences were found among noodles 3, 4 and 5 in the iron content.

Table (5): Nutritional characteristics of gluten-free noodles

Parameters	Gluten-free noodles					
	C	1	2	3	4	5
Moisture %	11.82 ^{b}±0.01	11.80 ^{b}±0.01	11.80 ^{b}±0.1	11.90^{a}±0.02	11.90 ^{a}±0.02	11.91 ^{a}±0.01
Protein(g/100g)*	8.72 ^{a}±0.00	8.67 ^{ab}±0.01	8.61 ^{bc}±0.01	8.57 ^{bc}±0.03	8.52 ^{c}±0.01	8.38 ^{d}±0.06
Fat (g/100g)*	1.28 ^{a}±0.04	1.25 ^{ab}±0.03	1.21 ^{bc}±0.02	1.18 ^{cd}±0.01	1.16 ^{cd}±0.01	1.14 ^{d}±0.01
Ash (g/100g)*	0.72^{bc}±0.01	0.72^{c}±0.00	0.72^{c}±0.00	0.72^{c}±0.00	0.73^{b}±0.00	0.74^{a}±0.00
Crude fiber (g/100g)*	2.88 ^{a}±0.01	2.69 ^{b}±0.02	2.48 ^{c}±0.00	2.29 ^{d}±0.00	2.08 ^{e}±0.01	1.89 ^{f}±0.00
T.C (g/100g)*	86.4^{-d}±1.15	86.88 ^{d}±1.24	86.98^{c}±1.54	87.24^{b}±1.31	87.51^{ab}±1.43	87.79 ^{a}±1.65
Minerals (mg/100g) Ca *	44.80 ^{a}±1.02	43.20 ^{a}±1.13	36.40^{b}±1.03	33.60^{c}±0.62	32.8 ^{d}±0.82	30.40 ^{e}±0.92
Fe *	1.86^{c}±0.02	1.88^{c}±0.02	1.89^{bc}±0.03	1.92^{ab}±0.03	1.93 ^{a}±0.02	1.95^{a}±0.03
Zn*	1.83 ^{a}±0.02	1.74 ^{a}±0.03	1.65 ^{b}±0.01	1.56 ^{b}±0.02	1.47 ^{bc}±0.03	1.38 ^{d}±0.04
Caloric value (Kcal/100g)*	392.00	393.45	393.25	393.86	394.56	394.94
ß-carotene (µg/100g)*	324.60	306.20	294.30	288.10	282.40	264.80
Vitamin A*	27.05	25.51	24.53	24.01	23.53	22.06

* on dry weight basis
Values are the average of 3 experiments ± SD. Mean values (within the same row) followed by different superscripts are significantly different at the 5% level.

Suliburska *et al*. (2013) reported that the gluten-free rice noodles contained 18.96, 19.7, 2.66, 1.75 and 0.41 mg/100g of calcium, magnesium, iron, zinc and copper, respectively. Calcium is the most abundant mineral in the human body; it works with vitamin D, phosphorus and magnesium to develop strong and healthy bones (Hassan *et al.,* 2007).

The results in Table (5), also, indicated that the control sample is the lowest caloric value content (392.00 Kcal/100g), while, increasing in rice percentage led to rise in the caloric value agreed with that found by Torun (2005).

Data showed that, *ß*- carotene content decreased from 324.6 to 264.8 µg/100g, this is may be due to the amounts of rice flour substitution and the calculated vitamin A content was depended on ß-carotene contents (Purwandari *et al*., 2014). Beta carotene is known to be a potent booster for the immune system, as well as an important nutrient for maintains healthy skin and bones and good vision. It converts to vitamin A in the body and is an important antioxidant nutrient, which may play role in disease prevention (DRI, 2001).

Color measurements of noodles

Color is one of the most important quality attributes of food product (Attia and Abd-Elhafeez, 2011). Color measurements of the noodles are illustrated in Table (6). Lightness (L*) values of gluten-free noodles were ranged from (71.94 and 77.17) where the increase was gradually by increasing the rice percent from noodles$_1$ to noodles $_5$. Redness (a*) values were ranged from 1.81 to 2.95, a decrease was happened in the values of redness with increasing the rice flour substitution level.

Yellowness b^* values found higher values in the control (29.78) than the other noodles. In general, the increasing of rice ratio in the noodles formula led to decrease in the carotenoids content.

Zhao *et al.* (2005) reported that, the differences in pasta color might be due to the presence of different coloring in the flour sources.

Table (6): Color measurements values of gluten-free noodles

Products	L*	a*	b*
Control	71.94 ^{f} ±0.04	2.95 ^{a} ±0.06	29.78^{a} ±0.07
Noodles $_{1}$	73.75 ^{e} ±0.05	2.61 ^{b} ±0.02	23.89 ^{c}±0.06
Noodles $_{2}$	75.81 ^{d} ±0.03	2.52 ^{c} ±0.01	25.69^{b} ±0.10
Noodles $_{3}$	76.62 ^{c} ±0.03	2.27 ^{d} ±0.03	22.93^{d} ±0.04
Noodles $_{4}$	76.72 ^{b} ±0.02	1.94 ^{e} ±0.04	19.83^{e} ±0.03
Noodles $_{5}$	77.17 ^{a} ±0.02	1.81 ^{f} ±0.06	18.77 ^{f} ±0.03

*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

Values are the average of 3 experiments ± SD. Mean values (within the same column) followed by different superscripts are significantly different at the 5% levels

Texture profile of gluten-free noodles

Texture analysis is primarily concerned with the evaluation of mechanical characteristics of food products. Texture measurements can be very valuable for quality control and process optimization as well as for the development of new products with desirable properties and characteristics. Measurement of textural parameters of cooked noodle is important for product consumers acceptability (Liu and Scanlon, 2004; Korczyk-Szabo and Lacko-Bartosova, 2013).

Data in Table (7) showed that the most important characteristics of texture had been evaluated in gluten-free noodles (Hardness, cohesiveness, chewiness and springiness).The illustrated data were significantly different among noodles formula. The hardness value of noodles made from yellow corn grits and rice ranged from 1907.5 to 2216.7g. The values increased by increasing the rice flour percentage, where the rice has a high value of amylose content which featuring with a high tendency to retrograde and produce tough gels and strong films (Ashogbon and Akintayo, 2014). This data are in agreement with that obtained by Walid (2016) who found that, the hardness of gluten-free cooked noodles (rice and cassava) is 2293g. The hardness value for different products may be due to the mixing of cereals and legumes starch and protein. Sozer (2009) reported that high fiber and protein content of the non-gluten flours helps to retain the absorbed water after cooking. This can also be attributed to added gums which increase the rehydration rate of noodles upon cooking.

Cohesiveness is an indicator of the extent of disruption of the noodle structure during first compression and is the ratio of the peak areas of first and second compressions of the force–time plot (Singh *et al.*, 2002). The greater cohesiveness of noodles was in that made from high level of rice (noodles $_{5}$), this is due to the nature of the granules of rice.

Table (7): Texture profile analysis of cooked gluten-free noodles

Products	Properties			
	Hardness (g)	**Cohesiveness**	**Chewiness (g)**	**Springiness**
Control	1907.5^{f}±0.95	0.65 ^{f}±0.01	954 ^{a}±0.05	0.78 ^{a}±0.01
Noodles $_{1}$	1925.3^{e} ±0.69	0.68 ^{e} ±0.02	912 ^{ab} ±0.06	0.65 ^{b} ±0.03
Noodles $_{2}$	1980.4^{d} ±0.02	0.72 ^{d} ±0.01	879 ^{b} ±0.02	0.59 ^{c} ±0.04
Noodles $_{3}$	2043.8^{c} ±0.03	0.78 ^{c} ±0.02	832 ^{b} ±0.04	0.54 ^{d} ±0.02
Noodles $_{4}$	2143.9^{b} ±0.03	0.83 ^{b} ±0.01	802 ^{c} ±0.02	0.46 ^{e} ±0.01
Noodles $_{5}$	2216.7^{a} ±0.77	0.86 ^{a} ±0.02	791^{c} ±0.03	0.38 ^{f} ±0.01

Values are the average of 3 experiments ± SD. Mean values (within the same column) followed by different superscripts are significantly different at the 5% level

The results in the same Table showed that, control noodles recorded the highest value of the chewiness (954g) compared with the other noodles. Data for the springiness of noodles showed that control noodles was the highest value (0.78) while $noodles_4$ (0.46) and $noodles_5$ (0.36) showed the lowest values. Springiness measures elasticity by determining the extent of recovery between the first and second compression (Lu *et al.,* 2010). Chewiness represents the amount of energy needed to disintegrate food for swallowing. The present findings agreed with Gómez *et al.* (2007), who stated that both, gumminess and chewiness are parameters dependent on firmness; therefore, their values, followed a similar trend with that of firmness.

Cooking quality of gluten- free cooked noodles

Cooking quality properties were of the most important factors for noodles manufactures and consumers of noodles. Noodles quality and cooking properties are dependent on the protein-starch developed matrix (Brennan *et al*, 2003). Cooked noodles must be firm and elastic with a good surface condition, a high degree of swell and low losses in cooking water (Purwandari *et al.,* 2014).

The results in Table (8) showed that the cooking time of noodle samples ranged from 5.0 to 6.30 min, the $noodles_4$ and $noodles_5$ had the highest cooking time (6.30 min) compared with control (5 min).

Cooking time has an influence on the texture, chemical composition and nutritional values of pasta (Sobota *et al.*, 2013). The extending in cooking time led to a decrease in the firmness of pasta and it causes an increase in cooking loss (Dziki and Laskowski, 2005). Ormenese and Chang (2003) found that, optimum cooking times for fresh and dry rice pasta were 4.5 and 11min, respectively. Therefore, gluten-free pastas will generally cook faster than those made from durum wheat, where they are made from softer flours and they will not have tooth exhibited by 100% durum wheat pasta.

On the other hand, cooking weight or water absorption was gradually increased in all noodles products (75.81-118.4%) and this may due to the addition of rice to all noodles and the increase levels of gelatinization starch during the manufacturing process of the noodles by increase the rice concentration. Rice starch gave the highest value of water absorption capacity (Alfauomy *et al.,* 2017).

Cooking loss is an important indicator of cooking performance by both consumers and industry, being mainly influenced by dissolving and releasing gelatinized starches from the surface of pasta through cooking water (Brennan *et al.,* 2003).

Cooking loss decreased in all resultant noodles where ranged from 18.5 to 10.20%, this may be due to the addition of rice and the properties of starch to it.

The swelling percentage, also, increased in all noodles (70.2 - 94.2%), wherein, the swelling volume was gradually increased from $noodles_1$ (70.2%) to $noodles_5$ (94.2%) because this formula contained 50% rice flour, compared with $noodles_1$ which contained 10% rice flour. This is may be due to the high rate of swelling in rice starch (Alfauomy *et al.*, 2017). The high swelling power might be due to higher viscosity in rice and differences in the morphological structure of starch granules among the corn and rice (Singh *et al*., 2002).

The protein loss during the cooking process decreased in all products (0.92-0.54%), due to the addition of rice flour. Hassan *et al.* (2007) reported that the addition of rice to noodles increasing cooking weight, swelling and reduced cooking loss.

Table (8): Cooking quality of gluten-free noodles

Products	Properties				
	Cooking time (min)	**Cooking weight (%)**	**Cooking loss (%)**	**Swelling (%)**	**Protein loss (%)**
Control	5.0 ^{d}±0.5	75.81^{f}±0.13	18.5^{a}±0.21	70.20^{f}±0.21	0.92^{a}±0.04
Noodles $_1$	5.50^{c} ±0.5	85.45^{e} ±0.24	16.20^{b} ±0.04	74.50^{e} ±0.24	0.87^{b} ±0.03
Noodles $_2$	5.50^{c} ±0.5	96.28^{d} ±0.21	13.50^{c} ±0.32	80.40^{d} ±1.02	0.83^{b} ±0.05
Noodles $_3$	6.0^{b} ±0.5	104.20^{c} ±0.32	12.10^{d} ±0.12	85.70^{c} ±1.23	0.72^{c} ±0.06
Noodles $_4$	6.30^{a} ±0.5	112.10^{b} ±0.12	11.30^{e} ±0.05	88.50^{b} ±0.42	0.63^{d} ±0.02
Noodles $_5$	6.30^{a} ±0.5	118.40^{a} ±0.22	10.20^{f} ±0.14	94.20^{a} ±0.32	0.54^{e} ±0.03

Values are the average of 3 experiments ± SD. Mean values (within the same row) followed by different superscripts are significantly different at the 5% level

The noodles should meet the criteria of high water absorption, low cooking losses and good texture. After cooking, it should be firm enough to resist surface disintegration and have no excessive stickiness (Bruneel *et al.,* 2010). The improvement of gluten-free noodle has been focused on the selection of materials (legume powders, and vegetable or fruits powder) and modified processing methods (Marcella *et al.*, 2012).

CONCLUSION

The formulation of gluten-free products included the use of different sources, such as yellow corn grits, rice flour and chickpea powder. Noodle products are supported to enhance their nutritional properties with high protein source such as chickpea. Yellow corn grits (200-350μm) has a high value of β-carotene, this gave the yellow color and it is a major source of vitamin A. Sensory evaluation revealed that the high acceptance of gluten-free noodles was found in noodles contained 50% yellow corn grits, 40% rice flour and 10% chickpea powder. Generally, utilization of yellow corn grits, rice flour, and chickpea powder gave good gluten-free noodles suitable for different category consumed gluten-free products

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الاستفادة من الذرة الصفراء فى تحضيرنودلز خالية من الجلوتين ذات قيمة غذائية عالية

سعد عزيز محجوب وغادة على الفيومى

قسم بحوث تكنولوجيا المحاصيل- معهد بحوث تكنولوجيا الاغذية - مركز البحوث الزراعية - الجيزة- مصر

تهدف الدراسة إلى تصنيع نودلز خالية من الجلوتين من مجروش الذرة الصفراء ودقيق الأرز ومسحوق دقيق الحمص ثم تقدير الخواص الحسية والتغذوية والتكنولوجيا لها. تم طحن الذرة الصفراء ونخلها للحصول على ثلاث مستويات من الحجم أقل من 200 و 200 - 350 و 350 - 450 ميكروميتر. ولوحظ أن أعلى نسبة بروتين وجدت فى 200 - 350 و 350 - 450 ميكروميتر. كما وجد أن مستوى طحن 200 - 350 ميكروميتر له أعلى water hydration index (WHI) لذلك تم استخدامه فى صناعة النودلز. حيث تم تصنيع نودلز مجروش الذرة الصفراء مع استبدال 10% من الذرة بنسبة مماثلة من مسحوق الحمص ونسب مختلفة من دقيق الارز (10، 20، 30، 40، 50%). وقد اظهرت النتائج ان النودلز المحتوية على 40% دقيق أرز تقترب فى الخواص الحسية من المكرونة المصنوعة من سيمولينا القمح. والنودلز المحتوية على 10% دقيق أرز تحتوى على نسبة عالية من البروتين والدهون وكذلك الكالسيوم والزنك والبيتاكاروتين بينما تنخفض فى نسبة الحديد والكربوهيدرات. كما اظهرت نتائج تحليل القوام texture profile أن أعلى نسبة صلابة وتماسك كانت مرتفعة فى النودلز بزيادة نسبة دقيق الأرز. كما أظهرت النتائج أن النودلز المصنوعة من 40 و 50 % دقيق الأرز استغرقت وقت أطول فى الطبخ. كما وجد زيادة فى النسبة المئوية لوزن و حجم النودلز ، مع الانخفاض فى نسبة الفقد فى الطبخ وأيضا الانخفاض فى نسبة الفقد فى البروتين بزيادة نسبة الأرز. كما وجد أيضا أن النودلز الخالية من الجلوتين المحتوية على 50% مجروش الذرة الصفراء مع 40% دقيق الارز و 10% مسحوق الحمص أعطت أعلى نسبة من القبول بالنسبة للخواص الحسية. وبذلك فإن هذه الدراسة توصى بامكانية الاستفادة من مجروش الذرة الصفراء ودقيق الأرز ومسحوق الحمص لعمل نودلز خالية من الجلوتين تناسب مرضى حساسية الجلوتين.

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