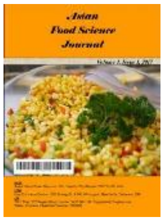

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Determination of Nutritional, Sensory and Biological Properties of Colored Pasta Prepared from Quinoa Grains

T. T. El-Sisy[1*] and Nivin S. Nail[1]

[1]*Regional Center for Food and Feed, Agriculture Research Central, Cairo, Egypt.*

Authors' contributions

This work was carried out in collaboration between both authors. The authors contribute equally to this work. Author TTES performed the preparation of the different pasta, chemical, physical and sensory evaluation. Author NSN conducted the biological experiment and managed the biological and histopathological data. Both authors collected the necessary materials, wrote and revised the paper.

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ABSTRACT

The present study investigates the nutritional, sensory and biological properties of colored pasta prepared from Quinoa *Chenopodium quinoa* grains. Four colored pasta were prepared from quinoa: White (control), red, orange and green. The sensory evaluation results indicated general acceptability of the coloured pasta compared to the white pasta (control) and commercial pasta made of durum wheat. The nutritional analysis revealed that the protein of the pasta increased by using Quinoa grains and thus the colored pasta is more nutritious than the white pasta. Orange pasta is considered a safe food for celiac patients, because it is gluten-free. Hence, the beneficial role of a Quinoa pasta diet to prevent of celiac disease was investigated in a 30 days biological study. The results revealed that the highest increase in body weight gain was noticed in rats fed orange pasta diet compared with other groups. Meanwhile, a significant increase in relative liver weight and decreased in intestine weight were observed in rats fed 10% wheat gluten. The substantial elevation of serum enzymatic activity level were significantly restored to normal in rats fed the orange pasta with10% wheat gluten compared with rat fed 10% wheat gluten. The activities

**Corresponding author: Email: tamerelsisy@yahoo.com;*

of antioxidant enzymes decreased in rats fed 10% wheat gluten compared with rat fed Orange pasta. The concentrations of serum Immunoglobulin Aantibodies were significantly higher in rats fed 10% wheat gluten and restored to normal levels in rats fed orange Quinoa pasta diet with 10% wheat gluten. Histopathological studies of the intestine and liver in rats fed orange Quinoa pasta diet with 10% wheat gluten revealed minimizing changes in these organs compared with rats fed orange Quinoa pasta diet alone which showed normal histopathological structure similar to control group. It can be concluded that Quinoa pasta could be considered a safe food for celiac patients.

Keywords: Quinoa; pasta; physical and chemical properties; sensory and biological evaluation; celiac disease.

1. INTRODUCTION

The Food and Agricultural Organization (FAO) in 2013 has officially declared that year as "The International Year of the Quinoa." For the important role to achievement of food security in worldwide and "high nutritive value," [1]. Andean peoples domesticated Quinoa around 3,000 years ago; it's an important staple where the plant is indigenous but relatively obscure in the rest of the world [2].

Between 2006 and early 2013 quinoa crop prices tripled as it become increasingly popular in many country where it is not typically grown which increases this crop value. Quinoa grains (100 g) have 368 calories, moderate sources of energy, which may be matched to some cereals such as wheat, maize, rice, chickpea and mung bean.100 g of Quinoa grains have 14-18 g of protein which composes almost of essential amino acids like lysine which is a limiting amino acid in grains. High soluble and insoluble dietary fiber in Quinoa grains prevents constipation by speeding up the movement through the gut. Fiber cabled to binds to toxins to excrete from the gut, protecting colon mucosa from cancers. Additionally, dietary fibers bind to bile salts, help lowering serum LDL cholesterol levels. Quinoa grains are contains B-complex vitamins, (a-tocopherol), folic acid and essential fatty acids such as linoleic and alpha-linolenic acid (18:3). Fresh quinoa leaves and flower-heads are rich sources of vitamin A and antioxidants (lutein, carotene, crypto-xanthin, and zea-xanthin) which are powerful removing harmful free radicals and protect from cancers, aging and degenerative neurological diseases. Quinoa has high contain of minerals like calcium (bone formation),iron (red blood cell life shelf), potassium (controlling blood pressure and heart beat), copper (red blood cells production), manganese is a co-factor for anti-oxidant enzyme (superoxide dismutase), magnesium (relaxes blood vessels leading to brain) and zinc (co-factor in enzymes that regulate, sperm generation and nucleic acid synthesis) [3,4].

Pasta is a low cost, easy prepared cereal-based food product (made with semolina from durum wheat), some ingredients can be added, like eggs, whey and herbal products which are becoming important in pasta manufacture. The textural and nutritional properties of pasta are important to the acceptability by the consumers who avoid products containing gluten; pasta can be made from rice flour in place of wheat. Pasta may be divided into two broad categories, fresh (*Pasta fresca*) and dried (*pasta secca*) [5].

Wheat allergy and cereal allergy (Celiac disease) are great problems; it's an inheritable chronic systemic autoimmune disorder that occurs in the small intestine. gluten-free basic foods keeps growing in the world using of pseudo cereals like buckwheat ,quinoa, millet , rice, taro flour and some legumes. Also physicochemical, chemical, textural and sensory properties of gluten free spaghetti produced from chick pea flours and maize was evaluation in the production of gluten free products [6].

The aim of the present work is to evaluate the sensory, nutritional and biological properties of coloured pasta prepared from quinoa grains as non-conventional free gluten flour.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Chemicals

All chemicals used in the study were of analytical grade. Kits used for the estimation of analyzed parameters were purchased from Biosystem, Spain and Biodiagnostic, France.

2.1.2 Quinoa samples

Quinoa grains *(Chenopodium quinoa)* cultivars were obtained from Egypt. White Quinoa which was obtained from one location National Consultants for Quinoa Production and Research – Corp Intensification Research Department - Field Crops Research Institute – Agricultural Research Center during 2017.

2.1.3 Commercial pasta

Commercial pasta high quality made of durum wheat (*Triticum durum)* was purchased from commercial hypermarket.

2.1.4 Wheat gluten

Wheat gluten was obtained from the Regional Center for Food and Feed, Agriculture Research center, Giza, Egypt.

2.1.5 Corn starch, corn oil, cellulose and sucrose

Corn starch and corn oil were purchased from the local market while sucrose and cellulose were purchased from Sigma Chemical Co. (St Louis, MO, USA).

2.1.6 Mineral salts and vitamins

Mineral salts and vitamins used for the preparation of the mineral salt and vitamin mixtures were obtained from Sigma Chemical Co. (St Louis, MO, USA) and prepared according to Reeves et al. [7].

2.1.7 Animals

Adult male albino rats weighing (90-100 g) were obtained from Faculty of Veterinary Medicine, Cairo University.

2.2 Methods

2.2.1 Preparation of quinoa flours

Ten kilograms of Quinoa were stored at temperature 25°C and relative humidity less than 62% according to the methods described in USDA [8]. Quinoa sample was cleaned mechanically to remove dirt, dockage, imparters and other strange grains by Carter Dockage Tester according to the methods described in USDA [9]. The extraction rate of flour sample was adjusted to recurred rate (100% extraction) \which had milled by laboratory mill 3100 Perten According to the methods described in AACC [10] for whole meal flour.

2.2.2 Quinoa pasta processing

The Quinoa was processed into flour, using the method of Fresh Pasta Dough According to the methods described in AACC [11].

2.2.3 Coloured pasta processing

Different colours of dough were used to produce Coloured Quinoa pasta according to the formula showed in Table 1.

Pasta was prepared according to the methods described in AACC [11]. All ingredient of pasta are shown in Table 1, The Pasta was produced according to the method of Fresh Pasta Dough in Regional Center for Food and Feed, Agri. Res. Center, Cairo, Egypt.

2.2.4 Physical properties of quinoa grains

Cleanliness, dockage, broken, foreign materials, total damaged kernels and total defects were separated and determined manually (hand picking). Test weight pound per bushel**,** Test weight P/B = (Kg ⁄ Hectoliter) ÷1.278 according to USDA [12]. A thousand kernel weights were determined by counting the kernels in a 10 g Quinoa sample [10]. Wet and dry gluten and falling number were determined to Quinoa whole mill according to AOAC [13]. Colour was evaluated by a colorimeter CR-400 (Konica Minolta, Japan) in the CIE LAB colour space: Commission International de l'Eclairage(CIE) tristimulus L* a* b* parameters were determined using colour meter (Colour Tec PCMTM Color Tec Associates, Inc., Clinton, NJ, USA). The colorimeter operates on the CIE L*, a*, b* colour scheme, *L (lightness) axis – 0 is black, 100 is white, *a (red-green) axis – positive values are red; negative values are green and 0 is neutral, *b (yellow-blue) axis – positive values are yellow; negative values are blue and 0 is neutral. The instrument was first standardized (L* = 93.24, a* = 00.96, b* = –02.75) with a Business Xerox 80 gm-2) white paper with 136 CIE whiteness D65. Three grams of plantain pasta were ground and weighed into a clean paper and the colour meter was placed on the sample by allowing the sensor to touch the sample. The reading was taken directly for L*-a Light to Dark direction [14].

Table 1. Different component were used to produce coloured pasta made of quinoa

Type of coloured pasta	Flour	Whole egg	Yolk egg	Juice
White (Control)	1000 g	8	6	Non
Red	1000 g	6	6	100ml Beet
Orange	1000 g	6	6	100ml Carrot
Green	1000 g	6	6	100ml Spinach

2.2.5 Chemical properties of quinoa grains

Moisture, crude protein, ash, crude fiber, fat, minerals, vitamins and aflatoxin were determined according to AOAC [13] and USDA [15]. The nitrogen free extract (NFE) was calculated by difference.

2.2.6 Cooking characteristics of pasta

Cooking characteristics considered in this study included cooking time, loss and water absorption. [11].

Cooking loss (%) = {(Dried residue in cooking water / Pasta weight before cooking) x100}

2.2.7 Sensory evaluation

Overall acceptability of the pasta was evaluated by 10 panelists to indicate their preference for the samples on a twenty point hedonic scale, where 1 and 20 represent dislike extremely and like extremely respectively [16].

2.2.8 Preparation of pasta for animal experiment

Orange quinoa pasta was dried at 50^{o}C in an oven under vaccum overnight. The dried pasta were ground, and then kept in polyethylene bags in refrigerator at 4°C until used.

2.2.9 Design of animal experiment

The rats were housed individually in polypropylene bottomed cages under standard laboratory conditions at (26-28°C) on a 12 h light: 12 h dark cycle for a week with free access to standard food and water ad libitum. The experimental procedure was carried out according to the rules and regulations by the animal's house of Regional Center for Food and Feed, Agriculture Research Center, Giza, Egypt. The diets given to animals were formulated and composed as shown in Table 2. The rats were divided into four groups each of 10 rats as follows:

Group 1, normal control rats fed basal diet.
Group 2, rats fed basal diet and 10% wheat gluten powder.
Group 3, rats fed orange pasta diet.
Group 4, rats fed orange pasta diet with 10% gluten powder.

The feeding period continued for 30 days. During the experimental period, the body weight of animals was followed. The organs were calculated related to body weights. At the end of the experimental period, rats were fasted overnight; blood was collected from the retro-orbital vein of each animal using a glass capillary tube and then sacrificed by cervical decapitation.

Table 2. Ingredient composition of the experimental diets fed to rats

Ingredients (g)	Group 1	Group 2	Group 3	Group 4
Corn starch	625	525	-	-
Quinoa pasta	-	-	625 (orange)	525 (orange)
Wheat gluten	-	100	-	100
Casein	140	140	140	140
Sucrose	100	100	100	100
Cellulose	50	50	50	50
Corn oil	40	40	40	40
Mineral mix	35	35	35	35
Vitamin mix	10	10	10	10
Total	1000	1000	1000	1000

2.3 Biochemical Analysis

The serum and plasma were separated and collected into sterilized tubes and stored at -20°C for further analysis. Serum was separated by centrifuging (Hettich, Universal 16, German) at 3000 rpm for 20 min at 4°C for biochemical analysis including enzymes activities of ALT and AST [17] and ALP [18]. Plasma was prepared by collect blood using an anticoagulant heparin and separated by centrifuging at 4000 rpm for 10 min at 4°C for the estimation of antioxidants GR [19], SOD [20] CAT [21] and MDA [22].

2.4 IgA Measurement

Serum IgA antibodies to wheat gluten antigens were measured by enzyme linked immunosorbent assay (ELISA) for coeliac disease according to El Alaoui and Gresti [23].

2.5 Histopathological Examination

Liver and intestine from each group were excised, washed in ice-cold saline to remove blood, submerged in 10% formalin and embedded in the paraffin. Microtome sections of 3-4 micron thickness were prepared according to the standard procedure and stained with haematoxylin and eosin. Sections were then examined for pathological findings of such as centrilobular necrosis, fatty and lymphocytes infiltration by the light microscope [24].

2.6 Statistical Analysis

Data of three replicates for analyses and ten replicates for rats were computed for the analysis of standard division (S.D) among the means were determined by Duncan's multiple range tests using SAS programs [25].

3. RESULTS AND DISCUSSION

3.1 Chemical and Physical Properties of Quinoa Kernels and Its Flour

Chemical composition of Quinoa kernels used in this study is given in Table 3. The moisture content of Quinoa was (13.0%), its protein content was (14.0%). On other hand nitrogen free extracts (NFE) % was 59%. Additionally Quinoa had higher fat (6.0%) compared to wheat grains and was lower in ash content (1.70%). The ash content of flour is related to the amount of bran in the flour and therefore to flour yield. The results of fiber showed that Quinoa had the significant highest value (6.30%) while Wheat had ranged between (1-3%). Wheat chemical composition used for comparison was obtained from The Egyptian standard no. 1601/1986 and its modification on 23/4/2002 [29]. These results agree with result obtained by Abdellatif [4].

Minerals for quinoa grains and commercial pasta made of wheat C.P.W Table 3 it can be noticed that (Mg) was 197.0 mg higher than C.P.W (0.18 mg) which refer to wheat grains. Iron content was 4.6 mg in quinoa and n for C.P.W. Some macro element were found in quinoa including Ca (47.0 mg), P (457.0 mg) and K (563.0 mg) higher by 6 folds for Ca, 8 folds for P and12 folds for K, than C.P.W respectively. Zn in Quinoa was (3.1) and C.P.W (5.0gm). On the other hand C.P.W had Mn (0.32) and not detected for Quinoa. These results agree with result obtained by MHU [26], Nagarajan [27] and Abdellatif [4].

Vitamins of quinoa grains and commercial pasta made of wheat (C.P.W) were used in these study are given in Table 3. The results showed that Thiamine (B1) of Quinoa was (31.0%) higher than C.P.W (2.0%) which refer to wheat grains. Riboflavin (B2), in Quinoa had the highest (B2) (27.0%) than C.P.W (2.0%). Niacin (B3) was (10.0%) than C.P.W (3.0%). Quinoa was higher in Pantothenic (B5) (15.0%) and it was higher in Pyridoxine (B6) (38.0%) in camper with C.P.W (2.0%) and (4.0%) respectively which refer to wheat grains. However, highest Folic Acid (B9) was observed in Quinoa (46.0%) than C.P.W (2.0%). Vitamin E was (16.0%) and non for C.P.W. These results agree with results obtained by WHO [28] and recommended by FAO [29].

Quinoa grains cultivars and commercial pasta made of wheat (C.P.W) were under the detection limit (0.5 ppb) for aflatoxin, ochratoxin, zearalenone, fumonisin. As recommended by WHO [28].

Mean value of physical properties of Quinoa kernel cultivars are presented in Table 4. Moisture content was 13.0%. It can be concluded that the test weight for Quinoa sample was 62.80 pound per bushel. Moreover the foreign material and broken kernels was (1.09%). For damage kernels (heat damage and total damage) Quinoa had low total damage kernels percentage (0.50%) while wheat damage kernels was (zero%). Quinoa is free from insect and ok odor. Results showed that 1000 kernels Quinoa was 4.0 gm. Additionally the Quinoa kernel colour was white and hardness was 61.1%.The results is like the Egyptian stander no.1601/1986 and it’s modification on 23/4/2002 has obligation that the dockage percent (first separated from sample) not exceed 1%, foreign material percent not exceed 1%, total damage kernels percent (heat damage, sprout damage, insect damage and mould damage kernels) not exceed than 4% and according to USDA [12], ES [30].

The data in Table 5 showed that the starch damage was in Quinoa flour (1.5%) and higher for commercial pasta made of wheat (C.P.W) (5.1%). Results from Tables 3 and 7 indicated the increases in protein content which was accompanied by Free in the wet and the dry gluten contents for Quinoa. Quinoa flour showed protein content of 14.0% have Free wet, dry gluten, hydration ratio and index but C.P.W were (20.40%), (6.52%), (2.12%) and (80.10%) respectively which refer to wheat grains. The same table reviewed that the falling number values was 360.0 sec higher than C.P.W (154.0 sec). Economic European community recommended that the falling number of flour should exceed than 230sec [31]. Egyptian stander no. 1419/2006 for white flour has the following requirement: protein content not less than 10.2% Ash content not exceed than 0.9% And the falling number showed exceed than 200 Sec [32]. Also, Egyptian standard no. 1649/2004 for durum wheat has obligation that protein content of durum wheat not less than 10.5% and ash content not exceed than 1.3% [33]. In Table 5 it can be concluded that the percentage of sediment for Quinoa flour was 35% higher than C.P.W (16.0%). Quinoa flour was highest sediment ratio which had good characteristics to produce pasta. Quinoa flour had a less value of whiteness colour 38.30% and C.P.W had the higher (39.9%).

Chemical composition of white pasta (control) made from Quinoa flours obtained quinoa kernels and commercial pasta made of wheat (C.P.W) is shown in Table 6. The Results indicated that chemical composition of flour in Quinoa sample moisture content 60, C.P.W have (62.0%). Protein content in quinoa was 11.50% and carbohydrates were (21.12%) but C.P.W was 5.8% and 30.90% respectively .Fat content was 4.90% and C.P.W (0.9%). On other hand the Quinoa had the lower ash content 1.30% than C.P.W which was (1.40%). Substituting Quinoa flour increase protein, crude fiber and fat in the pasta sample is of health benefit to consumers. Protein is needed for physiological functioning and reducing protein-energy malnutrition; crude fiber is anti-diabetic while vegetable fat is a good source of energy and helps in absorption of most fat soluble vitamins and minerals [29] and [34].

Table 3. Proximate analysis for Quinoa kernels and commercial pasta made of wheat (C.P.W)

	Chemical composition	Quinoa Kernels	C.P.W
	Moisture content %	13.0^{b}	62.0^{a}
	Protein content %	14.0^{a}	5.80^{b}
	Fat content %	6.0^{a}	0.9^{b}
	Ash content %	1.70^{a}	1.40^{b}
	Fiber content %	6.30^{a}	1.80^{b}
	Nitrogen free extracts (NFE) %	59.0^{a}	30.9^{b}
	Total caloric values%	346.0^{a}	154.9^{b}
Minerals (mg)	Magnesium (Mg)	197.0^{a}	0.18^{b}
	Iron (Fe)	4.6	Non
	Calcium (Ca)	47.0^{a}	7.0^{b}
	Phosphorus (P)	457.0^{a}	58.0^{b}
	Potassium (K)	563.0^{a}	44.0^{b}
	Zinc (Zn)	3.1^{a}	5.0^{a}
	Manganese (Mn)	0.0	0.32
Vitamins %	Thiamine(B1)	31.0^{a}	2.0^{b}
	Riboflavin(B2)	27.0^{a}	2.0^{b}
	Niacin (B3)	10.0^{a}	3.0^{b}
	Pantothenic acid (B5)	15.0^{a}	2.0^{b}
	Pyridoxine(B6)	38.0^{a}	4.0^{b}
	Folic Acid (B9)	46.0^{a}	2.0^{b}
	Vitamin E	16.0	Non

a,b,…Means with the same letter in the same row are not significantly different at ($P \le 0.05$)

Table 4. Physical properties of quinoa kernels cultivars

Parameters		Quinoa kernels
Moisture Content (M.C)%		13.0
Test weight (T.W) p/b		62.80
Broken kernels & Foreign Material (BNFM) %		1.09
Damage Kernels	Heat Damage (H.D)%	0.0
(D.K) %	Total Damage (T.D) %	0.50
Odor		Ok
Insect		Free
Weigh per 1000 kernels gm		4.0
Hardness%		61.1
Colour		White

p/b= Pound per Bushel (American unit)

Table 5. Physicochemical properties of flour obtained from quinoa kernels and commercial pasta made of wheat (C.P.W)

	Parameters	Quinoa kernels	C.P.W
Starch damage %		1.50 [b]	5.10 [a]
	Wet%	Free	20.40
Gluten quantity	Dry%	Free	6.52
	Hydration ratio%	Free	2.12
	Index%	Free	80.10
Falling number Sec.		360.0 [a]	154.0 [b]
Protein sediment %		35.0 [a]	16.0 [b]
flour colour %	White	38.30 [b]	39.90 [a]
	Yellow	14.40 [a]	12.80 [b]

a,b,…Means with the same letter in the same row are not significantly different at ($P \leq 0.05$)
Free= free of wheat gluten

Table 6. Chemical composition of white pasta (control) made from quinoa flour and commercial pasta made of wheat (C.P.W)

Chemical composition	Quinoa pasta	C.P.W
	White (control)	
Moisture content %	60.0 [a]	62.0 [a]
Protein content %	11.50 [a]	5.80 [b]
Fat content %	4.90 [a]	0.9 [b]
Ash content %	1.30 [a]	1.40 [a]
Fiber content %	5.18 [a]	1.80 [b]
Carbohydrates %	21.12 [b]	30.9 [a]
Total caloric values%	174.58 [a]	154.9 [b]

a,b,…Means with the same letter in the same row are not significantly different at ($P \leq 0.05$)

Vitamin and minerals in coloured pasta made from Quinoa flour and different juice obtained from (Beet, carrot and spinach) and commercial pasta made of wheat (C.P.W) are given from Table 7. The results indicated that chemical composition of pasta is different in all investigated samples. Vitamin A are ranged from 23% (green pasta) to 60.0% (orange pasta) which have contain highest vitamin C (13.2%), vitamin K (59.0%), vitamin E (13.5%) and Selenium (Se) (0.001).The lowest in vitamin A and vitamin K was (green pasta) (23.0%), (28.1%) respectively, however (red pasta) has the lowest in vitamin C and vitamin E (2.0%), (13.1%) respectively compared with other studied sample of C.P.W which was non in all. Substituting vegetables juice for Quinoa flour increase vitamin A, vitamin C, vitamin K, vitamin E and Selenium (Se) in the pasta samples is of health benefit to consumers. Vegetable fat is a good source of energy and helps in absorption of most fat soluble vitamins and minerals [29] and [34].

The colour of the uncooked and cooked for coloured pasta and commercial pasta made of wheat (C.P.W) samples are shown in Table 8. The data obtained showed significant differences ($p<0.05$) among all coloured pasta samples for "L*", "a*", and "b*" colour values. The L* colour values for all the uncooked coloured pasta ranged from 84.24 to 56.42. C.P.W had the highest L* colour value of 84.24 followed by white pasta (81.88), while red pasta had the lowest L* colour value of 56.42. The a* colour values ranged from -20.71 to 19.12, while red pasta had the highest a* colour value of 19.12, green pasta had the lowest a* value of -20.71. The b* colour values ranged from -10.23 to 20.96. While C.P.W had the highest b*colour value of 20.96 followed by white pasta (19.41), green pasta had the lowest b* colour value of -10.23. The L* colour values for the cooked coloured pasta, ranged from 69.24 to 83.41 with white pasta having the highest value of 83.41 and red pasta with lowest value of 69.24. The a* colour values ranged from -18.56 to 14.31 with red pasta having the highest value of 14.31 and green pasta having the lowest value of -18.56. The b* colour values ranged from -8.71 to 18.72 with C.P.W having the highest value of 18.72 followed by white pasta (15.64) and green pasta with the lowest value of (-8.71). These results are parallel with the results obtained by Francis et al. [14].

The result of the cooking characteristics of coloured pasta comprising white (control), red, orange, green pasta and commercial pasta made of wheat (C.P.W) are shown in Table 9. There was significant differences ($p<0.05$) in the cooking characteristics among all coloured pasta and C.P.W samples. The cooking time ranged from 7.10 to 10.1 minutes, orange pasta had the lowest time (7.10 minutes), while C.P.W had the highest time of 10.1 minutes followed by white pasta (control) (8.29) minutes. Cooking loss ranged from 6.4 to 7.79%, with white pasta (control) having the lowest value of 6.4% and C.P.W with the highest cooking loss of 7.79%. Furthermore, water absorption of the coloured pasta samples ranged from 111.3% white pasta (control) to 135.6 % (C.P.W) according to AACC [11].

Results of Sensory evaluation of coloured pasta made from Quinoa flour are shown in Table 10. From obtained results it can be noticed that the Statistical analysis for total score was significantly differences between all coloured pasta prepared from Quinoa cultivars which ranged from 75.42 to 87.63%, orange pasta had highest total scores than white (control) and green pasta 84.84 and 78.29 respectively until the lowest one is red pasta 75.42. The Statistical analysis for colour was significantly differences between all pasta making from different vegetables juice which ranged from 7.92 to 8.78%. Highest mean score for colour (8.78) was obtained by orange pasta whereas white (control) pasta got the lowest score (7.92). For mouth feel orange pasta was at the top (18.02) followed by white (control) pasta (17.56) and found to be the least (16.59) for red pasta. Maximum flavor score (17.85) was attained by orange pasta while red pasta received the minimum score (14.0). For texture, highest mean score (8.5) was obtained by orange pasta followed by green pasta (8.39). As regards taste quality, orange pasta got the maximum score (17.28) and red pasta obtained the minimum score (12.84). Red pasta obtained the least score (15.28) for appearance whereas orange pasta received the highest score (17.20). With respect to overall acceptability of pasta, highest score (87.63) was obtained by orange pasta and thus regarded as more acceptable than other coloured pasta while lowest score (75.42) was obtained by red pasta thus considered least acceptable. These results are parallel with the results obtained by Iwe [16].

Table 7. Vitamin and minerals in coloured pasta made from quinoa flour and commercial pasta made of wheat (C.P.W)

Parameters	Coloured pasta				
	White (Control)	Red	Orange	Green	C.P.W
Vitamin A %	N.D.	33.0 [b]	60.0 [a]	23 [c]	N.D.
Vitamin C %	N.D.	2.0 [c]	13.2 [a]	4.8 [b]	N.D.
Vitamin K %	N.D.	49 [b]	59.0 [a]	28.1 [c]	N.D.
Vitamin E %	13.4 [a]	13.1 [a]	13.5 [a]	13.2 [a]	N.D.
Selenium (Se) ppm	N.D.	N.D.	0.001	N.D.	N.D.

a,b,…Means with the same letter in the same row are not significantly different at ($P \leq 0.05$).
N.D. not detected

Table 8. The colour of uncooked and cooked coloured pasta made from quinoa flour and commercial pasta made of wheat (C.P.W)

Treatments		Uncooked pasta			Cooked pasta		
		L*	a*	b*	L*	a*	b*
Coloured Pasta	White control	81.88 b	-5.42 d	19.41 b	83.41 a	-3.11 d	15.64 ab
	Red	56.42 e	19.12 a	-8.16 d	69.24 a	14.31 a	-6.43 c
	Orange	76.82 c	10.23 b	10.12 c	80.11 a	8.56 b	12.18 b
	Green	68.61 d	-20.71 e	-10.23 e	71.21 a	-18.56 e	-8.71 c
	C.P.W	84.24 a	1.23 c	20.96 a	80.12 a	0.32 c	18.72 a

a,b,c,d…Means with the same letter in the same row are not significantly different at (P ≤ 0.05)

Table 9. The cooking characteristics of cooked coloured pasta made from quinoa flour and commercial pasta made of wheat (C.P.W).

	Treatments	Cooking time (minutes)	Cooking loss (%)	Water Absorption (%)
Coloured Pasta	White control	8.29 b	6.40 c	111.30 d
	Red	7.20 c	7.10 b	120.60 b
	Orange	7.10 c	7.20 ab	115.30 c
	Green	7.15 c	7.25 ab	116.10 c
	C.P.W	10.10 a	7.79 a	135.6 a

a,b,…Means with the same letter in the same row are not significantly different at (P ≤ 0.05)

Table 10. Sensory evaluation of colored pasta made from quinoa flours

Coloured Pasta	Appearance 20%	Flavour 20%	Taste 20%	Texture 10%	Colour 10%	Mouth feeling 20%	Overall 100%
White (control)	17.14 a	17.0 b	17.14 a	8.0 b	7.92 b	17.64 c	84.84 c
Red	15.28 c	14.0 c	12.84 b	8.07 b	8.64 a	16.59 e	75.42 e
Orange	17.20 a	17.85 a	17.28 a	8.50 ab	8.78 a	18.02 b	87.63 a
Green	15.78 b	14.35 c	14.21 b	8.39 ab	8.60 a	16.96 d	78.29 d
C.P.W	17.19 a	17.21 a	17.22 a	8.61 a	8.61 a	18.2 a	87.04 b

a,b,…Means with the same letter in the same row are not significantly different at (P ≤ 0.05)

3.2 Biological Experiment for Orange Quinoa Pasta

3.2.1 Body and organ weights of rats fed different experimental diets

Initial, final body weight and the relative weights of liver and intestine are shown in Fig. 1. The highest significant increase in body weight gain was noticed in rats fed orange quinoa pasta diet alone (47.8 g) compared with normal control group (40.8 g). On the other hand, the lowest significant decrease in final body weight was observed in rats fed 10% wheat gluten alone (23.8 g) due to wheat gluten. Furthermore, feeding the orange quinoa pasta diet with 10% wheat gluten to rats reversed the weight loss (41.2 g) to normal level.

The relative liver weight was significantly ($P < 0.05$) increased while the relative intestine weight was significantly decreased (4.20 and 3.05 g, respectively) in rats fed 10% wheat gluten alone. Non-significant differences in these relative weights in groups of rats fed other different diets. This goes in parallel with the finding of Ludvigsson et al. [35] who reported that cealic disease (CD) is a chronic small intestinal immune mediated enteropathy precipitated by exposure to dietary gluten in genetically predisposed individuals. Also [36] showed that CD is now considered a multisystem disorder affecting multiple organs, such as the skin, thyroid, heart, nervous system, pancreas, spleen and liver.

3.2.2 Serum liver enzymes activities of rats fed different experimental diets

Alanine aminotransferase, aspartate aminotransferase and alkaline phosphatase were measured to determine liver injure. Low levels of these enzymes are normally found in the blood, but in liver injure, it releases these enzymes into the blood. Data are presented in Fig. 2 and 3, demonstrate that the substantially elevation.

The results of serum enzymatic ALT, AST and ALP activities were significantly restored towards near to normalization (42.0, 40.0 and 336.0 U/l, respectively) after four weeks of the rats fed the orange quinoa pasta diet with10% wheat diet compared with rats fed 10% wheat gluten alone (50.0, 49.0 and 354.0 U/l, respectively). On the other hand, no significant differences were showed in the activities of ALT, AST and ALP enzymes between rats fed the orange quinoa pasta diet alone and normal control group.

3.2.3 Antioxidant enzymes activities and lipid peroxidation of rats fed different experimental diets

Superoxide dismutase and catalase are the two major scavenging enzymes that remove toxic free radicals *in vivo*. In this study we investigated the activities of antioxidant enzymes and the levels of MDA to explain the role of oxidative stress in the diagnosis of celiac disease. The activities of antioxidant enzymes (GR, SOD and CAT) and the levels of MDA are summarized in Fig. 4 and 5. The results indicate that the antioxidant enzymes activities GR, SOD and CAT were significantly decreased (17.2, 329.8 and 30.0 U/ml, respectively) in rats fed 10% wheat gluten compared with rats fed the orange quinoa pasta diet with 10% wheat gluten caused a significant increase (22.8, 346.0 and 37.6 U/ml, respectively) in these antioxidant enzymes activities. MDA is one of the end-products of polyunsaturated fatty acid peroxidation and is a good indicator of the degree of lipid peroxidation (LPO). The level of MDA was significantly increased (26.8±0.73 nmol/ml) in rats fed 10% wheat gluten, but the values were reduced (18.4±0.51nmol/ml) in rats fed the orange quinoa pasta diet with10% wheat gluten. Our findings are in accordance with the results of Stojiljković et al. [37] who found that the LPO concentration in patients with active and silent celiac disease was 80–100% higher than in the control group. Even in gluten free diet group LPO concentration was elevated for 25% in comparison to the control group. Meanwhile, rats fed orange quinoa pasta diet alone did not induce significant changes in the activities of GR, SOD, CAT and the level of MDA when compared with normal control group.

3.2.4 Total serum IgA concentrations of rats fed different experimental diets

Detection of IgA antibodies is a reliable marker of severe intestinal mucosal damage, more sensitive and more specific for celiac disease. As presented in Fig. 6, at the end of the experiment the concentrations of serum IgA antibodies were significantly higher in rats fed 10% wheat gluten (3.5 mg/ml), as indicator of celiac disease and restored to normal levels in rats fed the orange quinoa pasta diet with10% wheat gluten (0.91 mg/ml). Also, a total serum IgA concentration was not statistically different between rats fed the orange quinoa pasta diet alone (0.91 mg/ml) and normal control group (0.91 mg/ml). Such observation has been reported by Sugai et al. [38] who showed that the concentrations of IgA were higher in celiac disease patients compared to non- celiac disease patients. The immune response of many gluten peptides in celiac disease was characterized by activation of gluten-specific T-cells leads to stimulate B cell release of anti-gluten, as well as anti-TG2 antibodies. Thus, the measurement of IgA isotype is more sensitive and specific in the diagnosis of celiac disease.

3.2.5 Intestine and liver histopathology of rats fed different experimental diets

3.2.5.1 Intestine histopathology

Intestine histopathology in rats fed the experimental diets is illustrated in Fig. 7. Representative photomicrographs of intestine histopathology (H and E, 200×): (A) Intestine of control rats showing normal intestine mucosa histology. (B) Intestine of rats fed 10% wheat gluten showed odema in lamina propria, mononuclear cells infiltration and activation of epithelial lining lamina epithelialise. (C) Intestine of rats fed orange quinoa pasta diet alone showed normal histopathological structure similar to control intestine sections. (D) Intestine of rats fed orange quinoa pasta diet with10% wheat gluten revealed minimizing changes in intestine sections. This lends further support to the findings of Jabri et al. [39] who stated that the immunogenicity of many gluten peptides (wheat gluten and related proteins) in celiac disease was assessed by activation of gluten-specific T-cells is accompanied by the production of a number of cytokines that can in turn promote inflammation and villous damage in the small intestine through the release of metalloproteinase by fibroblasts and inflammatory cells.

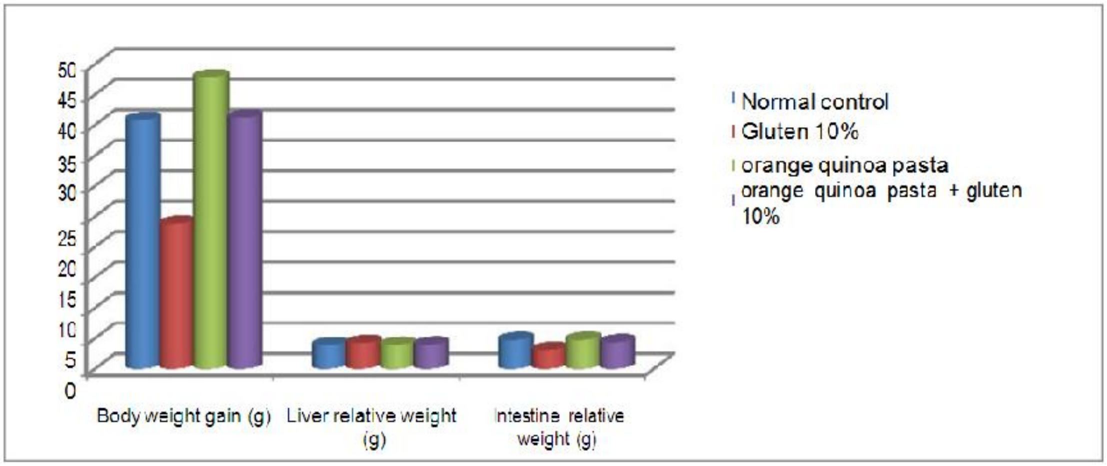


Fig. 1. Body and organ weights of rats fed different experimental diets

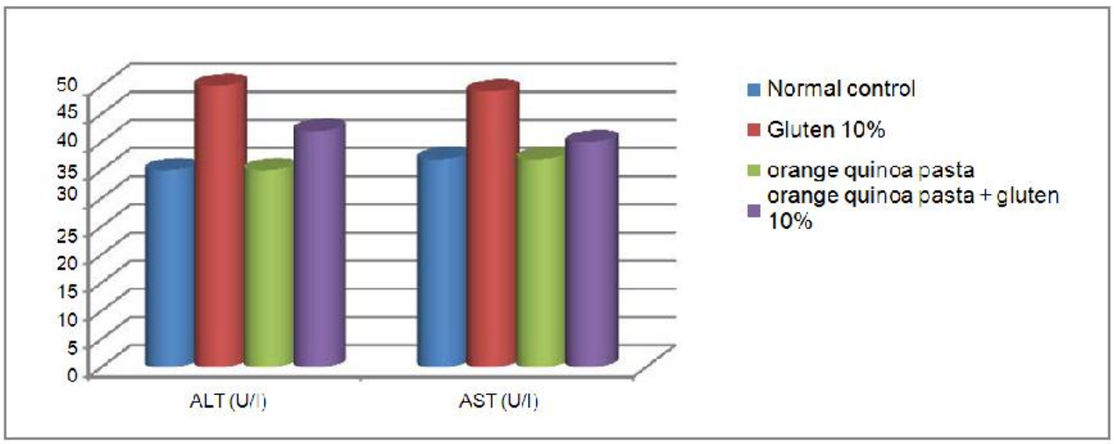


Fig. 2. Activities of aminotransferase ALT and AST of rats fed different experimental diets

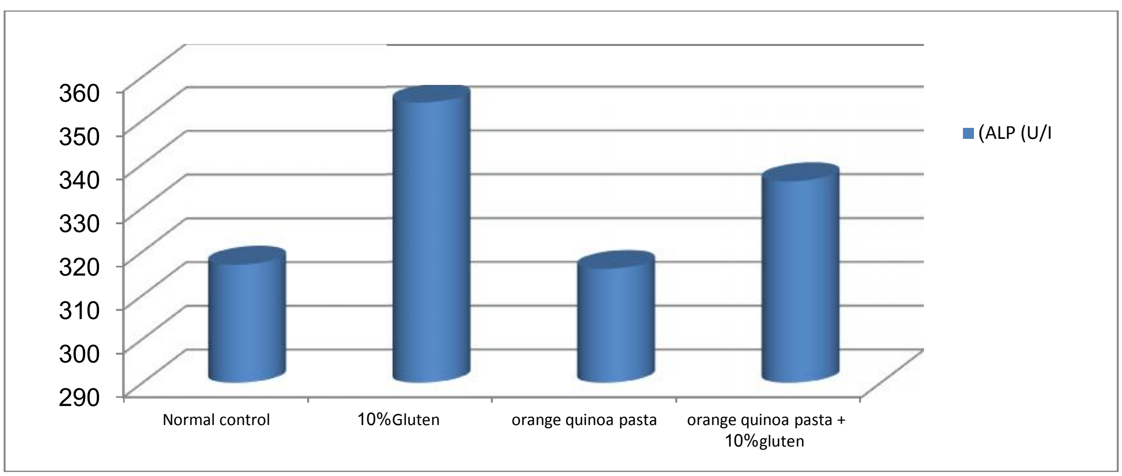


Fig. 3. Activities of ALP of rats fed different experimental diets

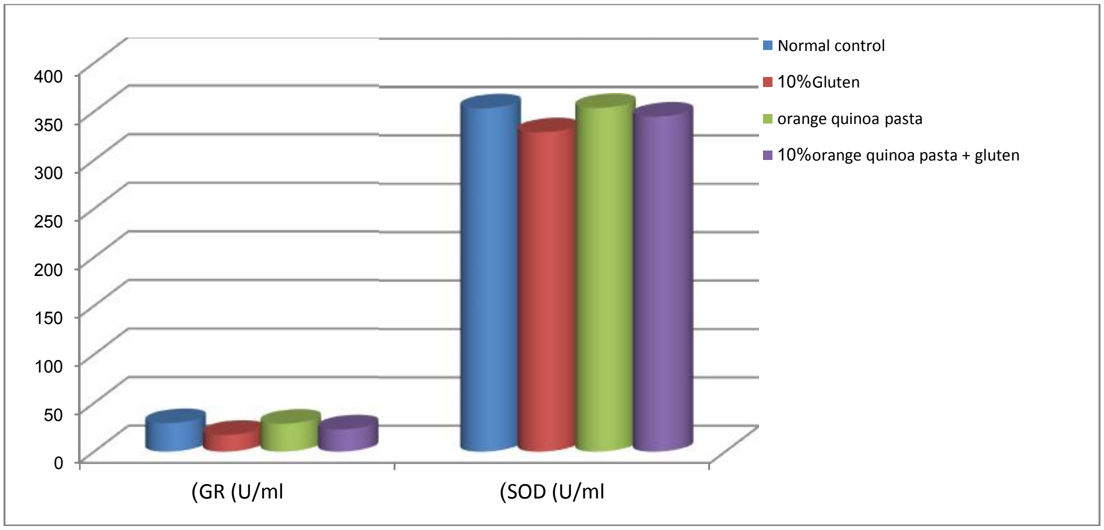


Fig. 4. Levels of glutathione reductase and superoxide dismutase of rats fed different experimental diets

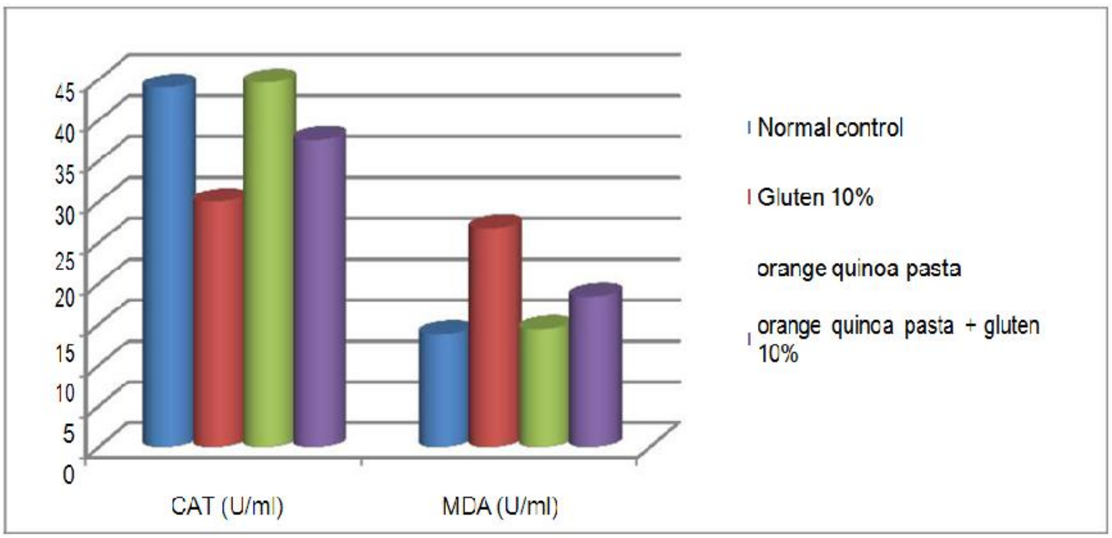


Fig. 5. Levels of catalase and lipid peroxidation of rats fed different experimental diets

3.2.5.2 Liver histopathology

Liver histopathology in rats fed the experimental diets is illustrated in Fig. 8. Representative photomicrographs of liver histopathology (H and E, 400×): (A) Liver of control rats showing normal histological structure of hepatic lobule. (B) Liver of rats fed 10% wheat gluten showed cytoplasmic vacuolization of hepatocytes, kupffer cells activation and focal hepatic necrosis associated with inflammatory cells infiltration. (C) Liver of rats fed orange quinoa pasta diet alone showed normal hepatocytes similar to control liver. (D) Liver of rats fed orange quinoa pasta diet with10% wheat gluten revealed apparent normal hepatocytes. These results are in agreement with Maggiore and Caprai [40] who concluded that celiac disease may present as a cryptogenic liver disorder being found in patients with a persistent and cryptogenetic elevation of serum aminotransferase activity and the liver biopsy of these patients showed different histopathological lesions ranging from reactive hepatitis to a moderately active chronic hepatitis.

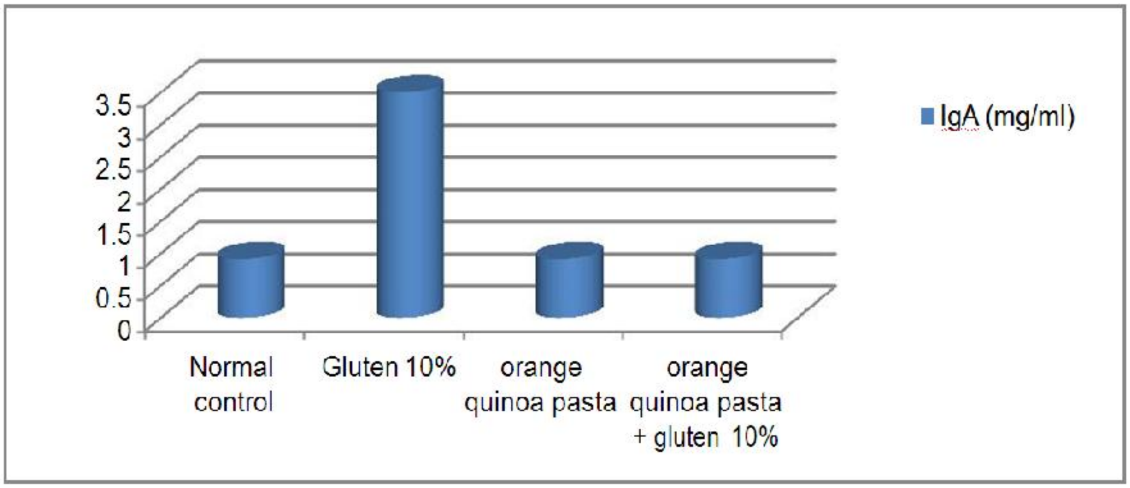


Fig. 6. Total serum IgA concentrations (mg/ml) of rats fed different experimental diets

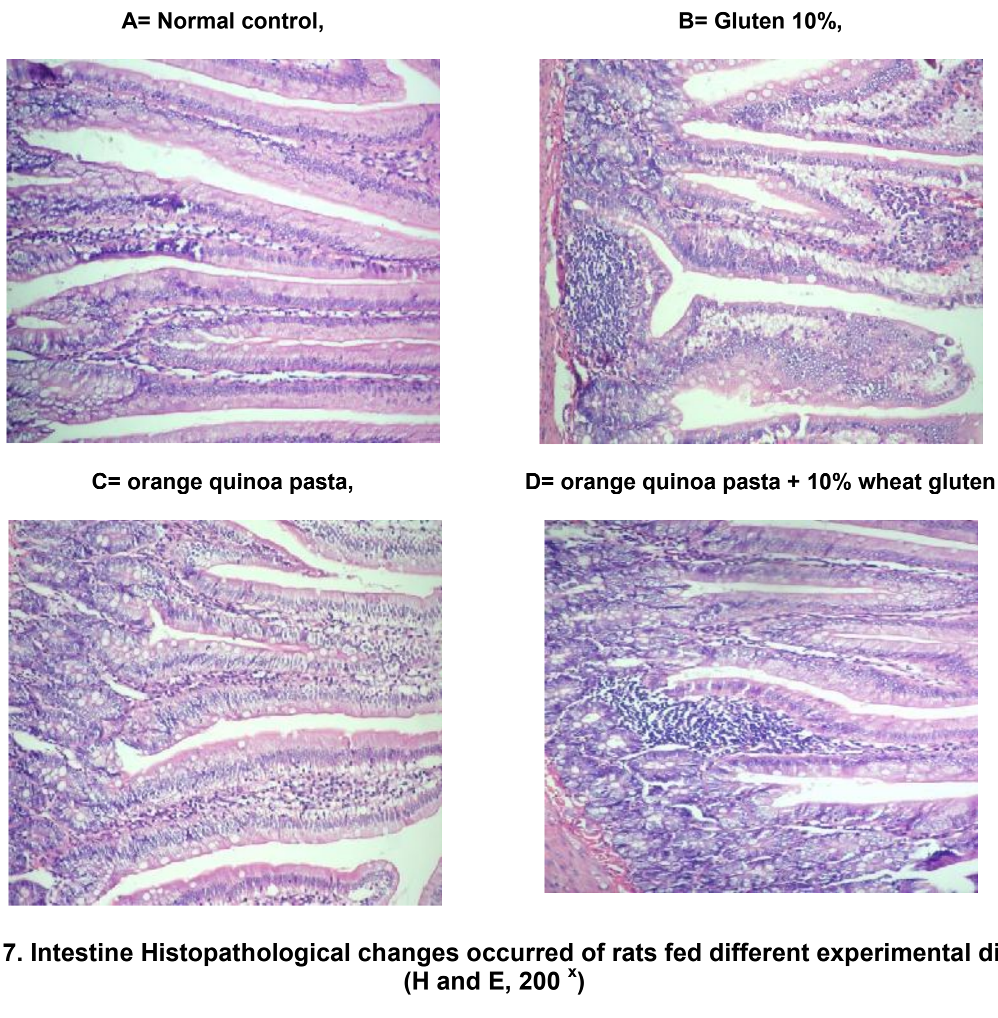
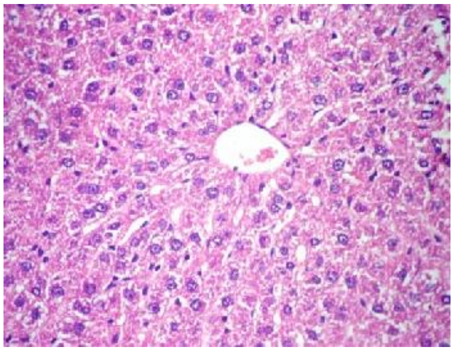
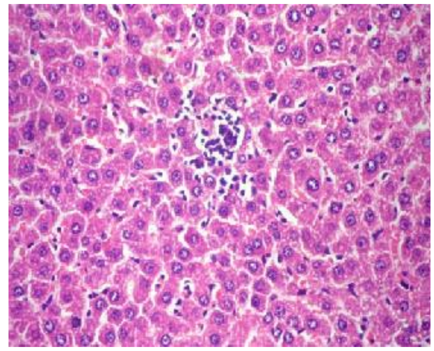


Fig. 7. Intestine Histopathological changes occurred of rats fed different experimental diets (H and E, 200 ^{x})

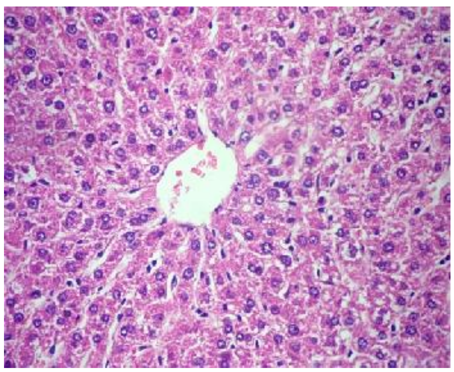
A= Normal control,



B= Gluten 10%,



C= orange quinoa pasta,



D=orange quinoa pasta + 10% wheat gluten

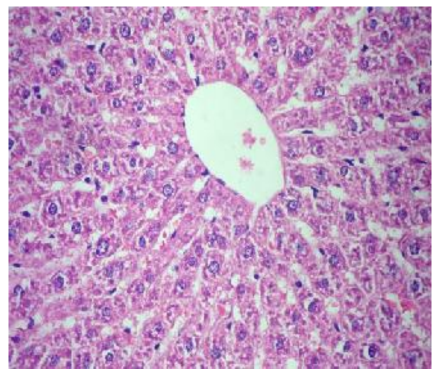


Fig. 8. Liver Histopathological changes occurred of rats fed different experimental diets (H and E, 400 ^{x})

4. CONCLUSION

The proximate analysis of the Quinoa flour indicates that the nutritional content of colored pasta increases as indicated by its content of protein. It is also observed that consumers prefer the orange pasta over the other colored pasta. Results in the present investigation suggested that Quinoa pasta has a potential role in controlling celiac disease, because it is gluten-free. Furthermore, feeding the Quinoa pasta diet with 10% wheat gluten to rats reversed the loss in the body weight, the relative intestine weights and the activities of antioxidant enzymes GR, SOD and CAT near to normal levels but the elevation of the relative liver weights, liver marker enzymes activities (ALT, AST and ALP), MDA level and IgA antibodies concentration were significantly restored towards near to normalization at the end of the experiment. Also the histopathological studies of the intestine and liver in rats fed the orange quinoa pasta diet with 10% wheat gluten showed minimizing changes in these organs compared with gluten group. Thus, the present study demonstrates that oxidative stress and immunogenicity are important factors in the diagnosis of celiac disease. Also, Quinoa pasta could be considered a safe food for celiac patients.

COMPETING INTERESTS

There is no competing interest with the company. The authors declare no conflict of interest with “sigma chemical co.” or any other.

The company name used for this research is commonly and predominantly selected in our area of research and country. There is absolutely no conflict of interest between the authors and company because we do not intend to use this company as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the company rather it was funded by personal efforts of the authors.

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