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Impact of Germinated vs. Non-Germinated Barley on Diabetes in Rat Models and its Relevance to Baladi Bread Quality

Emad El-Kolie, Mai Khafagy, Safaa Arafa, Samar Abd Rabou

Department of Nutrition and Food Sciences, Faculty of Home Economics, Menoufia University, Shibin El Kom, Egypt

*Corresponding author**:** Emad El-Kolie, e-mail: emad.elkhouli@hec.menofia.edu.eg

ABSTRACT:

Barley (*Hordeum vulgare, L.*) is the world's fourth most significant cereal crop, following wheat, rice, and maize. It is reasonably priced and contains the most dietary fiber of any cereal, which may benefit metabolic syndrome. This study looked at the effects of germinated and non-germinated barley on diabetes in rats induced with alloxan. A total of 36 rats were divided into six major groups of six rats each: A healthy group and a diabetic group, which were divided into five experimental subgroups: the first was diabetic and untreated, the second and third were diabetic and treated with 5 and 10% and non-germinated barley, the fourth and fifth group were diabetic and treated with 5 and 10% germinated barley. The treatment lasted four weeks. The results demonstrated a considerable improvement in blood glucose levels in the groups treated with germinated and non-germinated barley compared to the untreated diabetic group. The treated groups also improved their lipid profiles, with lower levels of triglycerides and total cholesterol, indicating a good influence on metabolic performance. Furthermore, liver and kidney functions improved significantly in the groups treated with germinated and non-germinated barley, as demonstrated by lower serum liver activity levels. This indicates that barley in the diet improves health outcomes and increases food palatability. This suggests that barley could be a useful dietary strategy for diabetes prevention and therapy.

Keywords: Hordeum vulgare, germination, Antihyperglycemic, diabetic rats .

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1. INTRODUCTION

Diabetes mellitus (DM) is a major metabolic condition characterized by hyperglycemia and decreased insulin secretion. The disease's progressive form is associated with ketosis, proteinuria, and a variety of comorbidities such as retinopathy, nephropathy, neuropathy, and peripheral vascular insufficiencies, all of which can lead to limb amputation (1). It is the most common endocrine illness in the world, affecting about 285 million people. If not controlled, the number of affected individuals is predicted to approach 333 million by 2025

(2). Various studies have shown that functional diets and herbal medicines can effectively manage diabetes and reduce its consequences (3).

Cereals and their derivatives are important nutritional components because of their high carbohydrate content, which provides energy needed to the body. Germination activates endogenous enzymes like protease, amylase, and lipase, which improves the nutritional quality of these grains (4). Furthermore, germinated cereals are rich in bioactive chemicals, including polyphenols, gamma-aminobutyric acid (GABA), flavonoids, and tannins, which have antioxidant characteristics and reduce the risk of noncommunicable diseases such as diabetes, cardiovascular disease, and obesity (5, 6 and 7). Germination changes the physical, chemical, textural, and sensory qualities of grains, making them more appealing and boosting their use in processed food products such as snacks, bakery items, and non-dairy beverages (8).

Barley (Hordeum vulgare, L.) is the world's fourth most important cereal crop, with the highest concentration of dietary fiber; its malt is utilized in functional meals. Regular consumption of whole grain barley and its hydroalcoholic extract, rich in phytochemicals including flavonoids, β-glucan, tocols, lignans, phytosterols, phenolic acids, and folate, has been linked to a lower risk of chronic diseases like cancer, obesity, cardiovascular disease, and diabetes, etc.) (9). Germinated seeds can improve the condition of blood vessels and reduce the development of heart diseases (10). This is mostly due to saponarin, a flavonoid present in immature barley leaves (11). Furthermore, barley is high in magnesium, which serves as a cofactor for over 300 enzymes, including those involved in glucose metabolism and insulin production. Studies have indicated that regular eating of whole grains can reduce the incidence of type 2 diabetes by 31%, emphasizing the benefits of whole grains in encouraging healthy blood sugar control (12). Furthermore, studies have discovered that eating whole grain barley can help manage blood sugar levels for up to 10 hours after ingestion (13). Barley seeds are great sources of soluble fiber, and their beneficial benefits on metabolic syndrome, lipid metabolism, and gastrointestinal function are well recognized (14).

High viscosity of water-soluble dietary fibers, especially β-glucan, causes delayed digestion and absorption of nutrients (15). Barley has a lower glycemic index (GI) and a suppressive effect on postprandial blood glucose increase because of its higher fiber content compared to white rice (16, 17 and 18). The antioxidant qualities of phenolic compounds contained barely add to their nutritional value and may improve its preventive benefits against chronic diseases by neutralizing reactive oxygen species, which are frequently raised in diabetics. Barley can help lower serum glucose levels in diabetic rats, confirming its potential as a dietary intervention for managing diabetes-related problems (19). Therefore, the purpose of this study was to determine how different doses of 5% and 10% powdered non-germinated and germinated barley affected diabetic male albino rats.

2. Material and Methods

2.1. Materials

2.1.1. Source of barley

Barley was acquired in local markets in Shebin El-Kom, Menoufia Governorate, Egypt.

2.1.2. Chemicals

Alloxan was received from SIGMA (USA) to develop diabetes mellitus in rats. El-Gomhoriya Company for Trading Drugs, Chemicals, and Medical Instruments in Cairo, Egypt supplied casein, vitamin mixture, salt combination, cellulose, L-Cystine, choline chloride, and methanol. Gamma Trade Company, situated in Cairo, Egypt, provided biochemical examination kits.

2.1.3. Experimental animals

The Medical Animal Research Institute in Dokki, Cairo, Egypt provided 36 mature male albino rats of the Sprague-Dawley strain, weighing 150 ± 10 grams each.

2.1.4. Baladi bread ingredients:

Wheat flour (82% extraction), sodium chloride and active dry yeast were obtained from local market, Cairo, Egypt.

2.2. Methods

2.2.1. Preparation of germinated barley

After removing the broken grains, dust, and contaminants, the grains were cleaned with 0.7% sodium hypochlorite before soaking in distilled water at room temperature for 12 hours with a grain-to-water ratio of 1:4. The grains were then dispersed on wet gauze in plastic baskets. Gauze cloths help to minimize contamination while also allowing oxygen to reach germinating grains. The grains are germinated at 25 ±3°C for 72 hours. Germinated grains were sprayed with distilled water on a frequent basis to maintain them moist before and after soaking. After that, the germinated plants were air dried for 48 hours before being processed. The dried germinated barely (GB) was processed till powdery using an electric mill and then passed through sieves (sifters) with 2 mm pores. The sample was stored at 4 ◦C for analysis before being used in the experiment. Finally, grains were weighed prior to germination, as described by (20).

2.2.2. Preparation of Baladi bread:

Baladi bread was prepared and processed according to the method described by (21). The recipe for the Baladi bread was 1 kg wheat flour or its blends mixed with other ingredients including 1.5% active dry yeast, 1.5% sodium chloride and 700 ml water. The mixture is well mixed in mixer (250rpm) for 20min. The dough was left to ferment (15min./30 °C/85% relative humidity), then divided into pieces (160g). Each piece of bread was laid on wooden board previously covered with a fine layer of bran and left to ferment 10-15 min. at the same mentioned temperature and relative humidity. The fermented dough pieces were flattened to about 20cm diameter. The flat loaves were proved at 380-400 °C for 1-2 min. in electric oven. Bread loaves were allowed to cool at room temperature before chemical and sensory evaluation. Wheat flour was replaced with un-germinated and germinated oats flour at the level of 0, 2.5, 5.0, 10.0 and 20.0% for giving the replacement Baladi bread.

2.2.3. Identification and quantification of non-germinated and germinated barely flour phenolic compounds by HPLC

With a few minor changes, the phenolic acid content of each extract was measured using an HPLC system in accordance with (22) technique. The analytical column utilized was an Agilent Technologies ODS column (5 µm, 4.6 mm × 250 mm, Santa Clara, CA, USA). A gradient elution was performed using solvents A (water containing 0.1% (v/v) acetic acid) and B (acetonitrile containing 0.1% (v/v) acetic acid). This was the gradient program: The gradients are as follows: 0-2 min, 92-90% A in B; 2-27 min, 90-70% A in B; 27-50 min, 70-10% A in B; 50-51 min, 10-0% A in B; 51-60 min, 0% A in B (isocratic); and 60-70 min, 0-92% A in B. The injection volume was 20 µL, and the flow rate was constant at 1 mL/min. At 280 nm, the UV detector was calibrated. Standard phenolic compounds are produced in HPLC-grade methanol. Standard curves were generated by injecting varying amounts of the phenolic acid standard into the HPLC system, allowing the phenolic acid levels to be quantified. Each peak area was compared to a standard peak area for verification, and the presence of standard phenolic acids in the samples confirmed the peaks. The total phenolic acid

content was calculated by summing the values of each individual phenolic acid component.

2.2.4. Biological experiment

Ethical Approval

All animal tests were authorized by the Animal Care and Use Committee of the Faculty of Home Economics at Menoufia University in Shebin El-Kom, Egypt. (Approval No. (MUFHE/NFS/40/24).

2.2.5. Preparing for the basal diet (BD)

The final constituents of the standard diet are (10%) protein, (10%) maize oil, (1%) vitamin combination, (4%) minerals combination, (0.20%) choline chloride, (0.3%) methionine, (5%) cellulose, and maize starch make up the final ingredients, according to (23). 10% of the rats' diet used to be supplemented with a fortified cake containing varying quantities of byproducts instead of maize starch.

2.2.6. Induction of diabetes mellitus.

According to (24), an injection of alloxan at a dose of 150 mg/kg rat weight caused long-term damage to pancreatic beta cells in normal and healthy rats.

2.2.7. Experimental design

All rats were given a baseline diet for a week. After the adaptation phase, six groups of six rats each were created. The first group of rats acted as a negative control (-ve), while the other five groups were each given a single intraperitoneal alloxan dose (150 mg/kg body weight) to induce diabetes; one group was kept as a positive control (+ve), and four diabetic groups were treated with 5% and 10% germinated and non-germinated barley.

2.2.8. Collecting blood samples

After a 12-hour fast, the rats were slain at the conclusion of the experiment. Blood samples from the portal vein were obtained using dry, sterile centrifuge tubes. The blood was centrifuged for 10 minutes at 3000 rpm to extract the serum. While they were awaiting chemical analysis, serum samples were kept at -20°C (25).

2.2.9. Biochemical analysis

2.2.9.1. Blood glucose

Blood glucose levels were tested using (26) technique.

2.2.9.2. Serum lipid profile

Triglycerides were assessed using the methodology described by (27). The total cholesterol was found to be (28). Using (29) methodology, the levels of HDL (high-density lipoprotein) cholesterol were ascertained. The following formulas were used to identify low-density lipoprotein (LDL) and very-low-density lipoprotein (VLDL): VLDL cholesterol = triglycerides / 5 (30). The AI (atherogenic index) was computed using the method provided by (31).

2.2.9.3. Liver function markers

The ALP (alkaline phosphatase) concentration was calculated using the (32) method. (33) measured ALT (alanine aminotransferase) levels, while (34) described a method for detecting AST (aspartate aminotransferase) levels.

2.2.9.4. Determination of serum protein fractions: total protein and albumin

The total protein was detected using the techniques described by (35 and 36). Albumin levels were determined using the (37) technique using Boehringer kits.

2.2.9.5. Kidney function

The serum creatinine, urea, and uric acid levels were measured using the procedures described by (38, 39 and 40) consecutively.

2.2.10. Sensory evaluation of bread

Bread samples were produced using the standardized methods described by (41). Fifteen Participants who participated from Menoufia University's Department of Nutrition and Food Science, Faculty of Home Economics, took part in the bread sensory evaluation. Panelists evaluated samples based on taste, flavor, color, appearance, texture, compressibility, and overall acceptability. Water was supplied to cleanse the palate in between samples. Bread samples were served on round, coded white plates. A 1-10 rating system was used, with 10 denoting "excellent" and 1 indicating "dislike greatly". The evaluations were carried out two hours after baking. The sensory examination was conducted in a well-lit controlled sensory evaluation laboratory at 25°C.

2.2.11. Statistical analysis

The data were analyzed using one-way ANOVA with SPSS statistical software. The data are provided as mean ± SD (standard deviation). Statistical significance between groups was considered at $p < 0.05$ (42).

3. Results and Discussion

Identification of phenolic acids in both germinated and non-germinated samples by HPLC.

Table (1) shows the phenolic chemicals contained in non-germinated and germinated scarcely as assessed using an HPLC method. The obtained results showed that catechin, ferulic acid, and -epicatechin were the most abundant phenolic components detected in non-germinated scarcely, with corresponding readings of 52.73, 28.74, and 17.59 mg/100g. Gallic acid, p-coumaric acid, and vanillic acid have the lowest quantities of phenolic components in non-germinated barely. The quantities were 2.88, 3.33, and 5.62 mg/100 g, respectively.

Conversely, the highest amounts of phenolic compounds detected in germinated barely were catechin, ferulic acid, and -epicatechin, with values of 64.28, 33.14, and 20.13 mg/100g, respectively. In contrast, gallic acid, p-coumaric acid, and vanillic acid have the lowest quantities of phenolic components in germinating barely. The levels were as follows: 3.90, 3.91, and 5.71 mg/100g. Chlorogenic acid and p-hydroxybenzoic acid were not detected under these conditions. The data also showed that the germinated method resulted in more phenolic chemicals than the ungerminated. These findings are consistent with those of (43), who reported that when employed as an elicitor for barley germination, chito-oligosaccharide applied at 10 mg/kg barley kernels during the first steeping cycle led to the maximum production.

Furthermore, (5) discovered that germinated plants contained minimal quantities of phenolic chemicals.

The flavonoids and phenolic content of barley germinated increased, as did its antioxidant activity (44). Furthermore, the phenolic acid content varied substantially during germination, and germinated barley demonstrated high activity in the removal of free radicals. The results are consistent with prior study by (45 and 46), who found that germination increases phenolic content. This rise is related to the enzymatic hydrolysis process, which produces phenolic chemicals in addition to lignin and arabinoxylase.

Table (1) Chromatographic quantification of phenolic acids in non-germinated and germinated barley

Phenolic compounds	Un-germinated (mg/100g)	Germinated (mg/100g)
Gallic acid	34.79	347.93
(-)-Epicatechin	17.59	20.13
Vanillic acid	5.62	5.71
P-coumaric	3.44	3.91
Chlorogenic acid	91.39	913.94
Synergic acid	6.83	68.34
Ferulic acid	28.74	33.14
Protocatechuic acid	8.95	10.15

Following germination, total phenolic and total flavonoid levels increased by 11.1% and 87.6%, respectively. Furthermore, barley sprouts are differentiated by their high saponarin content, a flavonoid-C-glycoside with strong antioxidant effects. These sprouts are also high in policosanol, polyphenols, vital minerals, and free amino acids, which boosts their nutritional value (10 and 47).

The data in Table (2) show how varying quantities of non-germinated and germinated barley powder altered diabetic rats' serum glucose levels. The diabetes control group had considerably higher glucose levels (P≤0.05) compared to the healthy control group, which were normal. Diabetic rats fed 10% germinated barley powder had the lowest glucose levels, while those fed 5% non-germinated barley powder had considerably higher levels (P≤0.05). When compared to the diabetic control group, those who ate 10% germinated barley powder had the lowest serum glucose levels. Both germinated and non-germinated barley have a good impact on blood glucose levels due to their high presence of soluble fibers, such as beta-glucan, which slows sugar absorption in the digestive tract, lowering post-meal blood glucose increases. Germination also raises the quantities of bioactive substances such as phenols and flavonoids, which boost antioxidant activity and contribute to better insulin sensitivity.

The effect of barley on blood glucose levels in diabetic rats is an important area of research, especially in terms of treating diabetes-related comorbidities such as renal impairment. (48) studied the hypoglycemic, hypolipidemic, and antioxidant effects of barley in diabetic rats and discovered a significant drop in fasting blood glucose levels as well as improvements in the lipid profile. This demonstrates that barley has a variety of applications in diabetes management. They also discovered that rats fed barley-enriched bread had significantly lower serum glucose levels compared to the control group. This supports the notion that barley could be a useful dietary intervention for regulating blood glucose in diabetes patients. Furthermore, it was discovered that barley therapy resulted in reduced fasting blood glucose levels compared to other treatment groups, highlighting its potential for controlling blood sugar levels in diabetic mice (49). Overall, these findings indicate that integrating barley into the diet could be a feasible method for improving blood glucose control and possibly improving kidney function outcomes in diabetics.

Barley's ability to lower blood glucose levels can be related to its influence on glucose utilization and glycemic responses, which are regulated by components such as β-glucan and the amylose/amylopectin ratio (50). Furthermore, barley's antioxidant and detoxifying qualities serve to reduce oxidative stress and remove toxins from the body, which may aid in diabetes management (51). Barley leaf phytochemicals also provide health benefits, such as anti-inflammatory, immune-boosting, and antioxidant capabilities. Research suggests that combining arabinoxylan with β-glucan can increase the release of GLP-1, a hormone used to manage type 2 diabetes, via short-chain fatty acids (SCFAs) produced during barley eating (52).

In rats with type 2 diabetes, soluble fibers from barely effectively lowered postprandial blood glucose levels, enhanced insulin sensitivity, and helped with weight loss (53). Propionic acid, which has been associated to improved glucose management and insulin response, was caused by arabinoxylan promoting Akkermansia growth in the stomach (54). (55) discovered that arabinoxylan and β-glucan boost the growth of butyrate-producing bacteria, leading to increased gut microbiota diversity and potential metabolic health benefits. (56) discovered that barley consumption lowered postprandial glucose and insulin levels, implying that barley may help prevent the onset of diabetes by moderating metabolic dysregulation.

The data in Table 3 show how varying amounts of non-germinated and germinated barley powder affect blood lipid levels in diabetic rats. The healthy group had normal levels of total cholesterol, LDL, VLDL, HDL, and triglycerides, indicating a balanced metabolic state. Diabetes negatively affects blood lipids, as seen by substantial increases in total cholesterol, LDL, VLDL, and triglycerides, as well as a decrease in HDL levels ($P < 0.05$). Significant reductions in total cholesterol, LDL, and VLDL, as well as a decrease in triglycerides and an increase in HDL levels ($P < 0.05$), were found in the treated groups. The group that received 10% non-germinated barley powder showed the most notable improvement. Germinated barley consumption resulted in significant reductions in total cholesterol, LDL, and VLDL, as well as an increase in HDL levels ($P \leq 0.05$), demonstrating its effectiveness in improving blood lipid profiles. Both germinated and non-germinated barley were found to improve blood lipid profiles in experimental rats. This benefit is likely owing to their high fiber content, notably β-glucan, which reduces cholesterol levels and modulates lipid metabolism, encouraging better cardiovascular health.

Table (2) Effect of non-germinated and germinated barley powder on glucose level of diabetic rats

Groups / Parameters		G1 C (-)	G2 C (+)	G3 (5% non-germinated barley powder)	G4 (10% non-germinated barley powder)	G5 (5% Germinated barley powder)	G6 (10% Germinated barley powder)
Glucose mg/dl	Mean±SD	101.7d±10	240.2a±23.5	168.2b±16.8	151.2bc±15	136.2c±13.6	123.7cd±12.3
	%of change	-	136.06	65.35	48.67	33.85	21.62

The findings are shown as mean ± SD. According to a one-way ANOVA and Duncan's test, different superscript letters (a, b, c, d, and e) denote statistically significant differences ($p < 0.05$) across treatment groups. G1 C (-) Healthy Control Group, G2 C (+) Diabetic Control Group, G3 5% Non-Sprouted Barley Group: Rats fed 5% non-sprouted barley, G 410% non-germinated Barley Group: Rats fed 10% non-germinated barley, G5 5% Sprouted Barley Group: Rats fed 5% germinated barley, G6 10% Sprouted Barley Group: Rats fed 10% germinated barley.

When a high-fat sucrose diet created with refined wheat flour was compared to one with whole grain barley, rat and mouse models showed significant decreases in fat accumulation (57 and 58). Randomized double-blind human trial demonstrated that barley rich in β-glucan effectively reduced visceral fat area, BMI, and waist circumference in obese Japanese subjects over 12 weeks (59) discovered that hamsters fed with 8 g/100 g of β-glucan from barley or oats had lower aortic cholesterol and higher neutral fecal cholesterol. Soluble β-glucan, found in barley or oat seeds, may help lower cholesterol by increasing intestinal viscosity and slowing fat absorption. Furthermore, β-glucan binds to bile acids and promotes their excretion, causing the body to replenish cholesterol. Tocopherol and tocotrienol have also been demonstrated to lower cholesterol levels, giving further benefits in the prevention and treatment of cardiovascular disease and cancer when consumed in a balanced diet. Barley is a high-fiber, low-fat, whole-grain cereal with a low energy density, which is consistent with the recommendations for a low-calorie, high-fiber diet for weight management (60).

High blood cholesterol is a significant risk factor for cardiovascular disease (61). Consuming more soluble fibers, including β-glucan, can lower LDL-C levels by 5-10% (62). Consuming barley β-glucan has consistently been associated with statistically significant decreases in total cholesterol and LDL-C in 78% of 19 study arms (63). Quinoa that has been germinated may be a potent nutraceutical therapeutic option for the treatment of hypercholesterolemic rats (64). Additionally, barley has been proven to improve lipid profiles in obese rats.

High-fat diets normally raise cholesterol and triglyceride levels, however barley supplementation has been shown to lower blood cholesterol and triglycerides significantly (48). This underlines barley's

potential to improve lipid metabolism and cardiovascular health in diabetics (65). Studies with diabetic rat models have indicated that barley supplementation leads to a reduction in serum cholesterol, triglycerides, and overall improvement in lipid profiles compared to control groups (66).

Table (3) Effect of non-germinated and germinated barley powder on serum lipid profile of diabetic rats

Parameters	Groups	G1 C (-)	G2 C (+)	G3 (5% non-germinated barley powder)	G4 (10% non-germinated barley powder)	G5 (5% Germinated barley powder)	G6 (10% Germinated barley powder)
TC	Mean ±SD	86.5c ±8.6	157a ±15.7	144a ±14.25	112b ±11.1	106bc ±10.55	94bc ±9.5
mg/dl	%of change	-	-81.50	66.47	29.47	22.54	8.67
TG	Mean ±SD	76.6d ±7.8	141a ±14.45	135a ±13.44	112.6b ±11.2	100.5bc ±10	83.1cd ±8.3
mg/dl	%of change	-	84.07	76.24	46.99	31.20	8.48
HDL-C	Mean ±SD	52.1a ±5.2	29.6d ±2.8	37.6c ±3.7	40.47bc ±3.6	45.5ab ±4.5	48ab ±4.6
mg/dl	%of change	-	-43.18	-27.83	-22.32	-12.66	-7.86
LDL-c	Mean ±SD	19.2d±1.88	99.33a ±9.9	79.39b ±7.6	49.65c ±4.89	40.89c ±3.99	29.6d ±2.85
mg/dl	%of change	-	417.34	313.48	158.59	112.96	54.166
VLDL-c	Mean ±SD	15.36d ±1.5	28.3a ±2.7	27a ±2.7	22.46b±2.3	20.16bc ±1.9	16.67cd±1.59
mg/dl	%of change	-	84.24	75.78	46.22	31.25	8.52
AI	Mean ±SD	0.66±	4.31±	2.82±	1.78±	1.34±	0.96±
	%of change	-	550.34	326.69	168.74	102.26	45.38

Results are reported as mean ± SD. Using a one-way ANOVA and Duncan's test, significant differences ($p < 0.05$) between treatment groups were identified. Significant differences between group means are indicated by different lowercase letters (a, b, c, d, and e). TC, LDL-C, VLDL-C, HDL-C, TG, and AI indicate total cholesterol, low-density lipoprotein cholesterol, very low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, triglycerides, and atherogenic index (TC/HDL-C), respectively.

Table 4 shows the effect of varying amounts of non-germinated and germinated barley powder on liver function in diabetic rats. The healthy group had normal levels of ALT, AST, and ALP enzymes, indicating proper liver function. The diabetic group had significantly higher levels of ALT, AST, and ALP ($P < 0.05$), demonstrating liver stress and diabetes' deleterious impact on liver function. Non-germinated barley treatment resulted in a significant decrease in enzyme levels compared to the diabetic group ($P \leq 0.05$). The group that consumed 10% non-germinated barley powder showed the greatest improvement, indicating its ability to alleviate liver stress. Germinated barley treatment significantly improved liver enzyme levels (ALT, AST, and ALP), with the group consuming 10% germinated barley powder showing the best results in reducing these enzyme levels ($P \leq 0.05$), indicating its effectiveness in improving liver health and mitigating the negative impact of diabetes on liver function. Both germinated and non-germinated barley can improve liver function in experimental rats because they include bioactive substances such polyphenols, vitamins, and minerals. These substances assist minimize oxidative stress and boost metabolic processes, enhancing the liver's ability to cleanse and sustain its normal activities.

Raised levels of AST have been linked to liver dysfunction in studies; however, it is crucial to note that this enzyme can also be raised in disorders affecting other organs such as the heart or muscles. Research on the potential benefits of barley, particularly germinated barley (GB), has yielded promising results in diabetic rats in terms of liver protection. For example, therapy with GB in rats with hepatic steatosis was observed to improve hepatocyte function and reduce inflammation (10). The glucoregulatory effects of beta-glucans found in barley have been identified as beneficial to liver health, particularly in alleviating damage induced by high-fat diets (67). Supplementing

with highland barley β-glucan reduced blood ALT and AST levels in male C57BL/6 mice fed a Western-style diet with sugar-sweetened water, indicating improvements in liver enzyme markers (68). (69) Found that introducing germinated barley into a high-fat diet effectively reduced liver damage, improved lipid profiles, and even altered liver structure in rats. In addition, it was discovered to lower hepatic inflammation and downregulate particular proteins involved in liver injury, such as SDC1, in liver tissue.

Barley fibers have also been demonstrated to improve liver function by boosting HDL cholesterol and lowering blood malondialdehyde levels. According to (52), barley may have antioxidant and cardioprotective capabilities comparable to those seen in β-glucan. To address the nutritional issues provided by grains, the process of germination (or sprouting) has arisen as a novel strategy to improve their functional and nutritional properties. Germinated cereals and pulses, especially barley, provide important amino acids and other bioactive chemicals that have been related to benefits in metabolic illnesses such as diabetes (70 and 71). Furthermore, polyphenols present in germinated cereals serve to protect against oxidative stress by providing antioxidant activity, which may help prevent chronic diseases (72 and 73). As a result, the demand for germinated cereal-based functional foods has grown, with barley sprouts being used in a number of processed products such as snacks, bakery items, and non-dairy beverages (8).

Barley and wheat grasses enhanced liver markers. Daily ingestion of barley grass powder improves liver function and immunity; lowers cholesterol and weight; has anticancer and anti-inflammatory properties; and helps prevent heart disease (74). Saponarin-rich barley sprouts protect the liver by decreasing the inflammatory response to alcohol use (10). Saponarin showed antioxidative and hepatoprotective effects against CCl4-induced liver injury in vitro and in vivo (75). Barley sprout extract protects liver cells from oxidative stress by activating nuclear factor erythroid 2-related factor 2 (Nrf2) and increasing glutathione synthesis, inhibiting glutathione depletion and hepatic lipid buildup, lowering serum biochemical indicators of liver injury, and suppressing inflammatory responses (49). Treatment of barley grass raised the total protein and albumin levels in rats' serum. Increased protein levels could be attributed to phenols found in barley grass, which have successfully prevented cell membrane damage (76). The consumption of barley grass extract boosted total protein to near-normal levels (77).

Table 5 shows the effect of various concentrations of non-germinated and germinated barley powder on kidney function in diabetic rats, including creatinine, urea, and uric acid levels. Diabetes negatively affects kidney function, as seen by significant increases in creatinine, urea, and uric acid levels ($P < 0.05$). Treatment with non-germinated barley significantly improved creatinine, urea, and uric acid levels compared to the diabetic group ($P < 0.05$), with substantial differences across the groups. The group that received 10% non-germinated barley showed the greatest improvement. The group that consumed 10% germinated barley showed the most significant reductions in creatinine, urea, and uric acid levels ($P \leq 0.05$), indicating its effectiveness in improving kidney function and mitigating the negative effects of diabetes. Both germinated and non-germinated barley significantly improved renal function in experimental rats. This impact is thought to be generated by its antioxidant and anti-inflammatory characteristics, as well as its fiber and mineral content, which assist support kidney tissue health and prevent damage caused by oxidative stress.

Studies on the effects of barley and related dietary interventions in diabetic animal models highlight barley's promising role in

blood glucose management. This data imply that incorporating barley into the diet could provide significant benefits for blood glucose control, perhaps improving kidney function outcomes in diabetic patients. Specifically, investigations examining renal function in diabetic rats by measuring creatinine and urea levels following barley supplementation have yielded interesting results. The diabetic control group had increased levels of urea and creatinine, indicating compromised kidney function. In contrast, rats given barley interventions had urea and creatinine levels comparable to the normal control group (48).

Table (4) Effect of non-germinated and germinated barley powder on liver functions of diabetic rats

Parameters	Groups	G1 C (-)	G2 C (+)	G3 (5% non-germinated barley powder)	G4 (10% non-germinated barley powder)	G5 (5% Germinated barley powder)	G6 (10% Germinated barley powder)
ALT	Mean ±SD	46.4d±4.65	95.5a±9.49	71.5b±7.1	67.6bc±6.7	57.4cd±5.7	51.3d±4.99
U/L	%of change	-	105.81	54.09	45.68	23.70	10.56
AST	Mean ±SD	32.5d±3	76.1a ±7.6	54.2b±5.4	45.08c±4.47	40.48cd±3.9	38.15cd±3.7
U/L	%of change	-	134.15	66.76	38.70	12355.38	17.38
ALP	Mean ±SD	23.76e±1.8	52.3a±5	42.4b±4	38.6bc±3.8	35.4cd±3.5	31.5d±3
U/L	%of change	-	120.11	78.45	62.45	48.98	32.57
Total protein	Mean ±SD	5.45a±8.2	4.22b±0.40	4.30b±0.43	5.05ab±0.5	5.08ab±0.5	5.30ab±0.72
(g/dl)	%of change	-	-35.06	-18.18	-7.79	-14.28	-2.59
Albumin	Mean ±SD	3.85a ±0.38	2.5c ±0.25	3.15b ±0.31	3.55ab±0.35	3.30ab±0.33	3.75ab±0.37
(g/dl)	%of change	-	-22.56	-21.1	-7.33	-6.78	-2.75

Results are expressed as mean ± SD. Statistical significance among treated groups was established by one-way ANOVA followed by Duncan's test. Significant differences ($p < 0.05$) are indicated by means that have different lowercase letters (a, b, c, d, and e). ALP stands for alkaline phosphatase; ALT for alanine aminotransferase; and AST for aspartate aminotransferase.

These findings imply that barley may have a protective effect on kidney function in diabetic rats, helping to preserve normal kidney indicators such as urea and creatinine. Thus, including barley into diabetics' diets may help to preserve renal function and prevent additional difficulties associated with diabetic nephropathy. Furthermore, several studies have shown that barley has the capacity to reduce inflammation-induced kidney impairment in diabetes animals. Barley has been demonstrated to target important enzymes involved in inflammation, including ADAM17 and neutral sphingomyelinase. Barley may help reduce inflammatory cell infiltration and proteinuria, mitigating kidney damage and improving overall renal function (78 and 79). Furthermore, barley consumption has been associated with a reduction in glomerular lesions, nodular sclerosis in the glomeruli, and renal arteriolar lesions, indicating that it may help to preserve kidney structure in diabetes patients. In addition, studies have shown that barley has a considerable effect on renal function markers in diabetic rats. Barley's beneficial components, including β-glucan, tocols, and resistant starch, have been linked to improved kidney health. Barley's high fiber content, which is renowned for its involvement in blood sugar regulation, is especially beneficial for diabetics (80).

Table 6 shows how substituting wheat flour with non-germinated and germinated barley powder affects the sensory evaluation of bread. The results showed that adding barely 5% and 10% concentrations resulted in substantial variations in major sensory qualities of the bread, such as appearance, color, texture, and overall acceptability, compared to control samples. It was also discovered that adding both non-germinated and germinated barley to the bread increased the product's sensory attributes, which had a

significant impact on overall acceptance. While some consumers noticed a color change that some may find unacceptable at higher concentrations, this change is acceptable due to the significant health benefits they would gain from the lower glycemic index and blood sugar levels when consuming bread fortified with non-germinated and germinated barley. Overall, the sensory evaluation results showed that barley might improve bread quality, and customers are likely to embrace it because of the health benefits. Both germinated and non-germinated barely improve bread's sensory characteristics, including texture, flavor, and acceptance. Barley has bioactive substances such as fiber and antioxidants, which contribute to a softer crumb and a more attractive taste, making it an ideal ingredient for functional bakery products.

Table (5) Effect of non-germinated and germinated barley powder on kidney functions of diabetic rats

Parameters	Groups	G1 C (-)	G2 C (+)	G3 (5% non-germinated barley powder)	G4 (10% non-germinated barley powder)	G5 (5% Germinated barley powder)	G6 (10% germinated barley powder)
Urea	Mean ±SD	31.2c ±2.8	50.2a ±5	41.1b ±3.9	38.4bc ±4	35.58bc±3	33.54c±3.34
mg/dl	%of change	-	60.89	31.73	23.07	14.03	7.5
Uric acid	Mean ±SD	6.5c ±0.6	10.35a±0.98	8.4b ±0.8	7.96bc ±0.7	7.48bc ±0.75	7bc ±0.69
mg/dl	% of change	-	59.23	29.23	22.46	15.07	7.69
Creatinine	Mean ±SD	0.65e ±0.06	1.87a ±0.1	1.35b ±0.12	1.08c ±0.1	0.94cd ±0.94	0.83d ±0.08
mg/dl	%of change	-	187.69	107.69	66.15	44.61	27.69

Results are reported as mean ± SD. Statistically significant differences ($p \leq 0.05$) between treated groups were determined by one-way ANOVA followed by Duncan's test. Dissimilar lowercase letters (a, b, c, d, e) within each row indicate significant differences between group means.

Barley is becoming more widely recognized for its functional and nutritional characteristics, making it an important ingredient in a variety of food products. According to research, barley is widely used in human nutrition, notably because of its versatility and health benefits. When used in various forms, such as malt, whole grain, or barley flour, it can improve the nutritional value of many dishes, including bread, soups, and pasta (81). Despite its potential, human consumption accounts for less than 5% of global barley production, with pearl barley, barley flakes, and barley flour being the most popular products. Barley has the potential to dramatically enhance the sensory properties of baked foods. For example, research has found that adding barley, particularly malted or germinated barley, increases the nutritional profile of bread and biscuits. Incorporating hulless barley into bread and biscuits also boosts fiber content, decreases the glycemic index, and provides additional flavor benefits. Cookies have also been flavored with barley malt, which is a healthier alternative to typical sweets. Although barley-based breakfast cereals, such as flakes, require additional seasoning to increase flavor, they are regarded as a beneficial supplement to the diet due to their high fiber content and potential health advantages (82).

Barley has a tremendous impact on the texture and overall quality of many food products. Arabinoxylan, a major component isolated from brewer's leftover grain, has been found to alter viscosity in bread and bakery goods, potentially improving their texture and structure (83). Furthermore, barley arabinoxylan lowers the glycemic index of foods, which is particularly beneficial to diabetics, by enhancing the bulk and binding qualities of the dough (84 and 85). This feature is also useful for creating low-calorie, high-fiber breads and pastas. Furthermore, barley arabinoxylan has been proven to improve the texture and enjoyment of snack products like

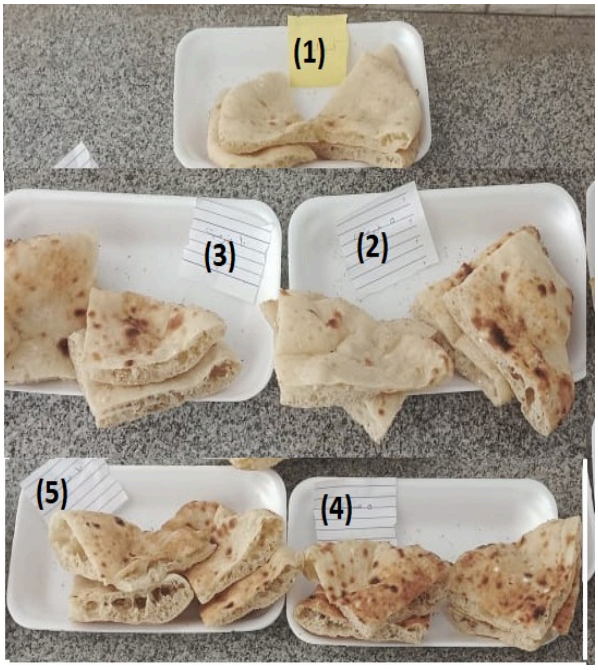
bars and chips by boosting fiber content and inducing satiety, which can help with weight control (86 and 87). Barley's ability to improve food texture extends beyond baked items to a wide range of other food categories, including beverages, snacks, and dairy replacements. Barley-based beverages, including barley water and barley tea, are becoming increasingly popular as pleasant and healthful alternatives to typical beverages (88). Furthermore, barley is increasingly being utilized to make plant-based dairy alternatives such as barley milk and barley yogurt, which give a nutritious and sustainable choice for dairy-free diets (89). Furthermore, barley fermentation improves its flavor, aroma, and nutritional value by increasing the growth of beneficial bacteria and enzymes, which contribute to enhanced gut health and potential probiotic health benefits (90).

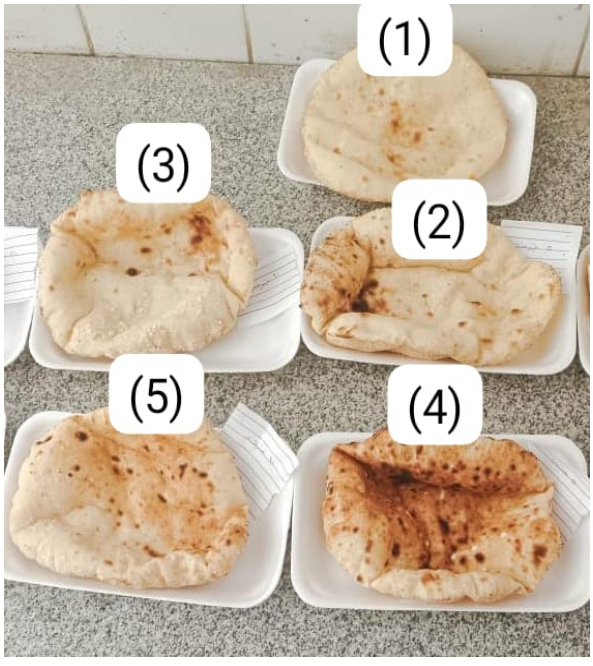
The use of barley in culinary products also includes convenient snack options. Barley-based snack foods, such as roasted barley chips and crackers, have a crunchy texture and savory flavor, making them a popular choice among consumers looking for healthful, guilt-free snacks (91 and 92). These items are frequently promoted as gluten-free and whole grain, which appeals to health-conscious customers.

Table (6) Sensory evaluation of bread made with varying amounts of germinated and non-germinated barley instead of wheat flour

	Control	5% germinated Barley	10% germinated Barley	5% non-germinated Barley	10% non-germinated Barley
Calor	9.64a±0.49	9.5ab±0.75	9.40ab±0.93	9.39ab ±0.8	9.00b ±0.91
Flavor	9.60a±0.73	9.39ab±0.90	8.75abc±1.0	8.10c±1.6	8.85abc±1.0
Taste	9.71a±0.72	9.25abc± 0.97	8.78abcd±101	8.30cd±1.0	8.25d±1.5
Texture	9.85a±0.36	9.39ab±0.80	9.2ab±0.89	9.17ab±1.0	9.0ab±0.95
Compressibility	9.96a±0.13	9.39ab±1.59	9.32ab±0.82	9.00b±1.14	8.96b ±1.0
Appearance	9.92a±0.26	9.32ab±0.74	9.32ab±0.82	9.17ab ± 1.26	9.14b±0.96
Softness	9.92a±0.18	9.5ab±0.45	9.42ab±0.91	9.32ab ±0.95	9.25ab±0.95
Overall acceptability	9.75a±0.42	9.35a±0.63	9.21a±0.84	9.10a±0.85	9.00a±1.37

Results are expressed as mean ± SD. The Duncan's test and one-way ANOVA were used to identify statistically significant differences ($p \leq 0.05$) between the treated groups. Significant differences between treatment means are indicated by different lowercase letters (a, b, c, d, and e) in each row.





The control group consisted of wheat flour, while the germinated and non-germinated barley groups were supplemented with 5% and 10% barley, respectively, by replacing wheat flour. Image 1 shows the control group, Image 2 shows 5% non-germinated barley, Image 3 shows 10% non-germinated barley, Image 4 shows 5% germinated barley, and Image 5 shows 10% germinated barley.

4. Conclusion

Barley is a versatile grain with benefits that extend beyond its conventional culinary uses. In experimental animals, both germinated and non-germinated barley lowered blood glucose and cholesterol levels and improved liver and kidney functions. Barley's rich nutritional value, including dietary fibers like β-glucan, minerals, and vitamins, makes it an excellent choice for promoting general health and preventing chronic diseases like diabetes and heart disease. Aside from its nutritional significance, barley has a significant impact on food sensory qualities, improving taste, texture, and color in baked goods, beverages, and snacks, increasing consumer appeal. As research into the benefits of barley continues, its role in boosting human health and expanding its use in functional foods is projected to grow, resulting in a healthier and more sustainable food system.

Conflict of Interest

The authors declare that there is no conflict of interest.

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5. References:

1. Bakhtiuary, Z. Herbal medicines in diabetes. Iran Journal Diabetes and Obesity, (2011); 2:88-95. http://ijdo.ssu.ac.ir/article-1-60-en.html

2. Unwin, N.; Gan, D. and Whiting, D. The IDF diabetes atlas: providing evidence, raising awareness and promoting action. Diabetes Research Clinical Practice, (2010); 87:2-https://doi:10.1016/j.diabres.2009.11.006

3. Minaiyan, M.; Zolfaghari, B. and Kamal, A. Effect of hydroalcoholic and buthanolic extract of Cucumis sativus seeds on blood glucose level of normal and streptozotocin-induced diabetic rats. Iran Journal Basic Medical Sciences, (2011); 14:436-442. https://pmc.ncbi.nlm.nih.gov/articles/PMC3586845/

4. Guzmán-Ortiz, F. A., Castro-Rosas, J., Gómez-Aldapa, C. A., Mora-Escobedo, R., Rojas-León, A., Rodríguez-Marín, M. L., et al. (2018). Enzyme activity during germination of different cereals: A review. *Food Reviews International*, *35*(3), 177–200. https://doi.org/10.1080/87559129.2018.1514623

5. Donkor, L.; Stojanovsk, P. Ginn, J. and Vasiljevic, A.T. Germinated grains – Sources of bioactive compounds. Journal Food Chemistry, (2012); 135 (3): 950-959.https://doi:10.1016/j.foodchem.2012.05.058

6. Pająk, P.; Socha, R.; Gałkowska, D.; Rożnowski, J. and Fortuna, T. Phenolic profile and antioxidant activity in selected seeds and sprouts. Food Chemistry, (2014); 143, 300–306. https://doi:10.1016/j.foodchem.2013.07.064

7. Liu, T.; Zhou, Y.; Wu, D.; Chen, Q. and Shu, X. Germinated high-resistant starch rice: A potential novel functional food. International Journal Food Science Technology, (2022); 57, 5439–5449. https://doi:10.1111/ijfs.15876

8. Penaranda, ˜ J.D.; Bueno, M.; Alvarez, ´ F.; P´erez, P.D. and Perez´ abad, L. Sprouted grains in product development. Case Stud. Sprout wheat Bak. flours Ferment. Beverages. International Journal Garston Food Science, (2021); 25: 1-7. https://doi.org/10.1016/j.ijgfs.2021.100375

9. Idehen, E.; Tang, Y. and Sang, S.: Bioactive phytochemicals in barley. Journal Food Drug Analysis, (2017) 25(1):148– 161. https://doi.10.1016/j.jfda.2016.08.002

10. Ragab, S.S.; Hany H. El-Gazzar, H.H. and Abd-Elwahab, N.E. Effect of germinated flaxseed, barley and beetroot on rats inducing cardiovascular failure disease. Journal of Home

Economics, (2022); 32 (3): 1-13. https://doi:10.21608/mkas.2022.116891.1112
11. Kamiyama, M. and Shibamoto, T. Flavonoids with potent antioxidant activity found in young green barley leaves. Journal Agriculture Food Chemistry, (2012); 60:6260-6267. https://doi:10.1021/jf301700j
12. Van Dam, R. M.; Hu, F. B.; Rosenberg, L.; Krishnan, S. and Palmer, J. R. Dietary calcium and magnesium, major food sources and risk of type 2 diabetes in U.S. black women. Diabetes Care. (2006); 29:2238-2243. https://doi:10.2337/dc06-1014
13. Nilsson, A.; Granfeldt, Y.; Ostman, E.; Preston, T. and Bjorck, I. Effects of GI and content of indigestible carbohydrates of cereal-based evening meals on glucose tolerance at a subsequent standardized breakfast. European Journal Clinical Nutrition, (2006); 60:1092-1099. https://doi:10.1038/sj.ejcn.1602423
14. Poppitt, S. D.; van Drunen, J. D.; McGill, A. T.; Mulvey, T. B. and Leahy, F. E. Supplementation of a highcarbohydrate breakfast with barley β-glucan improves postprandial glycemic response for meals but not beverages. Asia Pacific Journal Clinical Nutrition, (2007); 16:16- 24. https://doi.org/10.6133/APJCN.2007.16.1.03
15. Tosh, S. M. Review of human studies investigating the post-prandial blood-glucose lowering ability of oat and barley food products. European Journal Clinical Nutrition, (2013); 67:310-7. https://doi:10.1038/ejcn.2013.25. Epub 2013 Feb 20.
16. Bui, T. N.; Le, T. H.; Nguyen, H.; Tran, Q. B.; Nguyen, T. L.; Le, D. T.; Nguyen, V. A.; Vu, A. L.; Aoto, H.; Okuhara, Y.; Ito, Y.; Yamamoto, S. and Kise, M. Pre-germinated brown rice reduced both blood glucose concentration and body weight in Vietnamese women with impaired glucose tolerance. Journal Nutrition Science Vitaminology, (Tokyo), (2014); 60:183-7. https://doi:10.3177/jnsv.60.183.
17. Galvão Cândido, F.; Silva Ton, W. T. and Gonçalves Alfenas, C. Addition of dietary fiber sources to shakes reduces postprandial glycemia and alters food intake. Nutrition Hospital, (2014); 31:299-306. https://doi:10.3305/nh.2015.31.1.7578.
18. Nakayama, T.; Nagai, Y.; Uehara, Y.; Nakamura, Y.; Ishii, S.; Kato, H. and Tanaka, Y. Eating glutinous brown rice twice a day for 8 weeks improves glycemic control in Japanese patients with diabetes mellitus. Nutrition Diabetes, (2017); 7: 273-281. https://doi:10.1038/nutd.2017.26.
19. Arcidiacono, M.V.; Carrillo-López, N.; Panizo, S.; Castro-Grattoni A.L. and Valcheva, P. Barley-$-glucans reduce systemic inflammation, renal injury and aortic calcification through ADAM17 and neutral-sphingomyelinase2 inhibition. Sci. Rep., (2019); 9: 1-10. https://doi:10.1038/s41598-019-54306-8.
20. Frias, J.; Martha, M.; Doblado, R.; Vidal-Valverde, C. Effect of germination and Fermentation on the antioxidant vitamin content and antioxidant capacity of Lupines albus L. var. Multolupa. Food Chemistry, (2005); 92 (2): 211-220. https://doi:10.1016/j.foodchem.2004.06.049
21. El-Ghamry MH, Taha MG, Yousef MH, Abd El-Rahim EA. Physicochemical and technological studies on improving the nutritional value of Egyptian balady bread using barley, sorghum and quinoa flours. Al-Azhar J Agric Res. 2023 Oct;(Special Issue):451-9. https://journals.ekb.eg/article_351335_ef7071ab264e4552e58d6e2eb76d0f3e.pdf
22. Kim, M.Y.; Jang, G.Y.; Lee, Y.; Li, M.; Ji, Y.M.; Yoon, N.; Lee, S.H.; Kim, K.M.; Lee, J. and Jeong, H.S. Free and bound form bioactive compound profiles in germinated black soybean (Glycine max, L.). Food Science Biotechnology, (2016); 25:1551-1559. https://doi:10.1007/s10068-016-0240-2.
23. AIN. American Institute of Nutrition. Purified Diet for Laboratory Rodent, final report. Journal Nutrition, (1993); 123:1939-1951. https://doi:10.1093/jn/123.11.1939.
24. Zhao, Z. H.; Watschinger, B.; Brown, C. D.; Beyer, M. M. and Friedman, E. A. Variations of susceptibility to alloxan induced diabetes in the rabbit. Hormone and Metabolic Research, (1987); 19 (11): 534-537. https://doi:10.1055/s-2007-1011876.
25. Druy, R. A. B. and Wallington, E. A. Carlton's Histological Techniques. 5th Ed., Oxford University Press (1980);. https://books.google.com.eg/books/about/Carleton_s_Histological_Technique.html?id=4-dqAAAAMAAJ&redir_esc=y
26. Kaplan, L. A. Clinical Chemistry. The C.V. Mosby Co. St Louis. Toronto. Princeton, (1984); 1032-1036. 33.

https://www.scirp.org/reference/referencespapers?referenceid=2042643
27. Fassati, P. and Prencipe, L. Triglyceride enzymatic colorimetric method. Journal of Clinical Chemistry, (1982); 28:2077. https://pubmed.ncbi.nlm.nih.gov/6812986/
28. Allain, C. Cholesterol Enzymatic colorimetric Method. Journal of Clinical Chemistry, (1974); 20: 470. https://pubmed.ncbi.nlm.nih.gov/4818200/
29. Lopez, m. F. HDL-Cholesterol colorimetric method. Journal of Clinical Chemistry, (1977); 23: 882. https://pubmed.ncbi.nlm.nih.gov/192488
30. Lee, R. and Nieman, D. Nutritional Assessment. 2nd Ed., Mosby, Missouri, (1996); USA.
https://www.scirp.org/reference/referencespapers?referenceid=2677534
31. Nakabayashi A.; Kitagawa Y.; Suwa.Y. and Akmoto K. " α Tocopherl enhances the hypocholeserolemic action of sesames in rats". International Journal Veterinary Nutrition Research, (1995); 65(3):162-168.
https://pubmed.ncbi.nlm.nih.gov/8829994/
32. IFCC. International Federation of Clinical Chemistry. Methods for the measurement of catalytic concentration of enzymes, part 5: IFCC, methods for alkaline phosphatase. Journal of Clinical Chemistry and Clinical Biochemistry, (1983); 21:731-748. https://doi:10.1016/0009-8981(83)90294-2.
33. Thefeld, W et al. “Refernzwerte für die Biestimmungen der Transaminasen GOT und GPT sowie der alkalischen Phosphatase im Serum mit optimierten Standardmethoden” [Reference values for the determination of GOT, GPT, and alkaline phosphatase in serum with optimal standard methods (author's transl)]. *Deutsche medizinische Wochenschrift (1946)* vol. 99,8 (1974): 343-4 passim. https://doi:10.1055/s-0028-1107760
34. Henry, R. j; Cannon, D.C. and Winkelman, J. w. Clinical Chemistry, Principles and Techniques. 2nd Ed., Harper, and Row Company, (1974); 337: 993. https://www.scirp.org/reference/referencespapers?referenceid=2571093
35. Palladino, Pasquale et al. “Colorimetric determination of total protein content in serum based on the polydopamine/protein adsorption competition on microplates.” *Talanta* vol. 198 (2019): 15-22. https://doi:10.1016/j.talanta.2019.01.095
36. Reinhold, J. G. Total protein, albumin and globulin. Stand. Methods Clin. Chem. (1953); 1:88-97.
https://www.scirp.org/reference/referencespapers?referenceid=2822256
37. Doumas, B.T.; Watson, W.A. and Biggs, H.G. "Colorimetric determination of serum Albumin". Clin. Chem. Acta., (1971); 31: 87-96. https://ejrs.journals.ekb.eg/article_420080_2a0047fe71ed43301a8ffbf677f94c7b.pdf
38. Toora, B D, and G Rajagopal. “Measurement of creatinine by Jaffe's reaction--determination of concentration of sodium hydroxide required for maximum color development in standard, urine and protein free filtrate of serum.” *Indian journal of experimental biology.*. vol. 40,3 (2002): 352-4. https://pubmed.ncbi.nlm.nih.gov/12635710/#:~:text=Creatinine%20in%20serum%20or%20urine,is%20measured%20at%20520%20nm.
39. While, B.A.; Erickson, M.M. and Steven, S. A. Chemistry for Medical Theologists. 3 rd Ed., C. V. Mosby Company Saint Louis, USA, p. (1970); 662. Cited by: http://doi.10.21608/mkas.2024.274808.1296
40. Malhotra, V. K. Practical Biochemistry for Students. Fourth Edition, Jaypee Brothers Medical Publishers (p) LT, New Delhi, (2003); India. https://www.jaypeedigital.com/book/9789350255049
41. Ihekoronye A. I. and Ngoddy, P. O. Integrated Food Science and Technology for the Tropics,” Macmillan Publisher LTD, (1985); London. https://www.scirp.org/reference/referencespapers?referenceid=1816732
42. SPSS, Statistical Package Package for Social Science. Computer Software, (1998); Ver.26. https://www.ibm.com/support/pages/downloading-ibm-spss-statistics-26-end-support-30-sep-2025
43. Guo, X.; Yu, Z.; Zhang, M.; Wenzhu Tang, W.; Sun, Y. and Xianzhen, L. Enhancing the production of phenolic compounds during barley germination by using chito-oligosaccharides to improve the antioxidant capacity of malt. Biotechnology Letter, (2018); 40:1335–1341. https://doi:10.1007/s10529-018-2582-8. Epub 2018 Jun 6.
44. Tesby, M.R.; Lotfy, N.; Agamy, F. and Younes, N.M. The effect of germination is barely on its chemical composition, nutritional value, and rheological properties. Journal Home Economics,

(2021); 37(2):81-108. https://doi:10.21608/jhe.2021.178699

45. Sharma, P. and Gujral, H.S. Antioxidant and polyphenol oxidase activity of germinated barley and its milling fractions. Food Chemistry, (2010); 120 (3): 673-678. https://doi:10.1016/j.foodchem.2009.10.059

46. El-Ashaal, E. S. Studies on some functional foods (Master Thesis). Faculty of Agriculture, (2013); Mansoura University. http://srv3.eulc.edu.eg/eulc_v5/Libraries/Thesis/BrowseThesisPages.aspx?fn=PublicDrawThesis&BibID=11671561

47. Lee, Y.H.; Kim, S. and Lee, S. Antioxidant effect of barley sprout extract via enhancement of nuclear factor-erythroid 2 related factor 2 activity and glutathione synthesis. Nutrients, (2017); 9(11):1252. https://doi:10.3390/nu9111252

48. Aly, A.A.; Abusharha, A.; Shafique, H.; El-Deeb, F.E. and Abdelazeem, A.A. Effects of adding whole barley flour to bread and its impact on anti-obesity action of female rats fed a high-fat diet. Arabian J. Chem., (2024); 17. 1-9. https://doi:10.1016/j.arabjc.2023.105438

49. Rotimi, S.O.; Rotimi, O.A.; Adelani, I.B.; Onuzulu, C.; Obi, P. and Okungbaye, R. Stevioside modulates oxidative damage in the liver and kidney of high fat/low streptozocin diabetic rats. Heliyon, (2018); 4: 1-0. https://doi:10.1016/j.heliyon.2018.e00640.

50. Suzuki, S. and Aoe, S. High $-glucan barley supplementation improves glucose tolerance by increasing GLP-1 secretion in diet-induced obesity mice. Nutrients, (2021); 13: 1-10. https://doi:10.3390/nu13020527.

51. Choi, J.S.; Kim, H.; Jung, M.H.; Hong, S. & Song, J. Consumption of barley $-glucan ameliorates fatty liver and insulin resistance in mice fed a high-fat diet. Mol. Nutr. Food Res., (2010); 54: 1004-1013. https://doi:10.1002/mnfr.200900127.

52. Nie, C.; Yan, X.; Xie, X.; Zhang, Z.; Zhu, J.; Wang, Y.; Wang, X.; Xu, N.; Luo, Y. and Sa, Z. Structure of β-glucan from Tibetan hull-less barley and its in vitro fermentation by human gut microbiota. Chem. Biol. Technol. Agric., (2021); 8, 1–14. https://chembioagro.springeropen.com/articles/10.1186/s40538-021-00212-z

53. Li, L.; Pan, M.; Pan, S.; Li, W.; Zhong, Y.; Hu, J. and Nie, S.P. Effects of insoluble and soluble fibers isolated from barley on blood glucose, serum lipids, liver function and caecal short-chain fatty acids in type 2 diabetic and normal rats. Food Chem. Toxicol. (2019); 135, 110937. https://doi:10.1016/j.fct.2019.110937. Epub 2019 Nov 1.

54. Lynch, K.M.; Strain, C.R.; Johnson, C.; Patangia, D.; Stanton, C.; Koc, F.; Gil-Martinez, J.; Riordan, P.O.; Sahin, A.W. and Ross, R.P. Extraction and characterisation of arabinoxylan from brewers spent grain and investigation of microbiome modulation potential. Eur. J. Nutr., (2021); 60, 4393–4411. https://doi:10.1007/s00394-021-02570-8.

55. Teixiera, C.; Prykhodko, O.; Alminger, M.; Hallenius, F.F. and Nyman, M. Barley Products of Different Fiber Composition Selectively Change Microbiota Composition in Rats. Mol. Nutr. Food Res. (2018); 62, 1701023. https://doi:10.1002/mnfr.201701023.

56. Liu, L.; Wang, X.; Li, Y. and Sun, C. Postprandial differences in the amino acid and biogenic amines profiles of impaired fasting glucose individuals after intake of highland barley. Nutrients, (2015); 7, 5556–5571. https://doi:10.3390/nu7075238.

57. Xia, X.; Li, G.; Xing, Y.; Ding, Y.; Ren, T. and Kan, J. Antioxidant activity of whole grain highland hull-less barley and its effect on liver protein expression profiles in rats fed with high-fat diets. European Journal Nutrition, (2018); 57, 2201–2208. https://doi:10.1007/s00394-017-1494-z.

58. Gong, L.; Wang, T.; Sun, C.; Wang, J. and Sun, B. Whole barley prevents obesity and dyslipidemia without the involvement of the gut microbiota in germ free C57BL/6J obese mice. Food Function, (2019); 10, 7498–7508. https://doi:10.1039/c9fo01268k.

59. Aoe, S.; Mio, K.; Yamanaka, C. and Kuge, T. Low Molecular Weight Barley β-Glucan Affects Glucose and Lipid Metabolism by Prebiotic Effects. Nutrients, (2021); 13, 130. https://doi:10.3390/nu13010130.

60. Delaney, B.; Nicolosi, R.J.; Wilson, T.A.; Carlson, T.; Frazer, S.; Zheng, G.H.; Hess, R.; Ostergren, K.; Haworth, J. and Knutson, N. Beta-glucan fractions from barley and oats are similarly antiatherogenic in hypercholesterolemic Syrian

golden hamsters. Journal Nutrition, (2003); 133, 468–475. https://doi:10.1093/jn/133.2.468.
61. Lau, D. C.; Douketis, J. D. and Morrison, K. M. Canadian clinical practice guidelines on the management and prevention of obesity in adults and children. CMAJ, (2006); 176:1-11. https://doi:10.1503/cmaj.061409
62. Fletcher, B.; Berra, K. and Ades, P. Managing abnormal blood lipids: a collaborative approach. Circulation, (2005); 112:3184-3209. https://doi:10.1161/CIRCULATIONAHA.105.169180.
63. Rondanelli, M.; Opizzi, A. and Monteferrario, F. Beta-glucan- or rice bran-enriched foods: a comparative crossover clinical trial on lipidic pattern in mildly hypercholesterolemic men. European Journal Clinical Nutrition, (2011); 65:864-871. https://doi:10.1038/ejcn.2011.48.
64. Health Canada. Summary of Health Canada's assessment of a health claim about barley products and blood cholesterol lowering. http://www.hc-sc.gc.ca/fn-an/alt_formats/pdf/label etiquet/claimsreclam/assess-evalu/barley-orge-eng.pdf Accessed (2012); January 22, 2014.
65. El-Kholie, E.M.; Ahmed, A. and Mohamed El-Sharkawy, M. Potential effects of ungerminated, and germinated quinoa Seeds (Chenopodium quinoa, W.) on hypercholesterolemic rats. Journal of Home Economics, (2023); 33 (2):75-86.https://doi:10.21608/mkas.2023.176554.1192
66. El-Sayyad, H.I.; El-Beih, M.E.; El-Gebaly A. and Fouda, Y.A. Ginger ameliorated the exocrine pancreatic structure of fetuses of diabetic mother Wistar albino rats. Endocrinol. Diabetes Metab. J., (2019); 3: 1-10. https://doi:10.31038/EDMJ.2019335
67. Naseri, M.; Sereshki, Z.K.; Ghavami, B.; Zangii B.M. and Kamalinejad, M. Preliminary results of effect of barley (Hordeum vulgare L.) extract on liver, pancreas, kidneys and cardiac tissues in streptozotocin induced diabetic rats. Eur. J. Transl. Myol., (2022); 32. 10.4081/ejtm.10108. https://doi:10.4081/ejtm.2022.10108.

68. Giannini, E. G.; Testa, R. and Savarino, V. Liver enzyme alteration: A guide for clinicians. CMAJ. (2005); Feb 01; 172(3):367-79. https://doi:10.1503/cmaj.1040752.
69. Liu, H.; Chen, T.; Xie, X.; Wang, X.; Luo, Y.; Xu, N.; et al. Hepatic lipidomics analysis reveals the ameliorative effects of highland barley β-glucan on western diet-induced nonalcoholic fatty liver disease mice. J. Agric. Food Chem., (2021); 69, 9287–9298. https://doi:10.1021/acs.jafc.1c03379.
70. Al-Shali, R. A. and Ramadan, W. S. Germinated barley down-regulates hepatic stearoyl – Co A desaturase -1 enzyme gene expression in a hepatic steatohepatitis rat model. J. Anatomical Science International, (2020); 95(1): 4 89-497. https://doi:10.1007/s12565-020-00546-y
71. Perri, G.; Calabrese, F.M.; Rizzello, C.G.,;De Angelis, M.; Gobbetti, M. and Calasso, M. Sprouting process affects the lactic acid bacteria and yeasts of cereal, pseudocereal and legume flours. Lwt, (2020); 126, 109314. https://doi.org/10.1016/j.lwt.2020.109314
72. Allai, F.M.; Azad, Z.R.A.A.; Gul, K. and Dar, B.N. Wholegrains: a review on the amino acid profile, mineral content, physicochemical, bioactive composition and health benefits. Int. J. Food Sci. Technol. (2022); 57, 1849–1865. https://doi:10.1111/IJFS.15071
73. Gumus, Z.P.; Moulahoum, H.; Tok, K.; Kocadag Kocazorbaz, E. and Zihnioglu, F. Activity-guided purification and identification of endogenous bioactive peptides from barley sprouts (Hordeum vulgare, L.) with diabetes treatment potential. Int. J. Food Sci. Technol. (2023); 58, 3285–3292. https://doi:10.1111/ijfs.16172
74. Wang, J.; Ma, Y.; Huang, X.; Song, L.; Li, N.; Cheng, Y.; et al. Changes in physio-biochemical metabolism, phenolics and antioxidant capacity of different Chinese pea varieties during germination. Int. J. Food Sci. Technol. (2023); 58, 167–180. https://doi.org/10.1111/ijfs.16185
75. Zuo, Y.; Zeng, Y, and Pu, X. Strategies of functional foods for heart disease prevention in human beings, in Proceedings from the ICERP 2016: International Conference on Environmental Research and Public Health of De Gruyter Open, pp. (2017); 108–123, Warsaw, Poland. https://doi:10.1515/9783110559040-015
76. Simeonova, R.; Kondeva-Burdina, M.; Vitcheva, V.; Krasteva, I.; Manov, V. and Mitcheva, M. Protective effects of the apigeninO/C-diglucosidesaponarin from Gypsophila trichotoma on carbone tetrachloride-induced hepatotoxicity in vitro/in vivo in rats. Phytomedicine, (2014); 21(2): 148–154. https://doi:10.1016/j.phymed.2013.07.014.

77. Datta, G.; Basu, A.; Sen, M. and Nath, P. Role of a-tocopherol, ßcarotene and ascorbic acid against alcohol induced hepatotoxicity: A comparative analysis. J. Pharm. Res., (2012); 5:2485-2488. https://www.researchgate.net/publication/230799480_Role_of_a_-tocopherol_ss_-carotene_and_ascorbic_acid_against_alcohol_induced_hepatotoxicity_A_comparative_analysis
78. Lakshmi, B.; Sudhakar, M.; Sudha, F. and Gopa, M. Ameliorative effect of Triticum aestivum Linn against experimentally induced arsenic toxicity in male albino rats. Scholars Research Library Der Pharmacia Letter, (2015); 7 (1):202-211. https://www.scholarsresearchlibrary.com/articles/ameliorative-effect-of-triticum-aestivum-linn-against-experimentally-induced-arsenic-toxicity-in-male-albino-rats.pdf
79. Garcia-Mazcorro, J.F.; Mills, D.A.; Murphy, K. and Noratto, G. Effect of barley supplementation on the fecal microbiota, caecal biochemistry, and key biomarkers of obesity and inflammation in obese db/db mice. Eur. J. Nutr., (2018); 57: 2513-2528. https://doi:10.1007/s00394-017-1523-y.
80. Verma, R.P.S.; Kharub, A.S.; Sarkar, B. and Dinesh, K. Barley: A crop for changing climate in India. Progressive Agric., (2011); 11: 63-73. Cited by: https://forageresearch.in/wp-content/uploads/2014/10/98-105.pdf
81. Das, A.; Raychaudhuri, U. and Chakraborty, R. Cereal based functional food of Indian subcontinent: a review, J. Food Sci. Technol. (2012); 49 (6) 665–672 https://doi:10.1007/s13197-011-0474-1
82. Kumar, D.; Narwal, S.; Kharub, A.S. and Singh, G.P. Scope of food barley research and development in India. Wheat Barley Research, (2019); 10 (3): 1-9. https://doi:10.25174/2249-4065/2018/84878
83. Mio, K.; Togo-Ohno, M.; Tadenuma, N.; Ogawa, R.; Yamanaka, C. and Aoe, S. A single administration of barley β-glucan and arabinoxylan extracts reduces blood glucose levels at the second meal via intestinal fermentation. Bioscience Biotechnology Biochemistry, (2022); 87 (1): 99-107. https://doi:10.1093/bbb/zbac171.
84. Gasparre, N.; Pasqualone, A.; Mefleh, M. and Boukid, F. Nutritional quality of gluten-free bakery products labeled ketogenic and/or low-carb sold in the global market. Foods, (2022); 11, 4095. https://doi.org/10.3390/foods11244095
85. Gasparre, N.; Rosell, C.M. and Boukid, F. The growing popularity of low-carb cereal-based products: The lay of the land. Eur. Food Res. Technol. (2024); 250, 455–467. https://doi:10.1007/s00217-023-04399-3
86. Boukid Klerks, M.; Pellegrini, N.; Fogliano, V.; Sanchez-Siles, L.; Roman, S. and Vittadini, E. Current and emerging trends in cereal snack bars: Implications for new product development. Int. J. Food Sci. Nutr., (2022); 73, 610–629. https://doi:10.1080/09637486.2022.2042211.

87. Fanari, F.; Comaposada, J.; Boukid, F.; Climent, E.; Claret Coma, A.; Guerrero, L. and Castellari, M. Enhancing energy bars with microalgae: A study on nutritional, physicochemical and sensory properties. Journal Function Food, (2023); 109, 105768. https://doi:10.1016/j.jff.2023.105768
88. Strieder, M.M.; Silva, E.K.; Mekala, S.; Meireles, M.A.A. and Saldana, M.D.A. Barley-Based Non-dairy Alternative Milk: Stabilization Mechanism, Protein Solubility, Physicochemical Properties, and Kinetic Stability. Food Bioprocess Technol. (2023); 16, 2231–2246. https://doi:10.1007/s11947-023-03037-w
89. Guo, T.; Horvath, C.; Chen, L.; Chen, J. and Zheng, B. Understanding the nutrient composition and nutritional functions of highland barley (Qingke): A review. Trend Food Sci. Technol. (2020); 103, 109–117. https://doi:10.1007/s11947-023-03037-w
90. Herrera-Balandrano, D.D.; Báez-González, J.G.; Carvajal-Millán, E.; Méndez-Zamora, G.; Urías-Orona, V.; Amaya-Guerra, C.A. and Niño-Medina, G. Feruloylated arabinoxylans from nixtamalized maize bran byproduct: A functional ingredient in frankfurter sausages. Molecule, (2019); 24, 2056. https://doi.org/10.3390/molecules24112056
91. Landschoot, A.V. Gluten-free barley malt beers. Cerevisiae, (2011); 36, 93-97. https://doi:10.1016/j.cervis.2011.09.001
92. Wazed, M.A. and Islam, M.R. Influence of barley, corn and rice flour on physical, chemical and sensory characteristics of gluten-free bread. Malays. Halal Research Journal, (2021); 4, 36–41. https://doi:10.2478/mjhr-2021-0008

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تأثير الشعير المنبت وغير المنبت على الداء السكري في الفئران وعلاقتهما بجودة الخبز البلدي

عماد الخولى، مى خفاجى، صفاء عرفه ، سمر عبد ربه
قسم التغذية وعلوم الأطعمة، كلية الاقتصاد المنزلي، جامعة المنوفية، شبين الكوم، مصر.
* **المؤلف المسئول:** عماد الخولي -البريد الالكتروني: emad.elkhouli@hec.menofia.edu.eg

الملخص العربى:
الشعير هو رابع أكبر محصول حبوب فى العالم بعد القمح، الأرز، والذرة. يُعتبر الشعير من الحبوب منخفضة التكلفة ويحتوي على أعلى نسبة ألياف غذائية مقارنة بأي نوع آخر من الحبوب، مما قد يفيد فى متلازمة التمثيل الغذائى. درست هذه الدراسة تأثيرات الشعير المنبت وغير المنبت على مرض السكري فى الفئران التى تم اصابتها بالسكر باستخدام الألوكسان. تم تقسيم ٣٦ فأراً إلى ست مجموعات رئيسية، كل مجموعة تضم ستة فئران: مجموعة سليمة ومجموعة مصابة بالسكري. تم تقسيم مجموعة السكري إلى خمس مجموعات فرعية تجريبية: الأولى كانت مصابة بالسكري ولم تُعالج، الثانية كانت مصابة بالسكري وعولجت بـ ٥% شعير غير منبت، الثالثة كانت مصابة بالسكري وعولجت بـ ١٠% شعير غير منبت، الرابعة كانت مصابة بالسكري وعولجت بـ ٥% شعير منبت، والخامسة كانت مصابة بالسكري وعولجت بـ ١٠% شعير منبت. استمر العلاج لمدة أربعة أسابيع. أظهرت النتائج تحسنًا ملحوظًا فى مستويات سكر الدم فى المجموعات التى تم علاجها بكل من الشعير المنبت وغير المنبت مقارنةً بمجموعة السكري غير المعالجة. كما تحسنت صورة الدهون فى الدم لدى المجموعات المعالجة، حيث تم ملاحظة انخفاض فى مستويات الدهون الثلاثية والكوليسترول الكلى، مما يشير إلى تأثير إيجابي على الأداء الأيضى. علاوة على ذلك، تحسنت وظائف الكبد والكلى بشكل ملحوظ فى المجموعات المعالجة بكل من الشعير المنبت وغير المنبت، كما تبين من خلال انخفاض مستويات وظائف الكبد فى السيرم. بالإضافة إلى ذلك، أظهرت المجموعات المعالجة بكل من الشعير المنبت وغير المنبت تحسنًا كبيرًا فى الخصائص الحسية للمنتجات الغذائية، مما يدل على أن إضافة الشعير إلى النظام الغذائي لم يحسن النتائج الصحية فحسب، بل زاد أيضًا من قبول الطعام. تشير هذه النتائج إلى أن تدعيم المنتجات الغذائية بالشعير، المنبت أو غير المنبت، قد تساعد فى تقليل أعراض مرض السكري وتحسين وظائف الأعضاء المختلفة فى الفئران المصابة بالسكري. وبالتالي الشعير قد يكون استراتيجية غذائية مفيدة للوقاية والعلاج من مرض السكري.

الكلمات الكاشفة: الشعير، الانبات، التأثير المضاد للسكر، الفئران المصابة بالسكر

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