The Effect of Popcorn Produced from Different Corn varieties on Oxidative Stressed Diabetic Rats

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Abstract

Food products made from low-glycemic index (GI) raw materials need to be modified to ensure they can still contribute to the nutritional adequacy of people with diabetes. This study aimed to investigate the efficacy of popcorn produced from different corn species on glucose concentration and oxidative stress in diabetic rats. Thirty rats were divided into two main groups: The first main group (n=6) was fed a basal diet only and kept as a control negative group (-ve), The second main group (n=24 diabetic rats) were injected by a single intra-peritoneal of freshly prepared STZ (60 mg/kg BW), which were further divided into 4 subgroups (6 rats each): Subgroup (1): diabetic rats fed on a basal diet as a positive control group. Subgroups (2- 4): diabetic rats fed on a basal diet supplemented with popcorn made from yellow corn, Balady corn, or hybrid corn, at the level of 10%, respectively. The results showed that popcorn made from different corn species increased ($P<0.05$) the final body weight, feed intake, and body weight gain% values when compared to the positive control rats. Moreover, rats treated with popcorn produced from different corn species showed a significant increase ($p<0.05$) in insulin concentration, lower glucose levels, and increase in the level of antioxidant enzymes as well as improving liver functions. The findings indicated that popcorn made from various corn species may have a therapeutic role in improving the oxidative stress as well as managing diabetes complications.

Keywords: Popcorn, Diabetes, Oxidative stress, Glucose, Lipid profile

INTRODUCTION

Diabetes mellitus (DM) is a chronic, progressive metabolic disorder characterized by abnormally elevated blood glucose levels, leading to multisystem organ damage. The global prevalence of diabetes has been steadily rising, with estimates indicating that the number of affected individuals will increase from 537 million in 2021 to 783 million (12.2% of the global population) by 2045 (**Sun et al., 2022**). This alarming trend is of significant concern, as diabetes is associated with an increased risk of morbidity and mortality, particularly due to the increased risk of cardiovascular disease, which accounts for nearly 75% of diabetes-related deaths (**Leon and Maddox, 2015**).

Hyperglycaemia produces an increase in free radicals in cells, which can lead to oxidative stress and the formation of Reactive Oxygen Species (ROS) or Reactive Nitrogen Species (RNS). This oxidative stress hastens the onset and progression of diabetes (**González et al., 2023**). Diet therapy, especially, is showing a bright future in the therapy of DM. In particular, the commonly consumed cereal grains have been reported to possess antidiabetic properties. There are a variety of grains and grain products that can be beneficial in lowering glucose and insulin responses. The synergistic effect of several wholegrains and wholegrain components such as dietary fiber, phytochemicals, vitamin E, Mg, or others may reduce the risk for type 2 diabetes mellitus (T2DM) (**Lillioja et al., 2013**). As a result, the development of food products made from low-glycemic index (GI) raw materials, such as modified maize, could contribute to improving the nutritional adequacy for people living with diabetes (**González et al., 2023**).

Maize, also commonly referred to as corn (*Zea mays*, L.), is a major annual cereal grain crop belonging to the Poaceae family. Maize is known by various regional names, such as zea, silk maize, Makka, and barajovar, among others. It is regarded as a staple food in many parts of the world and is the third most important crop globally, following rice and wheat (**Khater and Shalan, 2022**). Nutritionists frequently regard snack foods as unhealthy due to their high sugar and fat content. While this assessment holds true for many snack options, some snacks can offer nutritional value beyond simply filling the gap between meals. Studies have linked snacking to better overall diet quality and increased consumption of whole grains in adults **(Zizza and Xu, 2012)**. For instance, popcorn is a popular whole grain snack that can serve as a healthier alternative to potato chips and other calorie-dense snacks **(Burgess-Champoux et al., 2010**).

Popcorn is a diverse and nutritious snack, providing dietary fiber, protein, and B-complex vitamins (**Donkeun et al., 2000)**. Some research has indicated that the antioxidant activity of corn may be affected by the release of additional phenolic compounds and the destruction or synthesis of redox-active metabolites during cooking **(Ruiz-Rodriguez et al., 2008)**. Moreover, studies have found an inverse relationship between whole grain intake and the risk of type 2 diabetes, which could be attributed to the effects of cereal fiber or other bioactive compounds in whole grains and whole grain products, such as lignans, tocotrienols, and phytic acids (**Montonen et al., 2003)**. So that, the present study was conducted to investigate the efficacy of popcorn produced from different corn varieties on blood glucose levels and oxidative stress in diabetic rats.

Materials and methods

Materials: Different Corn Species were obtained from the Agriculture Research Center. Casein, vitamins, minerals, cellulose and Alloxan were purchased from El-Gomhoria Company, Cairo, Egypt. Kits for blood analysis were purchased from Alkan Company for Biodiagnostic Reagents, Dokki, Cairo, Egypt. Adult male rats (Sprague Dawley strain) (n=30 rats) weighing approximately (190 g.) were purchased from Helwan Farm, Ministry of Health and Population, Cairo, Egypt.

Methods

Chemical composition: The gross chemical composition of Corn and their mineral content were determined according to the official methods **(AOAC, 2019).**

Induction of Animal Model of Diabetes: Diabetes was induced by a single intraperitoneal injection of freshly prepared (STZ) (60 mg/kg BW) of rat. Three days later, random blood. Random blood samples were taken from the eye of rats, then the level of the blood glucose was assessed and the glucose level ≥250 mg/dl was considered as diabetic **(Sarkar et al., 1996).**

Preparation of corn powdered: Popcorn was made from different corn species (yellow, Balady, hybrid), then the popcorn was ground and placed in the diet.

The Biological study: This study was carried out at the Postgraduate Lab of Home Economic Faculty, Helwan University. Thirty-five adult male Sprague-Dawley rats were fed on standard diet for one week for adaptation. Rats then were randomly divided into two main groups as follow:

- The first main group (n= 6) were fed on basal diet only and served as a control negative group (-ve). The second main group " diabetic rats" (n=24) were fed on basal diet and were divided into four subgroups as follow: The first subgroup was fed on basal diet and served as positive control group (+ve). The subgroups from (2 – 4) were fed on basal diet supplemented with popcorn produced from yellow corn, balady corn, hybrid corn at the level of 10%, respectively.

All rats were observed each day. Their feed intake (FI) was determined daily, and body weights were obtained every week throughout the experimental period. Body weight gain (BWG%) and feed efficiency ratio (FER) were calculated according to the method of **(Chapman et al., 1959)** using the following equation:

BWG % = (Final weight-Initial weight)/(Initial weight) × 100

FER = Body weight gain (g/d) / Feed intake (g/d)

Biochemical analysis: Serum was analyzed to determine the following parameters: Glucose concentation was determined according to **(Asatoor and King, 1954).** Insulin activity was estimated using enzyme linked immunosorbent assay ELISA method as described by **(Clark and Hales, 1994).** Serum total cholesterol (TC) was determined according to **(Richmond, 1973),** serum triglycerides (TG) was determined according to **(Wahlefeld, 1974),** high density lipoproteins (HDL-c) was determined according to **(Albers et al., 1983),** the concentrations of very low-density lipoproteins (VLDL-c) and low-density lipoproteins (LDL-c) were estimated according to the method described by **(Friedewald et al., 1972).**

LDL-c = Total cholesterol – (HDL-c + VLDL-c); VLDL-c = Triglyceride / 5

Antioxidant enzymes: Serum catalase (CAT) was determined according to **(Hissin and Hilf, 1976),** serum Malondialdehyde (MDA) was determined according to **(Draper and Hadley, 1990).**

Statistical analysis: The obtained results were analyzed according to SPSS program. Results are expressed as mean ± standard error (SE). ANOVA (Analysis of Variance) test was used to compare results among different groups. All differences were considered significant if ($P<0.05$).

Results and discussion:

The chemical composition of various corn varieties, including moisture, carbohydrates, fiber, ash, protein, and minerals such as phosphorus (P) sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), and iron (Fe) were recorded at Table (1). The results revealed that moisture levels in the corn samples ranged from 10.50% to 11.50%. Ash content, which reflects mineral composition, ranged from 1.50% to 2.90%. The crude fiber levels ranged from 2.20% to 2.90%, and the crude protein levels ranged from 10.10% to 12.30%. Fiber is an important nutritional component of whole grains, contributing to their health benefits **(Nirmala and Iris, 2020).** In terms of mineral content, the corn varieties were found to be particularly rich in key nutrients like potassium, magnesium, calcium, and phosphorus. These minerals play crucial roles in supporting bone development, energy metabolism, and muscle/nerve function. The diversity observed in the chemical profiles of the different corn varieties is likely attributable to factors such as genetics, growing conditions, and post-harvest processing methods. This variability in nutritional composition could consequently impact the functional and health-promoting properties of the corn samples **(Culețu et al., 2023)**.

Table (1): Chemical composition different corn species.

Nutrients	Unit	Yellow Corn	Balady Corn	Hybrid Corn
Moisture	(g/100g)	11.50	11.1	10.50
Carbohydrate		72.30	73.3	73.2
Crude fiber		2.2	2.6	2.9
Protein		12.30	10.1	11.9
Ash		1.7	2.9	1.5
P	(mg/100g)	290.6	267.8	275.4
K		314.8	317.7	318.6
Ca		46.3	46.3	46.3
Mg		105.9	101.2	103.7
Na		55.2	54.4	51.6

The results presented in **Table (2)** illustrate the effect of popcorn produced from different corn species on body weight status in diabetic adult male rats.There was no significant difference in the mean of IBW among all the rat groups. A significant ($p<0.05$) decrease in the FBW was observed in the control positive group as compared to the control negative group. Regarding the effect of popcorn from different corn species, rats fed popcorn from yellow corn had the highest FBW (233.57 g), followed by those fed on popcorn from Balady corn, while rats fed popcorn from hybrid corn had the lowest FBW (224.65 g).

Similarly, there was a significant decrease in BWG% in the control positive group compared to the control negative group. Rats fed popcorn from yellow corn had the highest BWG% (11.05%), followed by those fed popcorn from Balady corn, while rats fed popcorn from hybrid corn had the lowest BWG% (6.31%). FI was decreased in the control positive group compared to the control negative group. Rats fed popcorn from yellow corn had the highest FI (15.00 g), followed by those fed popcorn from Balady corn (14.70 g), while rats fed popcorn from hybrid corn had the lowest FI (14.30 g). FER also decreased in the control positive group compared to the control negative group. Rats fed popcorn from yellow corn and Balady corn had the highest FER (0.03 g), while rats fed popcorn from hybrid corn had the lowest FER (0.02 g).

Changes in food and nutritional status have a strong influence on body weight, which is a frequently used anthropometric measurement for assessing nutritional status **(Diaz-Canul et al., 2021).** Insulin deficiency in diabetics is known to disrupt protein and fat metabolism, leading to weight loss **(Huang et al., 2022).** The weight gain observed in this study agrees with the previous report of **Adeyibi et al., (2021),** who recorded a positive weight gain from a blend of cereals and legumes. Protein is required for building and maintaining muscle, which contributes to weight gain **(Igbua et al., 2024).** The weight performance exhibited by rats in the present study is in line with the earlier report of **Bintu et al., (2017).** The FER recorded in the current study was lower than the feed conversion ratio (FCR) values observed by **Shiriki et al., (2015) and Anaemene, (2021).** High FCR is not a desirable quality for both animals and feed, while low FCR values indicate that the feed is efficiently converted into rat weight gain **(Cottle and Pitchford, 2014).**

Table 2: The effect of the popcorn produced from different corn species on body weight status in diabetic adult male rats

Parameters / Groups	IBW (g)	FBW (g)	BWG %	FI (g/d/rat)	FER
Control negative	206.90 ± 2.42[a]	253.83 ± 1.06[a]	22.74± 1.75[a]	18.00	0.065 ± 0.004[a]
Control positive	209.54 ± 1.18[a]	219.87 ± 1.50[c]	4.92± 0.38[c]	13.00	0.020 ± 0.001[c]
Popcorn (Yellow Corn)	210.35 ± 0.92[a]	233.57 ± 1.75[b]	11.05± 1.20[b]	15.00	0.039 ± 0.004[b]
Popcorn (Balady Corn)	209.73 ± 1.39[a]	231.32 ± 2.16[b]	10.30± 1.20[b]	14.70	0.037 ± 0.040[b]
Popcorn (Hybrid Corn)	211.37 ± 2.01[a]	224.65 ± 2.48[c]	6.31± 1.57[c]	14.30	0.023 ± 0.005[c]

Results are expressed as mean ± SE. Means with different superscript letters in the same column are significantly different at ($P<0.05$).

The results presented in **Table 3** illustrate the effect of popcorn made from different corn varieties on the lipid profile (TC,TG,HDL,VLDL, and LDL) in diabetic adult male rats. The injection with streptozotocin (STZ) resulted in an elevation of the overall lipid profile in the diabetic rats. These findings are consistent with a previous study by **Negm (2020),** which observed a significant ($p\leq0.05$) increase in lipid profile levels in the STZ-induced diabetic group compared to the negative control group.

The results showed that the diabetic rats fed on popcorn made from Yellow corn had the lowest TC value at 175.62 mg/dL, followed by those fed popcorn made from Balady corn at 188.17 mg/dL. Similarly, Diabetic rats fed on popcorn made from yellow corn had the lowest TG value at 117.22 mg/dL. These results indicate that the type of corn used to produce the popcorn influenced the lipid profile in the diabetic rats, with hybrid corn resulting in the highest TC and TG levels, while yellow corn resulted in the lowest levels.

There was a significant decrease in serum HDL-c for the control positive group compared to the control negative group. Rats fed on popcorn produced from yellow corn displayed the highest value of HDL-c (54.77 mg/dl), followed by rats fed on popcorn produced from Balady corn (42.86mg/dl), whereas rats fed on popcorn produced from hybrid corn displayed the lowest value of HDL-c (37.90 mg/dl). There was a significant increase in VLDL-c for the control positive group compared to the control negative group. Rats fed on popcorn produced from Balady corn displayed the highest value of VLDL (28.34mg/dl), followed by rats fed on popcorn produced from yellow corn (26.72 mg/dl), whereas rats fed on popcorn produced from hybrid corn displayed the lowest value of VLDL-c (23.44mg/dl).

There was a significant increase in LDL-c for the control positive group compared to the control negative group. Rats fed on popcorn produced from Balady corn displayed the highest value of LDL-c (116.96 mg/dl), followed by rats fed on popcorn produced from hybrid corn (141.72 mg/dl), whereas rats fed on popcorn produced from yellow corn displayed the lowest value of LDL-c (94.13 mg/dl). These findings were in accordance previous findings of **Hu et al., (2008)** who showed a reduction in serum cholesterol levels when compared to those fed the control diet, when corn or corn products were added to the atherogenic diet in Sprague-Dawley rats over a six-week period. High-whole-grain diets are associated with reduced blood TAG, total and LDL cholesterol, inflammatory markers, and increased plasma or serum enter lactone, as well as improved BMI and insulin sensitivity. The methods by which whole-grain cereals protect the gut and help prevent obesity, diabetes, cardiovascular disease, and cancer **Newby et al., (2007).** These findings support those of

Ludvik et al., (2004), who suggest that HDL-c role in reverse cholesterol transport makes it a protective factor against atherosclerosis. HDL-c stimulates lipoprotein lipase, which is involved in the metabolism of triglyceride-rich lipoprotein. **Also, Jaleel et al., (2005)** discovered that higher lipid marker activity is linked to insulin resistance, metabolic disorder, and type 2 diabetes mellitus, as well as the therapeutic benefits of sweet potato methanol extract in diabetic rats.

Table 3 : The effect of the popcorn produced from different corn species on lipid picture in diabetic adult male rats.

Parameters / Groups	TC	TG	HDL-c	VLDL-c	LDL-c
	(mg/dl)				
Control negative	112.72 ± 1.65[e]	66.00 ± 2.06[e]	63.07 ± 1.17[a]	13.20 ± 0.41[e]	36.45 ± 2.00[e]
Control positive	220.56 ± 1.36[a]	153.35 ± 1.94[a]	29.21 ± 0.59[e]	30.67 ± 0.38[a]	160.67 ± 1.18[a]
Popcorn (Yellow Corn)	175.62 ± 3.75[d]	117.22 ± 2.93[d]	54.77 ± 1.42[b]	26.72 ± 0.38[c]	94.13 ± 2.82[d]
Popcorn (Balady Corn)	188.17 ± 2.68[c]	133.60 ± 1.92[c]	42.86 ± 1.56[c]	28.34 ± 0.45[b]	116.96 ± 3.21[c]
Popcorn (Hybrid Corn)	203.06 ± 4.19[b]	141.74 ± 2.28[b]	37.90 ± 2.28[d]	23.44 ± 0.58[d]	141.72 ± 6.13[b]

Results are expressed as mean ± SE. Means with different superscript letters in the same column are significantly different at ($P<0.05$).

Adamu et al., (2008) stated that after 45 days of feeding, the concentrations of VLDL and LDL for control groups were lower ($P \leq 0.05$) than that of corn grains group. Similarly, there were significant differences between all groups for values of VLDL and LDL after 91 days of study. Any significant alteration of lipids in their plasma levels could lead to a variety of clinical disorders in the affected animals. **Khater and Shalan, (2022)** indicated that eating powder popcorn, roasted corn, or their mixture increased HDL-c significantly ($P \leq 0.05$).

The effect of the popcorn produced from different corn species on glucose, and insulin concentrations in diabetic adult male rats was displayed at Table (4). There was a significant increase ($P<0.05$) in glucose for the control positive group compared to the control negative group. Rats fed on popcorn produced from yellow corn displayed the lowest value of glucose (198.46mg/dl) followed by popcorn from balady, then hybrid corn. There is a significant differences in glucose level among the three different popcorn.

There was a significant decrease in insulin for the control positive group compared to the control negative group. Rats fed on popcorn produced from yellow corn displayed the highest value of insulin (13.21 **mIU/ml**), followed by rats fed on popcorn produced from Balady corn (11.30 **mIU/ml**), whereas rats fed on popcorn produced from hybrid corn displayed the lowest value of insulin (10.59 **mIU/ml**). There was a significant difference in insulin concentration between rats fed on popcorn from yellow corn and either popcorn produced from balady or hybrid corn. Accordingly, this is consistent with previous studies, demonstrating that the STZ-induced diabetes in the rodent is known as the standard model of diabetes induction (**Negm, 2020).** This carbohydrate released as glucose functionally provides cells, tissues and organs with energy and then stored as glycogen in the liver and muscles **Akinjayeju et al., (2020).** The improper carbohydrate metabolism result to diabetes mellitus, which is caused by lack of or resistance to insulin leading to hypoglycemia or hyperglycemia. The decrease in the glucose levels is in agreement with **Oluwajuyitan and Ijarotimi, (2019)** whoreported that plantain flour-based product manages diabetes, reduces the blood glucose level and lower starch digestion rate in the body. **Famakin et al., (2016)** reported lower glycemic index and blood glucose level of rats fed composite flour when compared to synthetic antidiabetic drugs. These findings are consistent with those of **Yamini and Trumbo, (2016)** who concluded that consumption of whole grains is linked to a lower incidence of type 2 diabetes in various recent reviews and epidemiology studies.

Whole grains contain dietary magnesium, fiber, and vitamin E, all of which aid in insulin metabolism. **Van Hung, (2016),** who reported that eating whole grains like popcorn can lower the risk of diabetes, heart disease, and hypertension due to it is contain many active compounds. It is critical, however, that the entire kernel be eaten. Despite accounting for only 15–20 percent of the overall weight of the popcorn kernel, the pericarp contains around 98 percent of the phenolic and antioxidant content. Regular ingestion of several compounds found in whole grains, according to **Slavin, (2004),** may help manage insulin levels. Furthermore, complete grains like maize and its derivatives (popcorn and roasted corn) may help manage insulin levels by releasing satiety and lowering body mass index (BMI). **Khater and Shalan, (2022)** indicated that eating powder popcorn, roasted corn, or their mixture improved serum glucose. This lower postprandial blood glucose level may also be due to the inhibition of glucose, digestion of starch and absorption process of alpha- glucosidase as reported by **Inoue et al., (2022).** It is interestingly to know that, the postprandial blood glucose response of all the experimental groups were within the normal range hence does not have any negative effect for whoever may consume the formulated diet **(Igbua, et al., 2024).**

Table 4: The effect of the popcorn produced from different corn species on blood picture in diabetic adult male rats.

Parameters / Groups	Glucose (mg/dl)	Insulin (mIU/ml)
control negative	96.98 ± 2.58[e]	18.98 ± 0.67[a]
control positive	265.97 ± 2.15[a]	6.71 ± 0.21[d]
Popcorn (Yellow Corn)	198.46 ± 2.80[d]	13.21 ± 0.35[b]
Popcorn (Balady Corn)	208.62 ± 1.37[c]	11.30 ± 0.30[c]
Popcorn (Hybrid Corn)	228.30 ± 3.03[b]	10.59 ± 0.16[c]

Results are expressed as mean ± SE. Means with different superscript letters in the same column are significantly different at ($P<0.05$).

Results recorded in **Table 5** illustrated the effect of the popcorn produced from different corn species on MDA, and CAT in diabetic adult male rats. There was a significant increase in MDA for the control positive group compared to the control negative group. In many studies, Oxidative stress has been demonstrated to participate in the progression of diabetes, which plays an important role in diabetes, including impairment of insulin action and the increased complication incidence rate **(Asmat et al., 2016).**

Supplementation with different popcorn significantly decreased the mean value of MDA as compared to the +ve control group. Popcorn produced from yellow corn displayed the lowest value of MDA (4.94**(µ/ml)**) followed by balady then hybrid corn. There was a significant decrease in CAT for the control positive group compared to the control negative group. Popcorn produced from different types of corn caused a significant increase in CAT as compared to the +ve control group. Rats fed on popcorn produced from yellow corn displayed the highest value of CAT (116.77 **(µ/ml)**), followed by rats fed on popcorn produced from Balady corn (104.54 **(µ/ml)**), whereas rats fed on popcorn produced from hybrid corn displayed the lowest value of CAT (92.42**(µ/ml)**) .

Hyperglycemia causes an increase in free radicals in cells, which can be toxic in excess, encouraging oxidative stress and the formation of reactive oxygen species (ROS) as well as reactive nitrogen species (RNS) **(Nagaraju et al., 2020).** Streptozotocin, a diabetogenic, can produce reactive oxygen, which, when induced in model animals, can result in increased levels of ROS. This oxidative stress exacerbates the progression and complications of diabetes **(Ogle et al., 2022).** As levels of free radicals increase, so does peroxidation of cell membrane lipids and production of MDA, one of the final products of peroxidation. Corn as an antioxidant, beta-carotene can protect beta-pancreatic cells from the cytotoxicity caused by oxidative stress in DM **(Ermawati et al., 2014).** According to **Furusho et al. (2002),** supplementation with beta-carotene at 20 mg/kg body weight significantly reduced the levels of ROS and increased the levels of antioxidant enzymes in diabetic rats. The antioxidant activity of beta-carotene has been shown to occur indirectly through the maintenance of cell membrane integrity against free radical attacks **(Khalil et al., 2021). Magaña-Cerino et al., (2020)** showed that consumption of nixtamal from a new variety of hybrid blue maize ameliorates liver oxidative stress and inflammation in a high-fat diet rat model.

Table 5: The effect of the popcorn produced from different corn species on MDA and CAT in diabetic adult male rats:

Parameters / Groups	MDA(μ/ml)	CAT(μ/ml)
control negative	3.40 ± 0.15^{d}	128.50 ± 1.21^{a}
control positive	8.09 ± 0.19^{a}	55.73 ± 2.11^{e}
Popcorn (Yellow Corn)	4.94 ± 0.11^{c}	116.77 ± 2.34^{b}
Popcorn (Balady Corn)	5.33 ± 0.12^{c}	104.54 ± 2.20^{c}
Popcorn (Hybrid Corn)	6.17 ± 0.14^{b}	92.42 ± 1.81^{d}

Results are expressed as mean ± SE. Means with different superscript letters in the same column are significantly different at (P<0.05).

There was a significant increase in liver functions concentrations for the control positive group compared to the control negative group as seen in table (6). These results agreement **Negm, (2020)** observed that the activities of serum AST and ALT were significantly increased (P≤0.05) in the diabetic control group injected with STZ, compared with the corresponding value of normal control group. In contract, Rats fed on popcorn produced from different corn had a significant decrease in serum liver functions as compared to the +ve control group. Popcorn produced from Yellow corn caused the most improvement in liver functions. This evidence agrees with the findings **Marchesini et al., (2001),** who showed that the enzyme level of transaminases elevated in diabetic rats**. Khater and Shalan, (2022)** indicated that eating powder popcorn, roasted corn, or their mixture improved kidney and liver functions by lowering ALT, AST, and ALP.

Table 6: The effect of the popcorn produced from different corn species on liver function in diabetic adult male rats:

Parameters / Groups	ALT	AST	ALP
	(μ/L)		
Control negative	33.09 ± 1.46^{d}	90.51 ± 2.69^{d}	68.32 ± 2.63^{d}
Control positive	81.40 ± 1.68^{a}	141.17 ± 1.15^{a}	116.21 ± 2.36^{a}
Popcorn (Yellow Corn)	54.64 ± 2.20^{c}	117.24 ± 2.32^{c}	81.32 ± 1.59^{c}
Popcorn (Balady Corn)	67.97 ± 1.42^{b}	122.90 ± 1.70^{c}	92.15 ± 1.55^{b}
Popcorn (Hybrid Corn)	72.00 ± 1.40^{b}	133.02 ± 2.43^{b}	95.74 ± 1.75^{b}

Results are expressed as mean ± SE. Means with different superscript letters in the same column are significantly different at (P<0.05).

Conclusion: This study found that eating popcorn made from various corn varieties can significantly reduce oxidative stress and improve metabolic outcomes in diabetic rats.

REFERENCES

Adamu, S., Ige, A., Isa, D. and Jatau, I. (2008): Changes in the serum profiles of lipids and cholesterol in sheep experimental model of acute African trypanosomiasis. Afr. J. Biotechnol ; 7: 2090-2098.

Adebiyi, F., Adediran, K., Olaoye, O., Mosuro, A., Olaomi, O. and Ogunwole, O. (2021): Biological evaluation of cereals and legumes weaning lends for infant weaning food. Food and Public Health, 11(2):44-52.

Akinjayeju, O., Ijarotimi, S., Awolu, O. and Fagbemi, T. (2020): Nutritional composition, glycaemic properties and anti-diabetic potentials of cereal-based soy-fortified flours for functional dough meal in diabetic induced rats. Journal of Food Science and Nutrition Research, 3(2): 102-120.

Albers, N., Benderson, V. and Warnick, G. (1983): Enzymatic determination of high density lipoprotein cholesterol, Selected Methods. Clin. Chem, 10(5):91-99.

Anaemene, D. (2021): Nutritional, physico-chemical and microbiological evaluation of cereal-based complementary foods fortified with pigeon pea (cajanus cajan) flour. A thesis Submitted to the department of Human Nutrition, Faculty of Public Health, University of Ibadan.

AOAC, (2019): Official Methods of Analysis, 21th Edition. Association of Official Analytical Chemists: Washington, 78 DC, USA.

Asatoor A. and King E. (1954): Simplified colorimetric blood sugar method. The Biochemical Journal, 56(325th Meeting), xliv.

Asmat, U., Abad, K. and Ismail, K. (2016): Diabetes mellitus and oxidative stress—A concise review. Saudi Pharm J 24(5):547–553.

Bintu, B., Falmata, A., Maryam, B., Zainab, M. and Modu, S. (2017): Effect of feeding complementary diet blends formulated from Zea mays (maize), vigna unguiculatal(cowpea), voandzeiasubterranean and arachishypogeal on weaning rats. African Journal of Food Science and Technology,8(5): 99-107

Burgess-Champoux, T., Larson, N., Neumark-Sztainer, D., Hannan, P. and Story, M. (2010): Longitudinal and Secular Trends in Adolescent Whole-Grain Consumption, 1999-2004. Am. J. Clin. Nutr.; 91 (1):154-159.

Chapman, D., Castillo, R. and Campbell, J. (1959): Evaluation of protein in foods: 1. A method for the determination of protein efficiency ratios. Canadian Journal of Biochemistry and Physiology, 37(5): 679-686.

Clark, P. and Hales, C. (1994): How to measure plasma insulin. Diabetes/metabolism reviews, 10(2): 79-90.

Cottle, D. and Pitchford, W. (2014): Production efficiency. Chapter 18 in Beef Cattle Production and Trade, Ed Lewis Kahn. Ciro Publishing, 439-440.

Culețu A, Susman IE, Mulțescu M, Cucu ȘE, Belc N. (2023): Corn Extrudates Enriched with Health-Promoting Ingredients: Physicochemical, Nutritional, and Functional Characteristics. Processes; 11(4):1108.

Diaz-Canul C., Coop-Gamas F., Ávila-Escalante M., Betancur-Ancona D. and Aranda-González I. (2021): Evaluation of minor steviol glycosides effect on insulin resistance, serum triglycerides, and antioxidant capacity of diabetized wistar rats. Int. Food Res. J. ;28:342–349.

Donkeun, P., Kenneth, G., Stermitz, F. and Maga, J. (2000): Chemical composition and physical characteristics of un-popped popcorn hybrids. J. Food Comp. Anal., 13 (6): 921-934.

Draper, H. and Hadley, M. (1990): Malondialdehyde determination as index of lipid Peroxidation. In Methods in enzymology. Academic press, 186, 421-431.

Ermawati D., Rachmawati B. and Widyastiti N. (2014): Efek suplementasi β-carotene terhadap kolesterol total, trigliserida dan malondialdehid pada tikus sprague dawley yang diabet. The Indones. J. Nutr. ;2:47–52.

Famakin, O., Fatoyinbo, A., Ijarotimi, O., Badejo, A. and Fagbemi, T. (2016): Assessment of nutritional quality, glycaemic index, antidiabetic and sensory properties of plantain (Musa paradisiaca)-based functional dough meals. Journal of Food Science and Technology, 53(11): 3865-387.

Friedewald, W., Levy, R. and Fredrickson, D. (1972): Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clinical chemistry, 18(6): 499-502.

Furusho T., Kataoka E., Yasuhara T., Wada M. and Innami S. (2002): Administration of beta-carotene suppresses lipid peroxidation in tissues and improves the glucose tolerance ability of Streptozotocin-induced diabetic rats. Int. J. Vitam. Nutr. Res. ;72:71–76.

González, P., Lozano, P., Ros, G. and Solano, F. (2023): Hyperglycemia and Oxidative Stress: An Integral, Updated and Critical Overview of Their Metabolic Interconnections. International journal of molecular sciences, 24(11), 9352.

Hissin, P. and Hilf, R. (1976): A fluorometric method for determination of oxidized and reduced glutathione in tissues. Analytical biochemistry, 74(1): 214-226.

Hu, Y., Wang, Z. and Xu, S. (2008): Corn bran dietary fiber modified by xylanase improves the mRNA expression of genes involved in lipids metabolism in rats. Food Chemistry; 109 (3): 499-505.

Huang Z., Zhao L., Zhu F., Liu Y., Xiao J., Chen Z., Lv X., Huang Y. and Liu B. (2022): Anti-diabetic effects of ethanol extract from Sanghuangporous vaninii in high-fat/sucrose diet and streptozotocin-induced diabetic mice by modulating gut microbiota. Foods ;11:974.

Igbua, F., Adejo, S., Kukwa, R., APE, S., Ojah, E. and DV, Z. (2024): Effect of maize-cassava-soybean flour blends intake on body weight and postbrandial blood glucose level of wistar rats. Romanian Journal of Diabetes, Nutrition and Metabolic Diseases, 31(1).

Inoue, Y., Cormanes, L., Yoshimura, K., Sano, A., Hori,Y., Suzuki, R. and Kanamoto, I.(2022): Effect of Apple consumption on postprandial blood glucose levels in normal glucose tolerance People versus those with impaired glucose tolerance. Foods, 11:1803.

Jaleel, A., Halvatsiotis, P. and Williamson, B. (2005): Identification of Amadori-modified plasma proteins in type 2 diabetes and the effect of short-term intensive insulin treatment. Diabetes Care; 28 (3): 645-652.

Khalil A., Tazeddinova D., Kazhmukhanbetkyzy K., Orazov A. and Toshev A. (2021): Carotenoids: Therapeutic strategy in the battle against viral emerging diseases, COVID-19: An overview. Prev. Nutr. Food Sci. ;26:241–246.

Khater,O. and Shalan, A. (2022): Possible effects of eating popcorn, and roasted corn on alloxan-induced diabetic rats. Journal of Home Economics ; 32 (3): 29-40.

Leon, B., and Maddox, T. (2015): Diabetes and cardiovascular disease: Epidemiology, biological mechanisms, treatment recommendations and future research. World journal of diabetes, 6(13):1246–1258.

Lillioja, S., Neal, A., Tapsell, L. and Jacobs, D. (2013): Whole grains, type 2 diabetes, coronary heart disease, and hypertension: links to the aleurone preferred over indigestible fiber. BioFactors (Oxford, England), 39(3):242–258.

Ludvik, B., Neuffer, B. and Pacini, G. (2004): Efficacy of Ipomoea batatas (Caiapo) on diabetes control in type 2 diabetic subjects treated with diet. Diabetes Care; 27 (2): 436-440.

Magaña-Cerino, J., Tiessen, A., Soto-Luna, I., Peniche-Pavía, H., Vargas-Guerrero, B., Domínguez-Rosales, J. and Gurrola-Díaz, C. (2020): Consumption of nixtamal from a new variety of hybrid blue maize ameliorates liver oxidative stress and inflammation in a high-fat diet rat model. Journal of Functional Foods, 72:104075.

Marchesini, G., Brizi, M., Bianchi, G. and Tomassetti, S. (2001): Nonalcoholic fatty liver disease: a feature of the metabolic syndrome. Diabetes; 50: 1844-1850.

Montonen, J., Knekt, P., Järvinen, R. and Aromaa, E. (2003): Whole-grain and fiber intake and the incidence of type 2 diabetes. Am. J. Clin. Nutr., 77: 622-629.

Nagaraju R., Sobhana P., Thappatla D., Epparapalli S., Kandlakunta B. and Korrapati D. (2020): Glycemic index and sensory evaluation of whole grain based multigrain Indian breads (Rotis) Prev. Nutr. Food Sci. ;25:194–202.

Negm, S. (2020): Study of Glycemic Control by Ketogenic Diet Supplemented with Different Oils in Type II Diabetic Rats. J. Home Econ. 36 (2), 21-40.

Newby, P. Maras, J. and Bakun, P. (2007): Intake of whole grains, refined grains, and cereal fiber measured with 7-d diet records and associations with risk factors for chronic disease. Am. J. Clin. Nutr., 86: 1745-1753.

Nirmala. P. V., & Joye, I. J. (2020): Dietary Fibre from Whole Grains and Their Benefits on Metabolic Health. Nutrients, 12(10), 3045.

Ogle G., James S., Dabelea D., Pihoker C., Svennson J., Maniam J., Klatman E. and Patterson C. (2022): Global estimates of incidence of type 1 diabetes in children and adolescents: Results from the International Diabetes Federation Atlas, 10th edition. Diabetes Res. Clin. Pract. ;183:109083.

Oluwajuyitan, T. and Ijarotimi, O. (2019): Nutritional, antioxidant, glycaemic index and Antihyperglycaemic properties of improved traditional plantain-based (Musa AAB) dough meal enriched with tigernut (Cyperusesculentus) and defatted soybean (Glycine max) flour for diabetic patients. Heliyon,5(4): 501-504.

Ruiz-Rodriguez, A., Marı´n, F., Ocan˜a, A. and Soler-Rivas, C. (2008): Effect of domestic processing on bioactive compounds. Phytochem. Rev., 7: 345-384.

Sarkar S., Pranava M. and Marita R. (1996): Demostration of the hyperglycemic action of Momordica charantia in a validated animal model of diabetes". Pharmacol. Res; 33: 1- 4.

Shiriki, D., Igyor, M. and Gernel, D. (2015): Nutritional evaluation of complementary foods formulation from maize, soybean and peanut fortified with moringa oleifera leaf powder. Food & Nutritional Science, 6: 494-500.

Slavin, J. (2004): Whole grains and human health. Nutr. Res. Rev., 17, 99-110.

Sun, H., Saeedi, P., Karuranga, S., Pinkepank, M., Ogurtsova, K., Duncan, B. B., Stein, C., Basit, A., Chan, J., Mbanya, J., Pavkov, M., Ramachandaran, A., Wild, S., James, S., Herman, W., Zhang, P., Bommer, C., Kuo, S., Boyko, E. and Magliano, D. (2022): IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. Diabetes research and clinical practice, 183, 109119.

Van Hung, P. (2016): Phenolic Compounds of Cereals and Their Antioxidant Capacity. Crit. Rev. Food Sci. Nutr., 56: 25-35.

Wahlefeld, A. (1974): Triglycerides determination after enzymatic hydrolysis. In Methods of enzymatic analysis. Academic Press, 4(2):1831-1835.

Yamini, S. and Trumbo, P. (2016): Qualified health claim for whole-grain intake and risk of type 2 diabetes: An evidence-based review by the US Food and Drug Administration, Nutr. Rev., 74: 601-611.

Zizza, C. and Xu, B. (2012): Snacking is associated with overall diet quality among adults. J. Acad. Nutr. Diet; 112: 291-296.

الملخص العربي

تأثير الفشار المنتج من أصناف مختلفة من الذرة على الفئران المصابة بداء السكري والإجهاد التأكسدي

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تحتاج المنتجات الغذائية المصنوعة من المواد الخام ذات المؤشر الجلايسيمي المنخفض الى التعديل لضمان قدرتها على المساهمة في الكفاية الغذائية للأشخاص المصابين بداء السكري. تهدف هذه الدراسة إلى معرفة مدى فعالية الفشار المنتج من أصناف مختلفة من الذرة على نسبة الجلوكوز في الدم والإجهاد التأكسدي في الفئران المصابة بالسكري. تم تقسيم ثلاثين فأرًا إلى مجموعتين رئيسيتين: المجموعة الرئيسية الأولى (ن = ٦) تم تغذيتها علي النظام الغذائي الأساسي فقط كمجموعة ضابطة سالبة (-ve) ، المجموعة الرئيسية الثانية (ن = ٢٤) تكونت من فئران مصابة بالسكري، وتم إحداث داء السكري لها عن طريق حقنة واحدة داخل الغشاء البريتوني من مادة الاستربتوزوتوسين المحضر حديثًا (٦٠ ملجم / كجم من وزن الجسم)، وتم تقسيم تلك الفئران إلى ٤ مجموعات فرعية (عدد = ٦ لكل منها): المجموعة الفرعية (١): الفئران التي تم تغذيتها بنظام غذائي أساسي كمجموعة ضابطه موجبة. المجموعات الفرعية (٢-٤): تم تغذية هذه الفئران على نظام غذائي أساسي مدعم بنسبة ١٠٪ من الفشار المصنوع من الذرة الصفراء أو الذرة البلدي أو الذرة الهجين على التوالي ، أشارت النتائج إلى أن النظام الغذائي المدعم من الفشار المُصنع من أنواع مختلفة من الذرة أدي الي حدوث زيادة معنوية في وزن الجسم النهائي، معدل تناول الطعام ، معدل الزيادة في الوزن المكتسب مقارنة بالمجموعة الضابطة الموجبة. سجلت الفئران المعالجة بالفشار المنتج من أنواع الذرة المختلفة زيادة معنوية ($P<0.05$) في تركيز الأنسولين وانخفاض مستويات الجلوكوز وارتفاع في مستوي الانزيمات المضادة للأكسدة وتحسين في وظائف الكبد. تشير النتائج إلى أن الفشار المصنع من أنواع الذرة المختلفة يمكن أن يكون لهما دور علاجي في تحسين الإجهاد التأكسدي وتقليل مضاعفات السكري.

الكلمات المفتاحية: الفشار، مرض السكري، الإجهاد التأكسدي، الجلوكوز، صورة الدهون.