Egyptian Journal of Nutrition
Official journal of the Egyptian Nutrition Society
Print ISSN: 1687-1235
Online ISSN: 2090-2514
Vol. 40 (1): 158 –180 (2025)
DOI 10.21608/enj.2025.373059.1104
https://ejn.journals.ekb.eg/

Effectiveness of Extrudate Dehulled Dark Barley (Giza 123 var)in Alleviating Metabolic Disorders Associated with diabetes in laboratory Rats

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ABSTRACT

This study aims to manufacture of healthy, high-quality puffed snacks from barley flour and rice powder (EBS) as well as to assess its impact in mitigation of metabolic disorders associated with diabetes. The perfect obtained extruded barley snacks (EBS) were 70:30% barely (dehulled Giza 123 Var): coarse rice grain. The results declared that EBS composed of lower moisture, protein and fiber and higher carbohydrates % than that of control Extruded corn snacks (ECS). EBS contains fewer calories than ECS, aligning with its reduced fat content. Moreover EBS had higher antioxidant activity than ECS and showed fair overall acceptability among panelist. Herein, the biological experiment on male adult rats revealed that replacing of 25% of their basal diet by EBS and ECS had no negative effect on any of tested parameters except for body weight and body weight gain which significantly increased in rats feed on ECS comparing to control. In contrary, injection of rats with single dose of streptozotocin (STZ, diabetic-induce agent, 65mg/kg bw) caused enhancing of lipid peroxidation and depletion of glutathione and catalase, and resulted in dramatic lowering of both body weight and weight gain, elevation of all tested biochemical parameters along with marked distortion of pancreas, liver, kidney and testis histology after five weeks. Feeding of diabetic rats on EBS and ECS successfully alleviated that deleterious effect of STZ. The EBS shows more reliable improvement than ECS. Our results augment the hypothesis of EBS could be beneficial and healthier choice for people with diabetes type2.

Keywords: Barely, Corn, Diabetes, Extrusions, Rats, Panel test

Received: 6-4-2925 ***Accepted: 30-4-2025*** ***Published: 3-2025***

INTRODUCTION

In Egypt, barley (*Hordeum vulgare L.*, a winter crop) is sown from late November to middle of December and harvested in April or May **(MALER, 2020)**. It grows well under many climatic and drought-stress situations **(Kumar et al., 2014**, **Idehen et al., 2017 and Ahmed &Hassan, 2019),** although its cultivation is concentrated in rain fed zones within the northern coastal district sand North Sinai of approximately 250-300 thousand feddans. Additionally, it is cultivated in both traditional and recently reclaimed regions that face challenges such as water scarcity, soil salinity, and low soil fertility **(Grando & Macpherson, 2005**). An additional avenue is development of the early-maturing barley cultivars some time recently cotton and to support wheat generation in Egypt for bread making to overcome the hole between wheat utilization and wheat generation **(Amer et al., 2017).**

Barley was among of the generation of Cereal-Based products (**Jasmina & Marko, 2022)**. Barley recorded as a grain whose utilization leads to a noteworthy dietary advantage for human wellbeing as a great source of dietary fiber, macro & microelements and phenolic compounds. The dietary fiber represents from 11 to 20 g/100g of barley **(Sullivan et al., 2013).** The foremost critical and important polysaccharide present in barley is β-glucan, which could represent about 2 to 10% of grain weight. In special barley varieties, it can really reach 20% **(Sullivan et al., 2013 and Gujral et al, 2013).** Also **Elbasyoni et al. (2020)** reported that, the barley grains contain 20% dietary fiber and 3-7% β-glucan compared to other cereals, which support health by lowering blood cholesterol, decrease the glycemic index of foods and reducing the chance of creating chronic illnesses so it is known as a nourishment fixing since of its high dietary fiber substance **(Sullivan et al., 2013 and Aly et al., 2021).** Many health benefits as a result of consumption of barely are recorded including, but are not limited to, reducing metabolic disorders and chronic diseases associated with obesity such as high blood pressure and insulin resistance **(Sullivan et al., 2013). Health Canada (2020)** has authorized certified barley products and made health claims refer to barley fiber as anti-hypercholesterimic agent". In the last fifteen years, barley's ranking as one of the most important grains in the world has remained largely unchanged. During the crop year 2021–2022, 147.05 million metric tons of barley were produced worldwide **(Shahbandeh, 2022).**

Barley is regarded as a one of great alternatives for diet fortification in low- protein areas **(Sarac & Henry, 1998**). Whole barley has moreover appositive impact in balancing of intestine microbiota.

Recently, the manufacturing of healthy foods made from grain, especially for patients with metabolic disorders, has become of at most importance and has been the focus of many recent studies.

The goals of this study were (1) Manufacturing of healthy, high-quality puffed snacks from barley (hulled Giza 123 Var) and rice powder (EBS) to create new functional foods and (2) Assess the impact of extruded barley snacks in alleviating metabolic disorders associated with diabetes in rats

MATERIALS AND METHODS

Materials

Grains: Dark Barley (*Hordeum vulgare L.*), hulled Giza 123 variety (Var) (after dehulled dark barley with locally made barley peeling machine) was obtained from Dr. Mira foundation for reviving ancient Egyptian heritage and community development (No.37,2021). Rice and corn grain was purchased from FCRI -Agricultural Research Center.

Chemicals: Streptozotocin (STZ) (Sigma Chemical Co.) was used to induce type 2 diabetes. It

worthy to note that, in the current study all of chemicals and reagents were of HPLC grade.

Methods

Physicochemical analysis of barely grain:

The mean weight of 1000 undamaged barely grain was recorded. Their volume was determined by transferring grains to a measuring cylinder (250 ml) and adding 100 ml of distilled water. Grain volume (g/ml) was calculated by subtracting total volume from 100. The density (g/ml) was recorded from the following formula: grain weight/grain volume **(William et al., 1983)**. A micrometer with an accuracy of 0.01 mm was used to determine the length and width of 10 randomly selected uniforms barely grains in duplicate measurement according to method of **Suwansri & Meullenet (2004).** The weight of 1000 kernels in grams were determined in triplicate and then extrapolating this weight to 1000 test weigh (hectolitres) according to the method of **AACC (2010)**.

For proximate analysis moisture, ash, fat, and fiber of grains were determined according to **AOAC (2019)** while crude protein was determined according to **AOAC (2023)**. Total carbohydrates were considered by subtracting the summation of proximate analysis parameters from 100. Total calories (Kerolles, 1986) were calculated according to the following equation: Total calories = 4 ×Protein + 4 ×Carbohydrates + 9 ×fat. Minerals content (sodium, zinc, calcium, phosphorus, iron, Magnesium, potassium, and Manganese) of hulled barely (Giza123 Var) were determined according to **AOAC (2023)** method.

Determination of barley β-glucan:

The method described by **Temelli (1997)** was employed to extract and determine β-glucan, with minor modifications. Barley (Giza 123 Var) flour (500g) was mixed with distilled water (5L) and sodium hydroxide (1M) was used to adjust the pH to 8. The suspension was then placed in a water bath at 55°C and shaken at 450 rpm for 3h and centrifugation at 5500 rpm at 4°C for 10 minutes to separate solids from liquids. To precipitate the β-glucan, equivalent volume of absolute ethyl alcohol (98%) was add to the supernatant after discarding the residue. After 12 hours at 4°C, the solution was skimmed and washed with ethanol to remove the β-glucan.

Extrusion preparation:

Different blends of barely flour and coarse rice grain were tried out to get the best extrusion snacks, after several trials, barely flour and coarse rice grain at 70:30 ratios was mixed with 10-12% water then, 1% salt, 14- 15% sunflower oil (purchased from local market) were added in a mixer with paddle for 1min. The blend was placed in an extruder (a single extruder American type, American extrusion) at extrusion condition as follow: Temperature of extruder was 170-180°C, screw speed 900 rpm and feeding rate 1.8 and 2kg/min., until we get a puffed snacks (Extruded barely snacks, EBS) with acceptable characteristics.

Extruded corn snacks (ECS) were made from 100% corn flour with the same above method of EBS.

Physical properties of prepared extruded barely and corn snacks:

Physical properties of the 10 selected EBS and ECS were determined and their averages were recorded. Colorimeter (Chroma meter, CR-400, Konica, Minolta, Tokyo, Japan) was used to determine snacks colors according to the method outlined by **Filipovic et al. (2015)**. To measure the length and diameter (mm) of selected EBS and ECS, digital vernier calipers were used. Meanwhile, a Rotronic Hygro Lap EAI0.SCS Switzerland water activity meter device was employed to measure water activity (wa) in triplicate.

Expansion ratio (ER) was considered according to the following mathematical calculation reported by Singh et al. (2000**):** Expansion ratio = Diameter of extruded snacks /mm Diameter of the die /mm. The radial expansion was measured at different parts of EBS and ECS by vernier calipers. While the bulk density (g/ml) was calculated by loading measuring cylinder (1L) with each snack products just over the liter mark and then drum on cylinder (12 times) till the snacks were elevated to the cylinder mark. The product's weight was taken, where the bulk density = Weight/gm/ Volume/ml.

Sensory evaluation of extruded barely and corn snacks:

Sensory evaluation of the extruded snacks products was carried out at Food and Feed Research Institute (RCFF), by ten panelists according to **Košutić et al., (2016)** for determining the Variation of the tested attributes (taste, odor, texture, color and overall acceptability) of snacks. The panelists were provided snacks on a white plate at ambient temperature.

Chemical analysis:

Proximate analysis and total calories were analyzed for EBS and ECS using the same methods as previously described for grain chemical analysis.

Antioxidant activity:

Antioxidant activity of both EBS and ECS were assessed by phosphomolybdenum method according to **Prieto et al., 1999.**

Biological Experiment

Animals and animals' husbandry:

Thirty adult male rats of *Sprague-Dawley spp*. (weighs from 185 to 195 gm) were dedicated to perform current biological experiments. Animals were supplied and housed by laboratory animal's department, FTRI, ARC, Giza, Egypt. Meanwhile, the number of animals and experimental protocol were officially agreed by ARC-IACUC, ARC (approval no: ARC/RCFF/71/24). Accommodation and welfare of animals were in accordance with guidelines of Directive of the European Council 86/609/EEC (1986) regarding protection of experimental animals. Rats accommodated in classical cages under controlled environment (12h light/dark) at room temperature 22±2^{O}C and 40-70% relative humidity. Rats were acclimatized for one week during which they fed on basal diet (prepared according to guidelines of National Research Council, 1995) and had free access to drinking water. Fasting blood sugar was measured after deprivation of animal from access to feed only for 12h. The normal blood glucose level was assured by Accu-Chek Instant glucometer (Roche, Germany) via tail vein. The experiment was conducted for five weeks after confirmation of induction of diabetes. All rats were weighed at the start and end of the trial.

Induction of type 2 diabetes:

Thirty rats were equally split into 2 groups (i.e: non diabetic and diabetic). Non diabetic groups were injected intraperitoneally (i.p.) by single dose of citrate buffer of 4.5 pH (5 ml/kg bw). The diabetic groups received a single i.p. injection at dose of 65 mg of STZ /kg bw after freshly dissolved in 5ml citrate buffer of 4.5 pH **(Rehman et al., 2023).** After three days of STZ injection, the induction of type 2 diabetes was confirmed by analyzing fasting blood glucose with a glucometer (Accu-Chek Instant (Roche, Germany). The rats having fasting blood sugar concentration ≥ 250 mg/dl were considered diabetic.

Experimental protocol: All rats are treated for five weeks after confirmation of induction of diabetes as follow:

Non diabetic rats (15 rats) were randomized and divided into 3 groups (n=5): G1 (control): Normal control received normal basal diet.

G2 (EBS): The 25% of basal diet was replaced by grounded extruded barley snacks and thoroughly mixed with basal diet.

G3 (ECS): The 25% of basal diet was replaced by grounded extruded corn snacks and thoroughly mixed with basal diet.

Diabetic rats (15 rats) were randomized and divided into 3 groups (n=5): G4 (STZ): Diabetic control (STZ, 65mg /kg bw+ normal basal diet)

G5 (STZ+EBS): Treated diabetic (STZ, 65 mg/kg bw + fed on 25% grounded extruded barley snacks replacement)

G6 (STZ+ECS): Treated diabetic (STZ, 65 mg /kg bw+ fed on 25% grounded extruded corn snacks replacement).

After completion of five weeks rats were humanly sacrificed by cervical dislocation and dissected to obtain pancreases, livers, kidneys and testes. Before scarification of rats, they fasted 12h and subjected to blood samples collection from eye (retro-orbital venous plexus) under CO_2 anesthesia. Aliquot of blood were collected into non hepranized tube in order to obtain serum. Another aliquot of blood was collected into hepranized tube to obtain plasma. Serum and plasma were separated and kept at -20ºC for further biochemical analysis.

Biochemical analysis:

At the end of our trial Biochemical Blood Analyzer was used to determine the following parameters in serum: fasting blood glucose, liver function markers including alanine aminotransferase (ALT), aspartate aminotransferase (AST) &alkaline phosphatase (ALP), kidney function markers including creatinine & urea and lipid profile indicators including total cholesterol, high density lipoprotein cholesterol (HDL), low density lipoprotein cholesterol (LDL) & triglycerides (Alfa Wassermann Dignostic Technologies, LLC, ACE, Alera, USA).

Plasma GSH, Catalase and MDA:

Glutathione (GSH) and catalase were considered as marker of antioxidant elements of body, and they measured spectrophotometrically in plasma at visible wave length (405 and 520 nm, respectively) by method of **Beutler et al. (1963) and Aebi (1984)**, respectively. Meanwhile lipid peroxidation an oxidative stress marker was estimated through measuring malondialdehyde (MDA, a lipid peroxidation product) by spectrophotometer (534 nm) in plasma according to method of **Onkawa et al., (1979).**

Histopathological studies:

Organs (pancreas, liver, kidney and testes) were immediately washed by normal saline after scarification then fixed in 10% buffered formalin. The histopathological technique and staining process by haematoxylin coupled with eosin (H&E) were conducted as method described by **Banchroft et al. (1996).** Stained tissues were further examined using computed light microscope.

Statistical analysis:

The mean± standard error (SE) was used to express the acquired data. Co Stat program (version 6.400 1998-2008Co Hort software) was employed to perform statistical analysis by Duncan and least significant difference test (LSD, at 5% of probability).

RESULTS AND DISCUSSION

Results

Physicals properties, Chemical composition and minerals content of barley grain (Giza123)

Physical properties such as Length, width, Density, 1000 kernel weight, Hectoliter and color measurement of dark barley grains (Giza 123 Var) were determined, and the finding are recorded in Table (1**)**. The length, width and density of barley grain were 0.61 mm, 0.34 mm and 0.68 g/ml, respectively. Also, 1000 kernel weight and Hectoliter of barley were 40.50 g, and 65.30 kg/hl, respectively.

Table (1): physicals properties, chemical composition and minerals content of barley grain (Giza 123 Var) (mean±SE).

physicals properties							
Seed length (mm)	**Seed width (mm)**	**Density (g/ml)**	**1000-kernel wt. (g)**	**Hectoliter (kg/hl)**	**Color measurement***		
					L	**a**	**B**
0.61±0.007	**0.34±0.01**	**0.68±0.01**	**40.50±0.41**	**65.3±1.49**	**66.71±1.04**	**-2.90±0.05**	**22.90±0.35**
Chemical composition							
Moisture%	**Crude Protein %**	**Crude Fat %**	**Ash %**	**Crude Fiber %**	**Total Carb %**	**β-glucan %**	**Total Calories Kcal**
9.84±0.04	**11.25±0.5**	**2.86±0.09**	**2.93±0.03**	**4.14±0.08**	**69.98±0.66**	**5.32±0.09**	**350.66±5.82**
Minerals content (mg/ 100 g)							
Na	**Zn**	**Ca**	**P**	**Fe**	**Mg**	**K**	**Mn**
44.0±1.53	**2.40±0.06**	**50±1.00**	**211±3.06**	**5.10±0.17**	**26±1.53**	**370±4.59**	**2.10±0.12**

Color parameter*, L = lightness (0 = black, 100 = white), a (-a = greenness, +a = redness), and b (-b = blueness, +b = yellowness)

The color values of barely grains presented in Table (1) Where lightness is (L), redness is (a), and yellowness is (b). The results revealed that the barely grains were dark as (L) value show 66.71, tend to greenish yellow where the value of (a) is negative (-2.90) and value of (b) is 22.90. A chemical composition of barley grains was tabulated in Table (1). The percentage of crude protein, crud fat, Ash and crude fiber in Giza 123 Var were 11.25, 2.86, 2.93, and 4.14%, respectively. Also, Giza 130 Var contained 69.98% total carbohydrate and 5.32% β-glucan.

Minerals results illustrated in Table (1) showed that dark barely have a substantial quantity of minerals (mg/100g) such as K, P, Ca, Mg, Fe, Zn and lastly Mn (370, 211, 50±1.00, 26, 5.10, 2.40 and 2.10, respectively). These results qualify dark barely to be a good food rich in beneficial dietary fiber and minerals as well encourage the use of it to manufacture of healthy snacks.

Physical properties and quality characteristics of extruded barley snacks comparing to extruded corn snacks.

Physical properties and quality characteristics of EBS and ECS results summarized in Table (2) and show that control sample (snacks made from corn flour) was significantly higher in length, diameter and ER (8.44, 4.28 and 3.14, respectively) than that of EBS sample (snacks made from barley 70% and 30% rice flour) (6.82, 3.10, and 1.90, respectively). Meanwhile for Bulk density, SF, wa the EBS sample showed significant higher values than ECS sample which were 0.071, 31.12 and 0.52, respectively and for control sample were 0.058, 10.61 and 0.47,

respectively. For color measurement parameters, EBS were significantly higher in (L) and (b) values (72.16 and 28.99, respectively) comparing with control ECS (66.28 and 13.90, respectively) and vice versa for (a) value, which attributed to dark green color of barely. From these results we concluded that corn snacks were bigger, crispy and lighter in color than barley snacks.

Table (2): Physical properties and quality characteristics of extruded snacks (mean±SE).

samples	ength cm)	iameter cm)	ulk density g / cm3)	xpansion atio (ER)	ardness SF)	ater ctivity wa)	Color parameter*		
ontrol ample snacks	.44 0.10a	.28 0.08a	.058 0.00b	.14 0.08a	0.61 0.12b	.47 0.01b	6.82 1.15b	2.60 0.22a	3.90 0.32b
arely ample nacks	.82 0.14b	.10 0.08b	.071 0.00a	.90 0.05b	1.12 0.83a	.52 0.01a	2.16 0.90a	.37 0.13b	8.99 0.87a
SD0.05	.37	.24	.004	.19	.77	.31	.07	.35	.94

Significant changes are indicated by varying superscript letters within the same measure (Duncan, $P < 0.05$). In which, control snacks (ECS) made from corn flour, and barley snacks (EBS) made from barley 70% and 30%rice flour. Color parameter*, L = lightness (0 = black, 100 = white), a (-a = greenness, +a = redness), and b (-b = blueness, +b = yellowness)

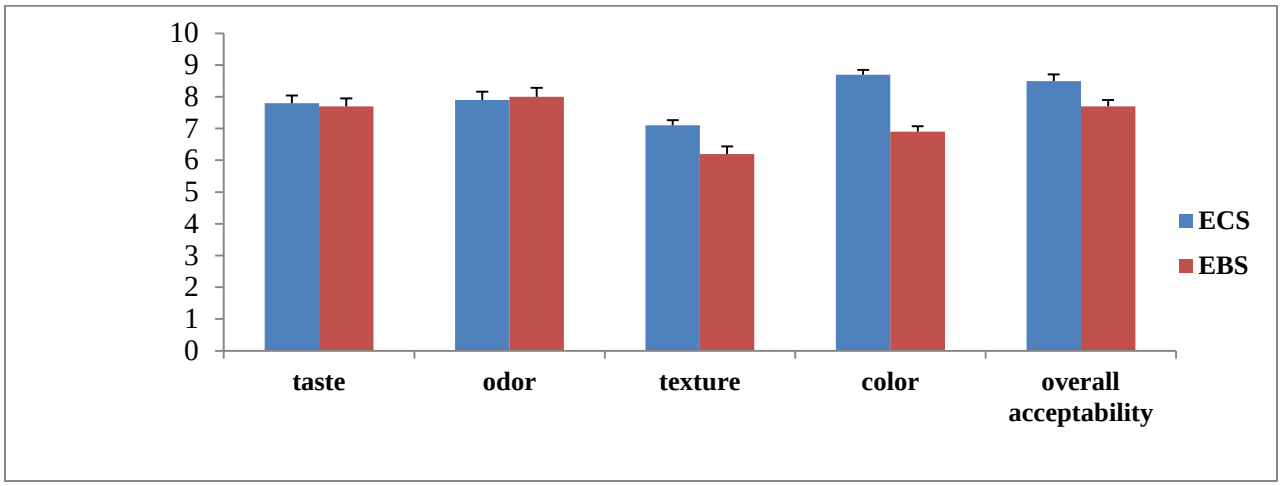
Sensory characteristics of prepared extruded snacks:

Sensory characteristics (Table 3, Fig.1) of EBS compared to control ECS were measured by recording the score of 10 consumers on a scale from 1 to 10, where 1 is extremely unacceptable and 9 is extremely acceptable. Analysis of variance indicated that, there is no significant difference in the scores of taste and odor between both extruded snacks. This indicates that the barley-based snacks are as palatable and aromatic as the corn-based ones. Meanwhile, EBS showed significant less favorable texture and color (score: 6.20 and 6.90, respectively) than ECS (score: 7.10 and 8.70, respectively). The
EBS recorded fair score in overall acceptability (7.70) which is expectedly significantly lower than the ECS (8.50).

Table (3): Sensory characteristics scale score of prepared extruded Snacks (mean±SE**).**

Snacks samples	Taste	Odor	Texture	Color	Overall acceptability
Control sample	**7.80±0.24^{a}**	**7.90±0.26^{a}**	**7.10±0.26^{a}**	**8.70±0.15^{a}**	**8.50±0.21^{a}**
Barely sample	**7.70±0.25^{a}**	**8.00±0.28^{a}**	**6.20±0.28^{b}**	**6.90±0.17^{b}**	**7.70±0.20^{b}**
$LSD_{0.05}$	**0.76**	**0.65**	**0.65**	**0.50**	**0.65**

Significant changes are indicated by varying superscript letters within the same measure (Duncan, $P < 0.05$).



In which, control snacks (ECS) made from corn, and barley snacks (EBS) made from barley 70% and 30% rice flour. ECS: Extruded corn snacks, EBS: Extruded barely snacks

Figure (1): sensory characteristics scale score of prepared extruded snacks

Chemical characteristics of extruded snacks

Table (4) in the document compares the chemical characteristics of EBS and ECS. The moisture content was slightly lower in EBS (10.75%) compared to the control ECS (11.82%). This difference could indicate improved shelf life for EBS, as reduced moisture content typically enhances stability. EBS had lower protein and fat content (9.52% and 3.90%, respectively) compared to control snacks (11.60% and 10.50%, respectively). Statistically there is no significant variation in fiber and Ash content between EBS and ECS. EBS contained significantly higher carbohydrate content (71.55%) than the control ECS (61.43%). Total calories were slightly lower in EBS (330.82 kcal) than control ECS (351.82 kcal), aligning with the reduced fat content. Moreover EBS sample showed higher antioxidant activity than control ECS sample (28 and 21%, respectively).

Table (4): Chemical characteristics of extruded snacks (mean±SE).

Snacks samples	Moisture %	Protein %	Fat %	Fiber %	Ash %	Carbohydrates %	Calories Kcal	Antioxidant Activity (%)
Control sample	11.82 ±0.16^{a}	11.60 ±0.49^{a}	10.50 ±0.76^{a}	2.80 ±0.21^{a}	1.80 ±0.12^{a}	61.43 ±2.12^{b}	351.82 ±3.63^{a}	21 ±0.58^{b}
Barely sample	10.75 ±0.20^{b}	9.52 ±0.36^{b}	3.90 ±0.38^{b}	2.68 ±0.16^{a}	1.60 ±0.10^{a}	71.55 ±2.38^{a}	330.82 ±2.94^{b}	28 ±0.76^{a}
$LSD_{0.05}$	0.71	1.69	2.37	0.74	0.42	8.83	12.95	2.66

Significant changes are indicated by varying superscript letters within the same measure (Duncan, *P <0.05*).In which, control snacks (ECS) made from corn, and barley snacks (EBS) made from barley 70% and 30%rice flour.

Biological Experiment:

Changes in body weight: After 5th week of experimental trial the body weight (Table 5) of non-diabetic rats (G1, G2 and G3) were significantly increased, the rats of G3 which fed on ECS showed the highest increase in body weight compared to control (*P<0.05*) and body weight gain (55.69%) comparing to control (48.02%) which indicated that corn hyper consumption could induce over weight gain, whereas the body weight of diabetic untreated group (G4) was lowered significantly comparing to control (*P<0.05*) and their body weight gain was dropped to -18.49%,

that dramatic decrease was reversed significantly comparing with normal control and diabetic control (G1 and G4, respectively, *P<0.05)* in diabetic rats received EBS and ECS (G5 and G6, respectively) as their blood glucose levels were decreased significantly and their body weight gain recorded 32.19 and 39.71% respectively.

Table (5) Changes in body weight of experimental rats (mean±SE) and body weight gain**.**

groups	Initial body weight (g)	Final body weight (g)	Body weight gain (%)
G1(control)	192.00±4.35^{a}	369.40±6.68^{b}	48.02
G2 (EBS)	191.60±2.71^{a}	350.80±5.35^{b}	45.38
G3 (ECS)	188.40±2.58^{a}	425.20±10.15^{a}	55.69
G4 (STZ)	194.80±3.57^{a}	164.40±8.09^{e}	-18.49
G5 (STZ+EBS)	193.80±3.88^{a}	285.80±8.18^{d}	32.19
G6 (STZ+ECS)	189.80±3.65^{a}	314.80±5.05^{c}	39.71
$LSD_{0.05}$	10.253	21.786	

Significant changes are indicated by varying superscript letters within the same measure (Duncan, *P <0.05*). G1: control; G2: EBS (extruded Barely snacks); G3: ECS (extruded corn snacks); G4: STZ (streptozotocin); G5: STZ+EBS (streptozotocin+ extruded Barely snacks) and G6: STZ+ECS (streptozotocin+ extruded corn snacks).

Fasting blood glucose Levels: The results recorded in Table (6) revealed that, feeding of rats on both EBS and ECS replacement (G2 and G3, respectively) didn't alter blood glucose level comparing to control (*P<0.05*). Meanwhile the STZ injection resulted in elevation of serum glucose levels of diabetic rats (G4, G5 and G6) comparing with control rats (G1) (*P<0.05*) after 3 days. After the 5 weeks of feeding of diabetic rats on both EBS and ECS replacement (G5 and G6, respectively) the blood glucose levels was depressed significantly comparing with diabetic control (G4) (*P<0.05*). That decrease was more pronounced in G5 rats which support the hypothesis that EBS could be beneficial and healthy for persons suffering from diabetes type 2.

Table (6): Fasting glucose concentrations and lipid profile (means ± SE).

Parameter	Blood glucose (mg/dL)		Lipid Profile			
groups	3 days	5th week	Total Cholesterol (mg/dL)	HDL (mg/dL)	LDL (mg/dL)	Triglycerides (mg/dL)
G1(control)	97.00±2.61^{b}	98.80±2.52^{d}	83.20±3.26^{de}	47.34±0.82^{a}	36.48±0.69^{c}	85.80±1.28^{cd}
G2 (EBS)	94.80±3.12^{b}	91.60±3.37^{d}	77.60±2.87^{e}	48.12±0.75^{a}	35.64±0.70^{c}	82.60±1.21^{d}
G3 (ECS)	98.20±3.53^{b}	100.80±2.73^{d}	86.40±2.18^{cd}	46.70±0.70^{a}	37.64±0.70^{c}	87.40±1.08^{c}
G4 (STZ)	348.80±9.43^{a}	454.60±7.79^{a}	152.80±2.99^{a}	24.40±0.96^{c}	112.44±1.84^{a}	127.20±1.77^{a}
G5 (STZ+EBS)	360.40±8.37^{a}	143.20±6.21^{c}	92.00±2.10^{c}	46.60±0.70^{a}	37.74±0.72^{c}	87.20±1.20^{c}
G6 (STZ+ECS)	355.00±9.39^{a}	276.00±7.78^{b}	117.80±2.50^{b}	40.14±0.96^{b}	41.78±0.76^{b}	95.80±1.28^{b}
$LSD_{0.05}$	19.799	16.204	7.835	2.403	2.899	3.857

Significant changes are indicated by varying superscript letters within the same measure (Duncan, *P <0.05*). G1: control; G2: EBS (extruded barely snacks); G3: ECS (extruded corn snacks); G4: STZ (streptozotocin); G5: STZ+EBS (streptozotocin+ extruded barely snacks) and G6: STZ+ECS (streptozotocin+ extruded corn snacks).

Lipid profile: Analysis of variance in Table (2) revealed no changes in cholesterol, HDL, LDL and triglycerides levels in serum of G2 and G3 rats which feed on EBS and ECS, respectively (comparing with control, *P*<0.05). It is worthy of attention that feeding of rats on EBS and ECS replacement significantly decline levels of cholesterol and triglycerides comparing with rats feed on ECS (*P<0.05).* The recorded elevation of glucose level in serum of diabetic control rats (G4) was accompanied with significant increase of cholesterol, LDL and triglycerides and significant decrease

in HDL concentrations (*P<0.05)* comparing with untreated control (G1). Fortunately feeding of diabetic rats (G5 and G6) on EBS and ECS significantly modulate the adverse effect of diabetes on lipid profile (comparing with untreated control and diabetic control (*P<0.05)*). The beneficial effect of EBS replacement was more pronounced than ECS as it able to restore HDL, LDL and triglycerides levels to normal (comparing with untreated control (*P<0.05)*).

Liver and kidney functions: Results tabulated in Table (7) demonstrated that feeding of normal rats on EBS and ECS (G2 and G3, respectively) didn't alter the liver function or kidney function parameters comparing with control (*P<0.05)*. Meanwhile, diabetes induced by single ip injection of STZ resulted insignificant elevation of blood AST, ALT, ALP, creatinine and urea concentration in G4 rats comparing with control (*P<0.05)* which reflect liver and kidney damage. That noticed increase was significantly depressed in diabetic rats fed on EBS and ECS (G4 and G5, respectively) comparing with diabetic control (G4) (*P<0.05).* The EBS showed more distinguished effect on ALP and urea levels than ECS however both of them were able to restore creatinine levels to normal (comparing with untreated control (G1) (*P<0.05)*).

Table (7): Liver and Kidney functions parameters (means±SE).

Parameters	Liver Functions			Kidney Functions	
groups	AST (U/L)	ALT (U/L)	ALP (U/L)	Creatinine (mg/dL)	Urea (mg/dL)
G1(control)	52.40±2.14^{c}	30.60±2.01^{c}	90.40±2.06^{d}	0.54±0.11^{b}	28.20±1.53^{d}
G2 (EBS)	50.20±1.98^{c}	28.80±2.06^{c}	91.20±2.20^{d}	0.48±0.07^{b}	26.80±1.74^{d}
G3 (ECS)	49.80±2.44^{c}	31.60±1.96^{c}	93.20±2.24^{d}	0.56±0.09^{b}	28.00±1.79^{d}
G4 (STZ)	116.40±2.62^{a}	57.40±1.75^{a}	187.80±3.94^{a}	1.24±0.09^{a}	62.00±2.19^{a}
G5 (STZ+EBS)	73.40±2.14^{b}	40.20±1.46^{b}	132.80±3.07^{c}	0.60±0.07^{b}	38.80±1.39^{c}
G6 (STZ+ECS)	78.80±1.88^{b}	43.00±2.07^{b}	154.60±3.50^{b}	0.58±0.12^{b}	46.40±1.81^{b}
$LSD_{0.05}$	6.461	5.546	8.541	0.271	5.136

Significant changes are indicated by varying superscript letters within the same measure (Duncan, *P <0.05*). G1: control; G2: EBS (extruded barely snacks); G3: ECS (extruded corn snacks); G4: STZ (streptozotocin); G5: STZ+EBS (streptozotocin+ extruded barely snacks) and G6: STZ+ECS (streptozotocin+ extruded corn snacks).

Antioxidant profile: Statistical analysis presented in Table (8) revealed that feeding of rats on both EBS and ECS (G2 and G3, respectively) didn't negatively alter antioxidant status comparing to control (*P<0.05*). Meanwhile**,** the metabolic disorder induced by STZ was accompanied with depletion of natural antioxidant (GSH and catalase) and enhancement of lipid peroxidation (MDA) in blood of diabetic control rat (G4) when compared with untreated control (*P<0.05)*).While, feeding of diabetic rats on EBS and ECS (G5 and G6, respectively) for 5 weeks resulted in enhancement of natural antioxidant (GSH and catalase) and depletion of lipid peroxidation (MDA) (comparing with diabetic control (G4) (*P<0.05)*). Furthermore, EBS produces its antidiabetic effect through restoration of antioxidant status (GSH and catalase) of body to normal (comparing with control (G1) (*P<0.05)*).

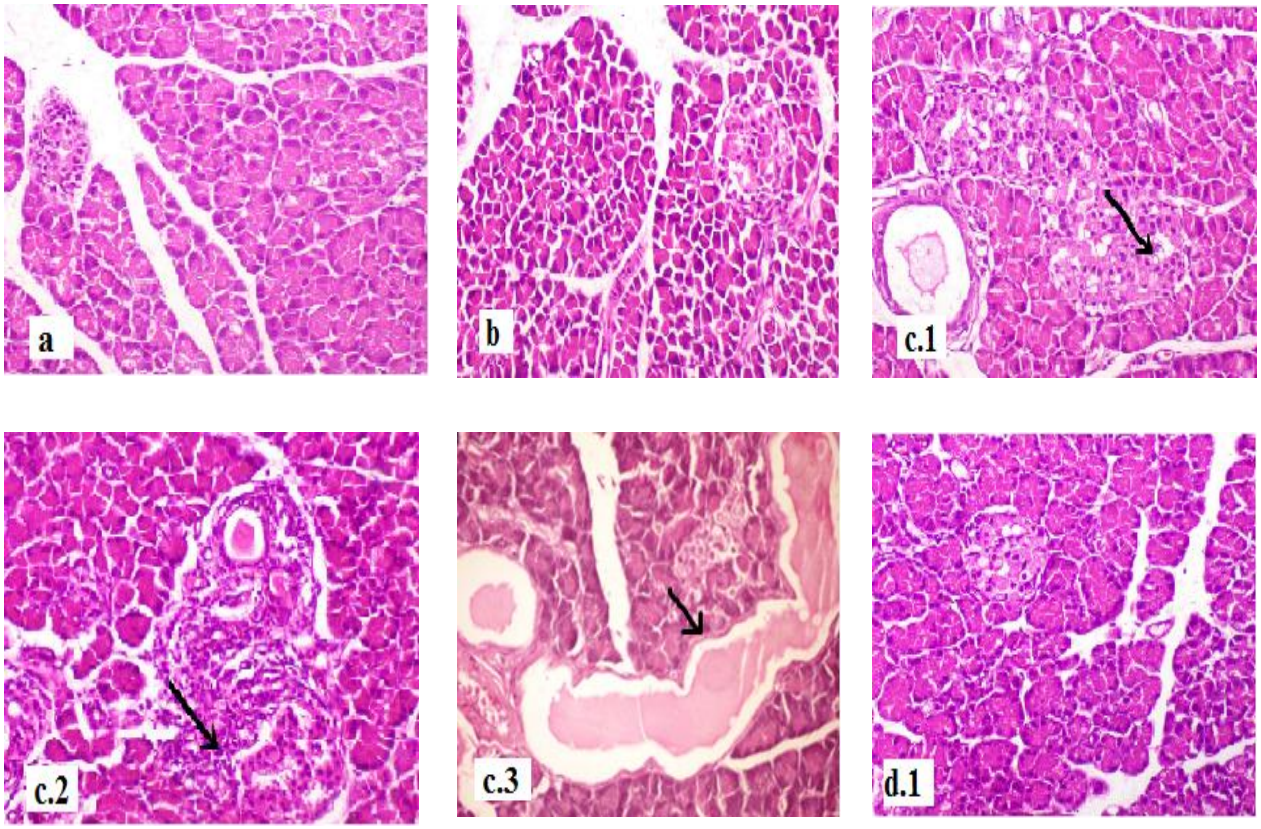
Table (8): GSH, catalase and MDA (means±SE).

groups	GSH (m.mol/ml)	Catalase (U/L)	MDA (m.mol/ml)
G1(control)	2.80±0.14^{ab}	87.80±1.66^{a}	58.20±3.02^{d}
G2 (EBS)	3.04±0.15^{a}	90.20±2.03^{a}	55.60±2.54^{d}
G3 (ECS)	2.76±0.14^{ab}	86.20±1.46^{a}	62.20±2.22^{cd}
G4 (STZ)	1.21±0.11^{d}	58.40±2.34^{c}	120.60±3.46^{a}
G5 (STZ+EBS)	2.62±0.12^{b}	84.40±1.81^{a}	67.80±2.15^{c}
G6 (STZ+ECS)	2.20±0.11^{c}	72.80±1.77^{b}	90.20±2.62^{b}
$LSD_{0.05}$	0.382	5.445	7.902

Significant changes are indicated by varying superscript letters within the same measure (Duncan, *P <0.05*). G1: control; G2: EBS (extruded barely snacks); G3: ECS (extruded corn snacks); G4: STZ (streptozotocin); G5: STZ+EBS (streptozotocin+ extruded barely snacks) and G6: STZ+ECS (streptozotocin+ extruded corn snacks).

Histopathological results:

Pancreas: Microscopically, pancreas of rats from G1 (control), G2 (fed on EBS) and G3 (fed on ECS) revealed normal histological structure (Figs. 2.a &2. b). In contrariwise, pancreas of diabetic rats from G4 showed histopathological damage (Fig. 2.c) characterized by vacuolization of cells of islets of Langerhan's, necrosis of cells of islets of Langerhan's associated with inflammatory cells infiltration, atrophy of β cells of islets of langerhan's and cystic dilatation of pancreatic duct. Meanwhile, some sections of pancreas of diabetic rats from G5 which fed on EBS showed histologically normal pancreatic tissue (Fig. 2. d.1), whereas other sections revealed vacuolization of sporadic cells of islets of Langerhan's (Fig.2.d.2). Furthermore, pancreas of diabetic rats from group 6 which fed on ECS exhibited vacuolization of some cells of islets of Langerhan's (Fig.2.e.1) and interacinar inflammatory cells infiltration (Fig. 2.e.2).



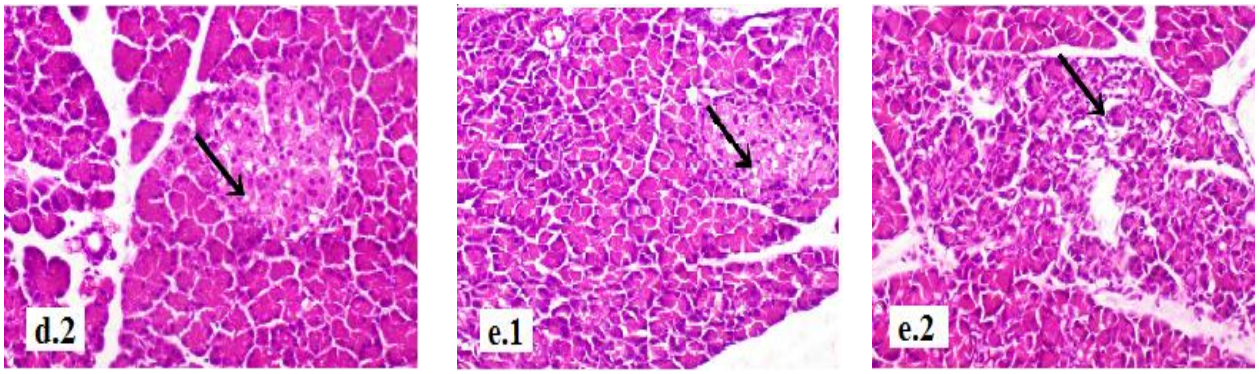
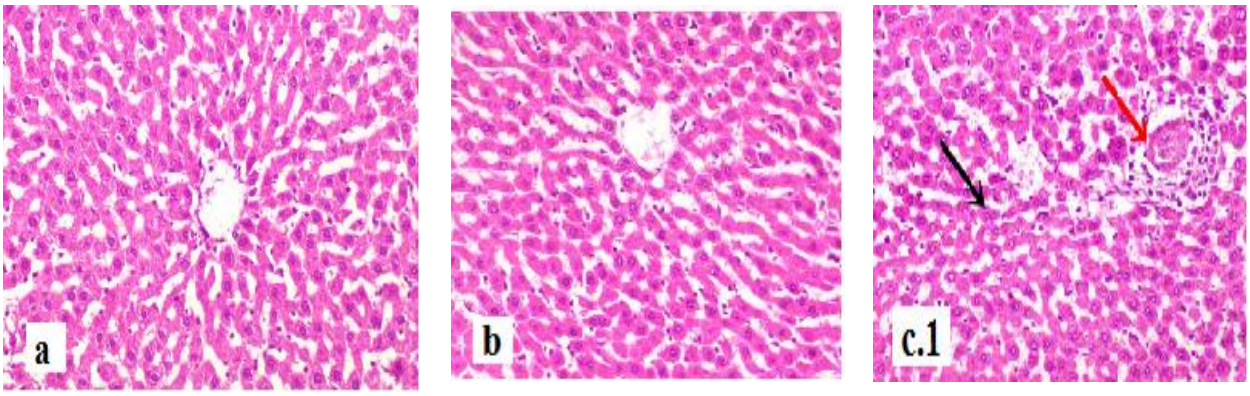


Figure 2: Effects of treatments on pancreas histology of normal and diabetic rats

a: Graph of pancreas of rat from G 2 showing normal pancreatic acini and normal islets of Langerhan's (H & E X 200). b. Graph of pancreas of rat from G 3 showing normal pancreatic acini and normal islets of Langerhan's (H & E X 200). c: diabetic rats (G4) including c.1: Graph of pancreas showing vacuolization of cells of islets of Langerhan's (black arrow) (H & E X 200), c.2: Graph of pancreas showing necrosis of cells of islets of Langerhan's invaded with inflammatory cells infiltration (black arrow) (H & E X 200) and c.3: Graph of pancreas of rat showing atrophy of β cells of islets of langerhan's and cystic dilatation of pancreatic duct (black arrow) (H and E X 400). d. diabetic rats (G5) including d.1: Graph of pancreas showing histologically normal pancreatic tissue (H & E X 200) and d.2: Graph of pancreas showing vacuolization of solitary scattered cells of islets of Langerhan's (black arrow) (H & E X 200). e: diabetic rats (G6) including e.1: Graph of pancreas showing vacuolization of sporadic cells of islets of Langerhan's (black arrow) (H & E X 200) and e.2: Graph of pancreas showing interacinar inflammatory cells infiltration (black arrow) (H & E X 200).

Liver: Microscopic analysis of liver sections from rats in G1 (untreated, control) revealed the sound histological appearance of the hepatic lobules. Moreover, livers of rats of G2 (fed on EBS) and G3 (fed on ECS) revealed normal hepatic lobules (Figs.3.a&3.b respectively). In adverse, liver of diabetic rats of G4 showed histopathological lesions described as Kupffer cells activation, focal hepatocellular necrosis associated with inflammatory cells infiltration (Fig. 3.c.1), vacuolar degeneration of hepatocytes, portal infiltration with inflammatory cells (Fig. 3.c.2), congestion of portal blood vessel and portal infiltration with inflammatory cells (Fig. 3.c.3). Meanwhile, liver of diabetic rats from G5 which fed on EBS exhibited apparent normal hepatic tissue (Fig. 3.d.1) except of small vacuoles in the cytoplasm of some hepatocytes (Fig. 3.d.2), while examined sections from diabetic rats of G6 which fed on ECS revealed vacuolar degeneration of some hepatocytes and few leucocytes in the hepatic sinusoids (Fig. 3.e).



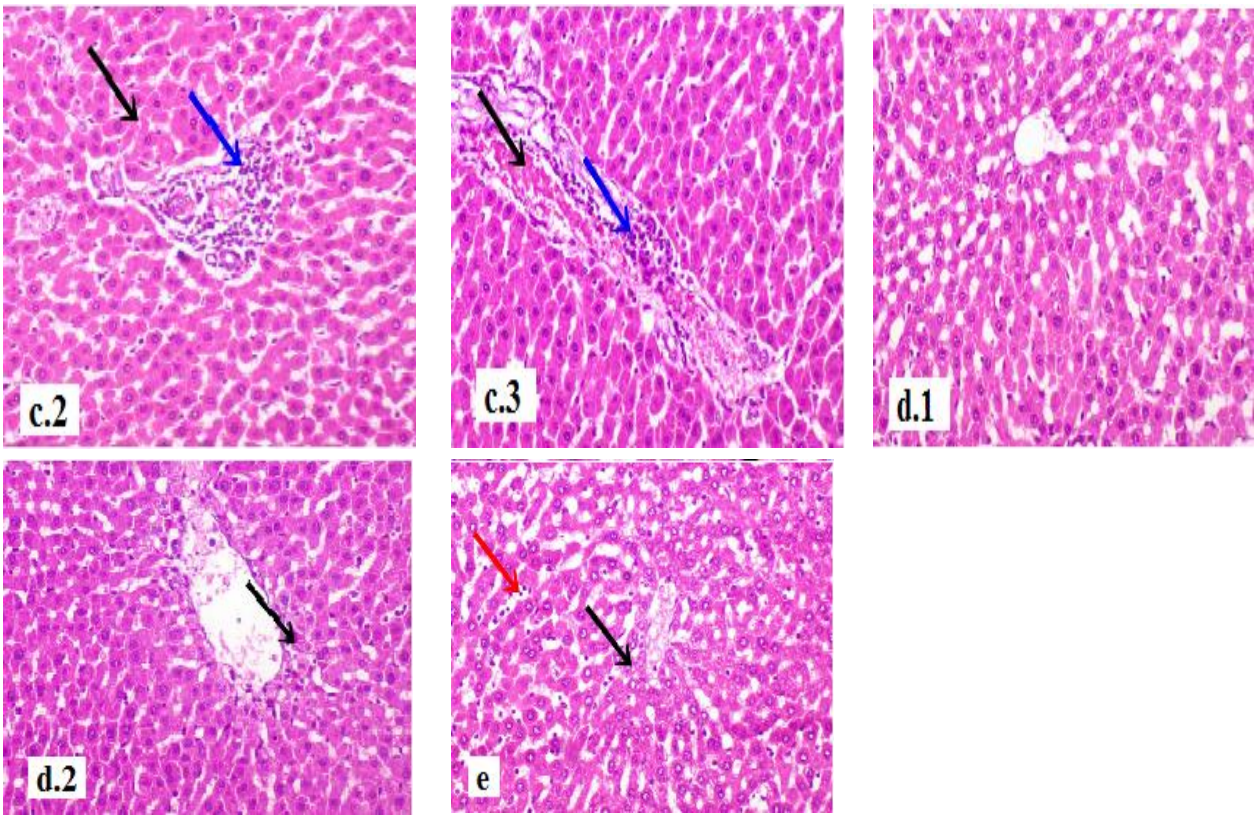


Figure 3: Effects of treatments on liver histology of normal and diabetic rats
a: Graph of liver of rat from G 2 showing the sound histological appearance of hepatic lobule(H & E X 200). b. Graph of liver of rat from G3 showing the normal histological architecture of hepatic lobule (H & E X 200). c: diabetic rats (G4) including c.1: Graph of liver showing Kupffer cells activation (black arrow) and focal hepatocellular necrosis invaded with inflammatory cells infiltration (red arrow) (H & E X 200),c.2: Graph of liver showing vacuolar degeneration of hepatocytes (black arrow) and portal infiltration with inflammatory cells (blue arrow) (H & E X 200), and c.3: Graph of liver showing congestion of portal blood vessel (black arrow) and portal infiltration with inflammatory cells (blue arrow) (H & E X 200). d. diabetic rats (G5) including d.1: Graph of liver showing histologically normal hepatic tissue (H & E X 200) and d.2: Graph of liver showing small vacuoles in the cytoplasm of sporadic hepatocytes (black arrow) (H & E X 200). e: Graph of liver of diabetic rats (G6) showing vacuolar degeneration of some hepatocytes (black arrow) and few leucocytes in the hepatic sinusoids (red arrow) (H & E X 200).

Kidney: Microscopic examination of kidneys of rats from G1 (control), G2 (fed on EBS) and G3 (fed on ECS) revealed the ordinary structure of renal tissue (Figs. 4.a &4. b). On contrary, kidneys of diabetic rats from G4 showed histopathological lesions (Fig. 4.c) summarized as necrobiosis of epithelial lining renal tubules (Fig.4.c.1), proteinaceous material in the lumen of renal tubules, congestion of renal blood vessel (Fig. 4.c.2) and intertubular inflammatory cells infiltration (Fig. 4.c.3). Otherwise, kidneys of diabetic rats from G5 which fed on EBS exhibited normal renal tissue except of vacuolar degeneration of epithelial lining some renal tubules (Figs. 4. d). Likewise, kidneys of diabetic rats from G6 (fed on ECS) described some vacuolar degeneration in renal tubules (Figs. 4.e.1&4. e.2) and congestion of renal blood vessel (Fig. 4.e.2).

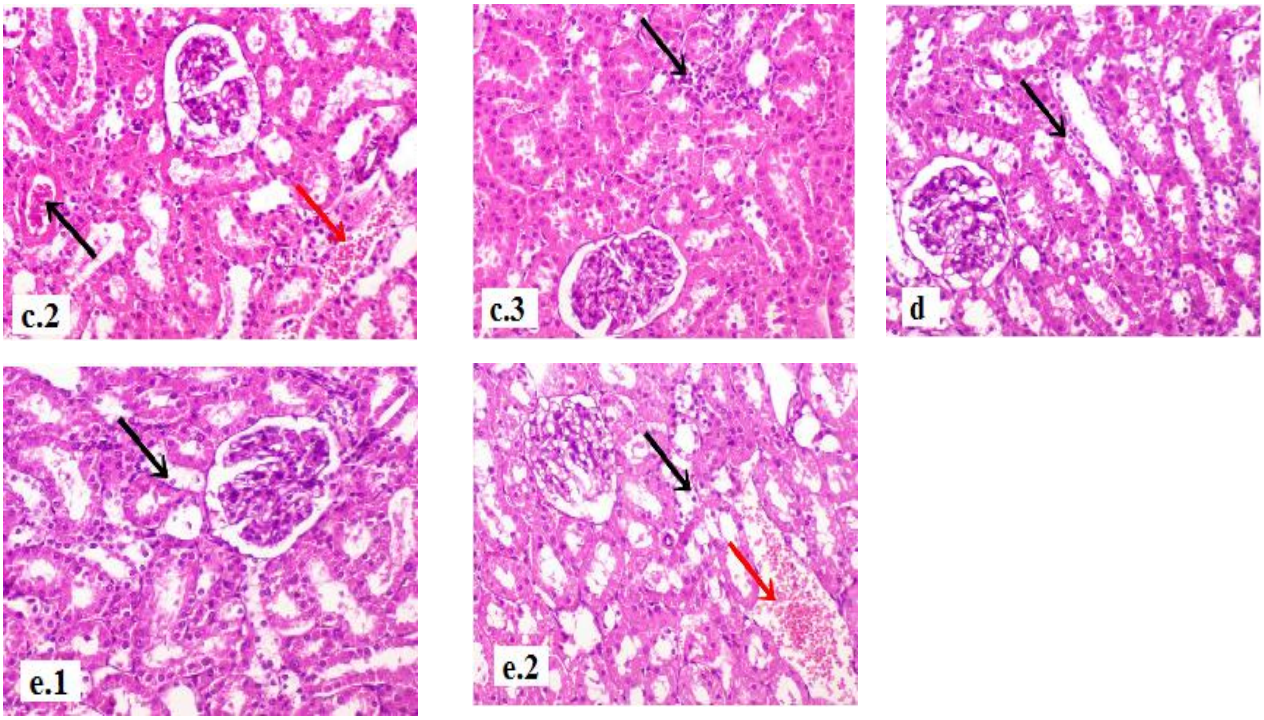
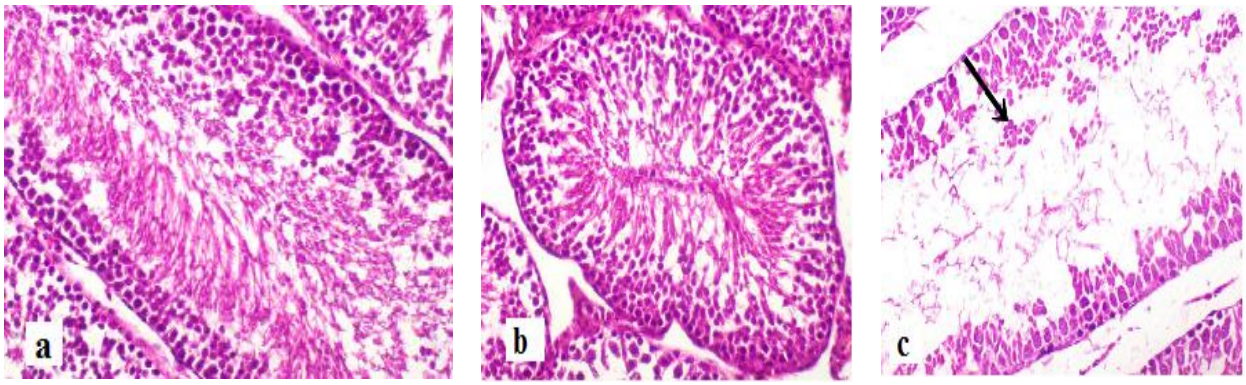


Figure 4: Effects of treatments on kidneys histology of normal and diabetic rats
a: Graph of kidney of rat from G 2 showing the typical histological architecture of renal tissue (H & E X 200).b.Graph of kidney of rat from G3 showing the typical histological architecture of renal tissue (H & E X 200).c:diabetic rats (G4) including c.1: Graph of kidney showing necrobiosis of epithelial lining renal tubules (blackarrow)(H & E X 200), c.2: Graph of kidney showing proteinaceous material in the lumen of renal tubules (blackarrow) and congestion of renal blood vessel (red arrow) (H & E X 200) and c.3: Graph of kidney showing intertubular inflammatory cells infiltration (black arrow) (H & E X 200). d. Graph of kidney of diabetic rat from G5 showing vacuolar degeneration of epithelial lining some renal tubules (black arrow) (H & E X 200). e: diabetic rats (G6) including e.1: Graph of kidney showing vacuolar degeneration of epithelial lining some renal tubules (black arrow) (H & E X 200) and e.2: Graph of kidney showing vacuolar degeneration of epithelial lining some renal tubules (black arrow) and congestion of renal blood vessel (red arrow)(H & E X 200).

Testes: Microscopically, testes of rats from G1 (control), G2 (fed on EBS) and G3 (fed on ECS) showed complete spermatogenesis, normal histological structure of seminiferous tubule and normal spermatogoneal cells (Figs. 5.a & 5.b). In adverse, testes of diabetic rats from G4 exhibited degeneration and necrosis of spermatogoneal cells lining seminiferous tubules (Fig. 5.c). Examined sections from diabetic rats of G5 and G6 which fed on EBS and ECS, respectively revealed apparent normal seminiferous tubules with normal germ cells (Figs 5.d&5. e, respectively).



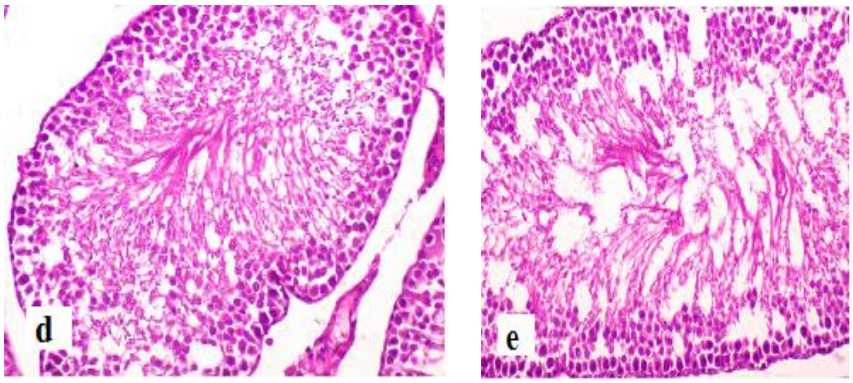


Figure 5: Effects of treatments on testes histology of normal and diabetic rats

a: Graph of testis of rat from G 2 showing the typical histological structure of seminiferous tubules with normal spermatogoneal cells and complete spermatogenesis (H & E X 200).b:Graph of testis of rat from G3 showing the normal histological structure of seminiferous tubules with normal spermatogoneal cells and complete spermatogenesis (H & E X 200).c: Graph of testis of diabetic rats (G4)showing degeneration and necrosis of spermatogoneal cells lining seminiferous tubules (black arrow)(H & E X 200).d:Graph of testis of diabetic rat from G5 showing apparent normal seminiferous tubules with normal germ cells (H & E X 200).e:Graph of testis of diabetic rat from G6showing apparent normal seminiferous tubules with normal germ cells (H & E X 200).

DISCUSSION:

Manufacturing high- quality healthy food products specially snacks is a big challenge, especially in light of the presence of tasty unhealthy snacks that everyone loves, which cause many health problem, most notably obesity. To address this, the current research attempts to manufacture a healthy puffed snacks with good taste and quality from dehulled dark barely grains.

The recorded physical properties of dark barely grains (Giza 123 Var) is more or less similar to those recorded by **Farooqui et al. (2018)** which could be attributed to the fact of the composition and characteristic of cereal grains affected by many agents such as environmental factors, land characteristics, used fertilizer and varieties (**Rodehutscord et al., 2016**). The current study revealed that dark barely grain possess a high nutritional quality with low fat content and substantial quantity of β-glucan. Our results are matched to results of **Elbasyoni et al. (2020)** and **Jasmina & Marko (2022)**. In addition, barley is rich in minerals, especially k, P, Ca, Na, Mg which also previously reported by **Fahmy & Abd al-maksod (2020)**. The next challenge is to made high quality snacks from barely. After several trials we concluded that the best combination for producing well-made EBS is: 70:30% barely flour (dehulled Giza 123 Var): coarse rice flour.

Comparison of physical properties and quality characteristics of our barely product with control corn snacks revealed that corn snacks were crispy, larger and lighter in color than barely product which could be attributed to dark greenish color and physical characteristics of barely grain. That quality characteristic of corn snacks make it more appealing to panelists in term of texture, color and overall acceptability. Barely snacks less visually appealing to panelists accustomed to lighter-colored snacks. However taste and odor of EBS were favorable for panelists. Regarding, nutritional content of both extruded snacks, EBS showed lower protein and higher carbohydrates % than the ECS which likely due to mixing barely with rice flour. They showed nearly similar content of Ash and fiber. Despite this, barley is known for its β-glucan content, which provides additional health benefits, such as reducing cholesterol and improving glycemic control as reported by **Sullivan et al. (2013)** and **Health Canada (2020)**. Our finding suggested that barley-based snacks could be an acceptable alternative to traditional corn-based snacks, especially given their nutritional advantages such as lower fat content, calories and higher antioxidant activity. The current results are concord with other studies (Elbasyoni et al., 2020, Aly et al.,

2021, and Jasmina & Marko, 2022).

A biological experiment on laboratory rats was conducted to assess the impact of extruded barely in mitigation of metabolic disorders associated with diabetes.

The recorded lowering in both weight and weight gain % in our experimental model as a result of hyperglycemia induced by STZ injection was compatible with finding of Eluehike & Onoagbe (2018) and Azad & Sulaima (2020) after 21 and 35 days of injection of STZ. The most pronounced characterization of diabetes illness is severing loss of body weight which contributed to imbalance between catabolism and anabolism, subsequently resulted in depilation of fat reservoir in adipose tissues and loss of body's muscle mass as a consequence of destruction of amino acids and structural protein. The noticed maintenance of body weight and weight gain in rats fed on EBS compared with those fed on ECS was attributed to nutritional properties of barley as it contains high dietary fiber which increases the feeling of satiety and thus reduces food consumption (Darwiche et al., 2003) along with its high contained from beneficial polysaccharide namely β-glucan and other bioactive compounds (Tosh, 2007) which helps in restoration of sound metabolism of the body and therefore it could be considered an ideal food for diabetics. It's worthy to note that, EBS significantly reversed the decrease in body weight induced by STZ thus it is the healthier choice as ECS induce significant unhealthy increase in body weight comparing with control. STZ is a famous agent used to induce diabetes in laboratory animals to test the beneficial effect of antidiabetic drugs (Solati & Soleimani, 2010). STZ induce elevation of blood glucose levels through partial damaging of pancreatic β-cells which in turn affecting insulin production. This is observed in current study as fasting blood glucose level was massively elevated 5 weeks after STZ injection (65mg /kg bw) as well as pathological alteration recorded in pancreases of diabetic rats. The data obtained are broadly consistent with finding of Eluehike & Onoagbe (2018) and Azad & Sulaima (2020) that tested same dose of STZ. Moreover, the results offered by Akbarzadeh et al. (2007) suggest that STZ upsurge blood glucose through swelling of pancreas and degeneration in Langerhans islet beta cells which compatible to our pathological finding. Fortunately, the tested extruded snacks (barely and corn) showed the ability to reduce glucose levels in blood of diabetic rats as well as improvement of pancreas architecture. Those effects were more pronounced in barley treated groups. The most likely explanation of our results is that barely contain reasonable amounts of β-glucan a polysaccharides that have ability to maintain normal blood glucose levels and keep balance between glucose and insulin according to Choi et al. (2010) and observation of Hajifaraji et al.(2012) in diabetic rats that fed on barely bread, along with its substantial contained of soluble dietary fibers that responsible for postprandial hinder of release of reduced sugar from food and lowering amylolysis (Wood et al., 1994). In human study held by Azam & Ahmed (2019) the postprandial glucose levels were significantly reduced after 90 min. in diabetics received barely. It's interesting to refer to corn- steep fermenting liquor which frequently used in various formulas for treatment of many diseases such as hyperglycemia (Olaiya & Karigidi, 2016) moreover; Wang et al. (2024) reported the hypoglycemic effect of active water-soluble polysaccharide isolated from sweet corncob in mice.

In our experimental model hyperglycemia was accompanied by hyperlipidemia manifested by increase of lipid profile parameters in serum of diabetic rats. Such systemic and metabolic disturbances due to diabetes were recorded by (Alimohammadi et al., 2013). Prior researches (Solati & Soleimani, 2010 and Azad & Sulaima, 2020) on diabetic rats (treated with STZ) confer with our finding. Such alterations were gladly ameliorated by extruded barely feeding as it significantly restores HDL, LDL and triglycerides levels to normal. Such antilipidaemic effect of barley was recorded by (Abulnaja et al., 2015) stated that the simultaneous oral serving of barley bran (5% and 10%) to the rats fed on 2% cholesterol for 8weeks resulted in significant amelioration of lipid profile. Same results obtained by Aly et al. (2024) in female rats received a high-fat diet and bread boosted with 60, 80% of whole barely. Once again β-glucan

ppears in picture as miracle glucose polymers that bind cholesterol in intestinal tract and get rid of it hrough feces and shifting cholesterol syntheses in liver to bile acid production (Swelim et al. 2019, Yun t al., 2003 and Åman, 2006).

In the current study the recorded elevation in liver (ALT, AST and ALP) and kidney (creatinine and urea) parameters in diabetic rats indicate damage of liver and kidney which allow enzymes to escape to circulation which clearly showed in histopathological examination of liver and kidney as described in figures (3&4). Similar to our results, Rehman et al. (2023) revealed that hyperglycaemia in STZ based induced-type 2 diabetic rats is accompanied with elevation of ALT, AST, ALP, creatinine and urea as a result of hepatic and renal injuries. The noticed changes in liver and kidney parameters as well as histological alterations were significantly ameliorated by feeding diabetic rats with extruded snacks of barely and corn. It worthy to note that extruded barely restore ALP and urea to normal and restore liver and kidney architectures to normal except of insignificant reversible lesions in some hepatocytes and some renal tubules. Earlier work by Abulnaja et al. (2015) revealed dose dependent improvement of liver enzymes and kidney function except for creatinine (non-significant decrease) along with restoration of liver and kidney tissue to normal in hypercholesterolemic male rats as a result of daily treatment with 5%, 10% barley bran. Meanwhile, treatment of hyperlipidemiac male rats with whole barley and barley bran resulted in enhancement of liver function comparing with affected groups (Elmhdwi et al., 2017). Same results recorded in hypercholesterolemic female rats which received bread made from whole barely flour by Aly et al. (2024) accompanied with improvement of structure of hepatic tissue. Comba et al. (2017) presumed that oral administration of barley grass (250 mg/kg/day) for 4weeks resulted in enhancing kidney function and protect renal tissue from damage. Swelim et al. (2019) and Belal (2011) supported the hypothesis of the barley β-glucan is responsible for kidney protection and liver protection, respectively against damage- accompanied metabolic disorders. The noted testicular damage in our study as a result of STZ injection was previously reported by Khaneshi et al. (2013) by the same dose of STZ (65mg /kg bw). (Shahreari et al., 2010) attributed the reproductive dysfunction induced by STZ to oxidative stress induced by reactive oxygen species accompanied with increased blood sugar and in consequence disrupt Leydig cell function, decrease testosterone production and alter architecture of seminiferous tubules and hence disturb sperm production. Herein, the testicular damage was totally repaired by feeding diabetic rats on EBS and ECS. The positive effect of barely against testicular damage could be attributed to high dietary fibers and its rich composition of bioactive compounds like β- glucan, flavonoids, phenolic acids, catechins **(Tosh, 2007**) which able to neutralize reactive oxygen spp. induced by type2 diabetes. On other hands, **Wang et al. (2024)** reported that the physiologically active polysaccharide (water-soluble one) extracted from sweet corncob was discovered to alleviate metabolic abnormalities linked with hyperglycemia in rats.

It is well known that diabetes type 2 induces free radicals production and negatively affect antioxidant status of body systems. This statement is strongly supported by the fact that a depilation of GSH and catalase and enhance of MDA production has been observed in current study**. Moody et al. (2008)** and **Mohamed et al. (2019**) concluded that the excessive reducing sugars that circulating in blood as a result to hyperglycemia induces oxidative stress and bind with vital molecules like lipid, protein, DNA generating lipid peroxidation, ROS and free radical and leading to more serious damages and negative effects on all body systems and organs. Fortunately, in the current study feeding of rats on both EBS and ECS improve antioxidant status of diabetic rats. Notably, EBS was able to restore GSH and catalase levels to normal**. Eldamaty (2020)**

recorded decrease in serum nitric oxide and MDA levels and increase catalase levels in rats intoxicated with tramadol and feed on high barely grass diet. Same results were provided with **Abulnaja et al., (2015)** who notice improvement in antioxidant pattern and great depression of MDA in hyperlipidemic rats supplemented with barley bran. **(Tosh, 2007**) reported the magnificent structure of barely as dietary fibers represent 11-34% and soluble fibers represent 3-20% of the total dietary fiber. Also, barely have considerable composition of starch, protein, β-glucan, free lipids and minerals (65-68%, 10-17%, 4-9%, 2-3% and 1.5-2.5%, respectively) alongside with flavonoids, phenolic acids such as ferulic acid, proanthocyanidins and catechins which act as free radical scavenging agents.

CONCLUSION

The findings suggest that extruded barley snacks are a viable alternative to traditional corn-based snacks. They offer lower fat and calorie content, making them suitable for health- conscious consumers, though improvements in protein levels could further enhance their nutritional profile. This main that it could produce acceptable quality extruded snacks with barley grains (Giza123). Moreover, the results obtained from current biological experiment model qualify extruded barely as an ideal snack for diabetic.

Abbreviations:

Var	Verity
GSH	glutathione
β-glucan	Beta-glucan
STZ	streptozotocin
wa	Water activity
SF	Shear force
ER	Expansion ratio
i.p.	Intraperitoneal
EBS	Extruded barley snacks
ECS	Extruded corn snacks
ALT	Alanine aminotransferase
AST	aspartate aminotransferase
ALP	Alkaline phosphatase
HDL	high density lipoprotein
LDL	Low density lipoprotein
MDA	Malondialdehyde
H&E	haematoxylin and eosin
SE	Standard error

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