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Research Article

Ameliorative Effects of Sunflower Seeds Powder on High Fat Diet Induced Metabolic Changes in Wistar Rats

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ABSTRACT

Background: Obesity and prediabetes are reversible disorders affecting people globally with no sex predilection. They can progress to diabetes mellitus with resultant complications. Studies have shown greater involvement of high fat diets in the etiology of obesity and prediabetic conditions. Sunflower (*Helianthus Anuus*) extracts with an LD50> 5000mg/kg has been found to be effective in reducing high blood sugar levels in both human and animal studies. Sunflower seed powder was used in this study to investigate its effects on high fat diet (HFD) induced metabolic changes in Wistar rats.

Methods: A total of 27 male Wistar rats (350 - 400 grams) were used for this study. They were randomly assigned to 9 groups of 3animals each and were fed for 6 weeks. Group 1 served as control (water and feed ad libitum) Group 2 (high fat diet alone); Group 3 (HFD + 5000mg/kg of sunflower seed concurrently); Group 4 (HFD + 3000mg/kg of sunflower seed concurrently); Group 5 (high fat diet + 2000mg/kg of sunflower seed concurrently); Group 6 (HFD for 5 weeks + 5000mg/kg of sunflower seed for 1week); Group 7 (HFD for 5weeks + 3000mg/kg of sunflower seed for 1wk); Group 8 (HFD for 5 wks + 2000 mg of sunflower seed for 1wk); Group 9 (HFD for 5 wks + 70mg/kg Metformin for 1 week). Animals were anesthetized with ketamine and blood collected via cardiac puncture. Blood glucose measurement was done using the glucose oxidase method and plasma insulin levels were measured using ultra sensitive rats Insulin ELISA kit marketed by Crystal chem, specificity 100% and sensitivity, 0.05 ng/ml, serum glycated albumin and haemoglobin was measured using the Variant TMIIT urbohigh-performance liquid chromatography system. Harvested pancreatic tissues were fixed in 10% formalin for histomorphological analyses.

Results: Blood glucose, plasma glycated haemoglobin in the HFD only group were significantly higher ($p<0.05$) compared to control and other groups. The sunflower treated groups with 5000mg, 3000mg and 2000mghad significantly decreased ($p<0.05$) insulin levels compared to control group and similar to metformin and HFD alone groups. Pancreatic histology results showed that HFD caused significant destruction of islet cells which was preserved in the sunflower co-administered groups.

Conclusions: Sunflower seed significantly reduce blood sugar level, reduced HbA1c, and conferred cyto-protection on islets of Langerhan cells.

1. Introduction

Over-weight and obesity results from accumulation of fats in the body. Recently, increasing fat to fiber ratio in the western diet is now considered among the major triggering factors of metabolic impairments such as obesity and pre-diabetes and diabetes (Aurelie et al., 2019). Eating lots of fats (> 40 grams per /kg / day) increases the risk of metabolic disorders (NIH 1995), but the mechanisms behind the problems have not wellbeing understood. Rehman et al., (2021) showed that more than half of the global population is expected to be overweight or obese by 2035. Sunflower (Helianthus annuus) is an annual herb with a rough hairy stem, fine flowers and seeds valuable from an economic as well as from ornamental point of view, both root and seeds are good for consumption; it is readily available in Nigeria and other countries in Africa, America and Asia (Ankit et al., 2019). It is called Orangila in Igbo, Tozalin in Hausa and Yunyum in Yoruba and Edemedong in Efik languages in Nigeria. The seed is under-researched despite its potential benefits derivable fromconstituents like phenolic acids, cardiac glycoside, flavonoids, tocopherols, tannins, saponins and terpenes (Adeneye 2012; Hansa et al.,2020). A protein complex called chlorogenic acid, which is readily available in sunflower seeds when chewed has been shown to have hypoglycemic and hypolipidemic effects (Yongwang et al., 2020). Supplementation of the sunflower seeds in diabetic patients have been found to be beneficial in significantly lowering blood sugar levels, with very minimal adverse effects (Guo et al., 2017). High fat diet fed at libitum has been found to cause insulin resistance and elevate HbA1c which are biomarkers for prediabetes that can progress to diabetes mellitus, which hasn't been given the required attention compared to other progressive medical conditions in Nigeria example HIV and sunflower seeds chewed raw or fried have been found to be effective in reducing plasma glucose in both human and animal studies, why this study sought to investigate the effects of sunflower seed powder on blood glucose, insulin level, HbA1c, serum glycated albumin and histo-morphology of pancreatic tissues in rats.

2. Materials and Methods

2.1. Animal Management

A total of 27 male Wistar rats, 14-16 weeks old, weighing 350-400 g were obtained from the Animals House, College of Health Sciences Benue State University Makurdi. Animals were kept in plastic cages containing freshly made 1kg sawdust for beddings and were allowed to acclimatize for 2 weeks before commencement of the experiment. The rats were maintained in a standard condition at room temperature (27 ± 2°C) and relative humidity (50 ± 5 %), with 12 hours Light / dark cycle. They were divided into nine groups of three animals each in a cage as follows:

Group 1 (Control): Received normal rat chow plus water, and rat were allowed to feed ad libitum) - for six weeks.

Group 2 (Pre-diabetic model): Received HFD 20g / kg body weight, per rat / day, + 20g/kg of normal rat chow per rat/day mixed completely together and animals were allowed to feed ad libitum) for six weeks.

Group 3: Received HFD 20g per kg body weight, per animal plus sunflower seeds powder 5000mg / kg body weight, per animal / day, concurrently, mixed completely together and animals were allowed to feed ad libitum).

Group 4: Received HFD 20g per / kg body weight per animal plus sunflower seeds powder 3000 mg / kg body weight, per rat / day (composed of 20g HFD + 3 g sunflower powder per kg/rat) concurrently, mixed completely together and rats were allowed to feed ad libitum).

Group 5: Received HFD 20g per / kg body weight per rat plus sunflower seeds powder 2000 mg / kg body weight, per rat / day (composed of 20g HFD + 2 g sunflower powder per kg/rat), concurrently, mixed completely together and rats were allowed to feed ad libitum).

Group 6: Received HFD 20g per / kg body weight per rat, alone for 5 weeks. Then, after 5 weeks of 20g HFD alone, rat, received sunflower seeds powder 5000 mg /kg body weight per rat / day + normal rat chow 20g / kg body weight per rat / day (composed of 20g of rat chew + 5 g sunflower powder per kg/rat for one week only) measured and mixed completely together and rats were allowed to feed ad libitum for one week.

Group 7: Received HFD 20g per / kg body weight / animal, alone for 5 weeks. Then after 5 weeks of 20g HFD alone, rat, received sunflower seeds powder 3000 mg /kg body weight per rat / day + normal rat chow 20g / kg body weight per rat / day (composed of 20g of rat chew + 3 g sunflower powder per kg/rat for one week only) measured and mixed completely together and rats were allowed to feed ad libitum for one week.

Group 8: Received HFD 20g per / kg body weight / rat, alone for 5 weeks. Then after 5 weeks of 20g HFD alone, rat, received sunflower seeds powder 2000 mg /kg body weight per rat / day + normal rat chow 20g /kg body weight per rat / day (composed of 20g of rat chew + 2 g sunflower powder per kg/rat for one week only) measured and mixed completely together and rats were allowed to feed ad libitum for one week.

Group 9: Received HFD 20g per / kg body weight / rat alone for 5 weeks. Then after 5 weeks of 20g HFD alone, rat received Metformin 70 mg / kg body weight per rat / day+ 20g / kg body weight per animal / day of normal rat chow measured and mixed completely together and animals were allowed to feed ad libitum for one week.

2.2. Ethical Approval

Ethical clearance for the use of animals for experiment was obtained from the ethical committee in the College of Health Sciences, Benue State University, Makurdi (THS REC No: CREC/THS/002). The sunflower seeds were submitted to the Botany Department, Benue state university for identification and sample was placed at the herbarium, with voucher number, HBI - 001-BSU23.

2.3. Sample collection and tissue harvesting

Weekly tail blood (using needle prick) was used to measure blood glucose levels and recorded for six weeks. After six weeks of the experiment, the mixture of isoflurane 30% (inhalational anesthesia) by API Manufacturer with FDA, UK. Marketed by Macfes medical store, high level Markurdi, Benue State, Nigeria. And 3.5% isoflurane (of the mixture of isoflurane 30%) at 100% oxygen was soaked in a cotton wool and dropped in clean and covered plastic container, and was used to anesthetized the rats, for the purpose of collecting blood from the rats by cardiac puncture, into the EDTA sample bottles, using 23G needles and 10 ml syringes and the sample was used for measurement of plasma insulin, glycated haemoglobin (HbA1c), glycated albumin and pancreatic tissues were harvested and used for histological analyses.

2.4 Serum Insulin Estimation

The A commercially available kit (Ultra sensitive rats Insulin ELISA, 10 kit pack, marketed by Crystal chem) specificity, 100% for rat insulin and sensitivity, 0.05 ng / ml, was used to quantify the amount of insulin in the plasma. This test uses a 96-well plate covered with an antibody that is specific for rats insulin, was assessed using these material 96 Tests, Microwell coated with ultra sensitive rats Insulin Standard 1: 1 vial (ready to use) 2 mL Insulin Standards 2-6: 5 vials (ready to use) 1 mL Insulin Enzyme Conjugate: 1 vial 1 mL Assay Diluent: 1 bottle (ready to use) 14 mL TMB Substrate: 1 bottle (ready to use) 12 mL Stop Solution: 1 bottle (ready to use) 12 mL 20x Wash concentrate: 1 bottle 25 ml.

2.5 Serum glycated albumin

Wire Measured enzymatically using an albumin-specific proteinase (keto amine oxidase) and albumin assay reagent (LUCICAGAL; Asahi Kasei Pharma Co., Tokyo, Japan) with a Hitachi7699P-moduleauto-analyzer (Hitachi Instruments Service, Tokyo, Japan).

2.6. HbA1c

Glycated haemoglobin was measured using the Variant TMIIT urbohigh-performance liquid chromatography system from Bio-Rad Laboratories in Hercules, California, USA. The normal limit for glycated haemoglobin is 11%to16% and HbA1c is 4.0% to 6.0% (Andrea et al., 2022).

2.7. Pancreatic Histology

The tissues were processed using processing schedule. The fixed plastic cassette tissues in 10%formalin were automatically processed by passing them through different grades of alcohol asfollows:70%alcohol2hrs 80%alcohol 2hrs 90% alcohol 2hrs 90% alcohol 2hrs 95% alcohol 2hrs Absolute 2hrs Xylene 1 2hrs Xylene II 2hrs Molten paraffin wax 1 2hrs Molten paraffin Wax II 2hrs.The tissues were taken out of their plastic cassettes after the final time, positioned in the center of the metallic tissue mold, and then filled with molten paraffin wax. Additionally, they were

allowed to firm before being put in the fridge at 5oC for 15 minutes. The blocks were taken from the metallic casing with a knife after cooling in the refrigerator for the previously mentioned (15 minutes), and the paraffin wax at the side of the blocks was then scraped off. On a rotary microtome, the blocks were then trimmed and sliced serially at 3 m. The sections were floated in water bath at 55oC and picked up by the use of a clean frosted end slides. The frosted end slides were now placed on the hot plate for 40 minutes for adequate attachment of the sections on the slides after which the sections were de-waxed, hydrated, air dried and stored in a slide box ready for staining process. The pancreas tissue sections for general tissue structure were stained by Haematoxylin plus Eosin technique. A single pancreas section was made per pancreas and were de-waxed in xylene and hydrated through descending grades of alcohol (absolute, 95%, 80% and 70%). The sections were stained in Harris haematoxylin for 5 minutes, rinsed in running tap-water to remove excess stain and differentiated in 1% acid alcohol for 3 seconds, counterstained with 1% eosin for 60 seconds. Sections were finally rinsed in water, dehydrated in ascending grades of alcohol (70%, 80, 95% and absolute) and cleared in xylene, air-dried and mounted with dibuthylphthalate propylene xylene (DPX) and slides were examined under a light microscope and photomicrographs were taken, at 400 x magnification.

2.8. Compounded High Fat Diet Meal

Assays High Fat Diet (HFD) was constituted locally. The formula was made from chow, tallow and soy oil at an inclusion rate of 60%, 25% and 15% respectively. The total caloric value of the diet was about 5340kcal/kg. The fat component comprises of 60% saturated and 40% unsaturated fat (Abi et al., 2018).

2.9. Statistcal Analysis

Serum Results were presented as mean ± SD. Differences between two groups was determined using independent t test, while differences between more than two groups was determined using One-Way ANOVA with Tukey post hoc test. Differences were considered significant when $P < 0.05$ Data were analyzed using SPSS version 23.0 software.

3. Results

3.1. Effect of Sunflower Seed Consumption on Blood Glucose in Rats Fed with High Fat Diet

Table 1 shows that sunflower seeds at a dose of 2000mg, 3000mg or 5000mg / Kg body weight for the period of one week after five weeks of high fat diets (HFD) significantly ($P < 0.05$) reduced blood glucose levels similar to metformin at the dose of 70mg / kg in rats. Likewise, consistent consumption of high fats diet alone for six weeks without sunflower seeds or metformin at the same dose caused an increase in blood glucose levels in rats

Groups	Initial (mmol/L)	Week 1 (mmol/L)	Week 2 (mmol/L)	Week 3 (mmol/L)	Week 4 (mmol/L)	Week 5 (mmol/L)	Week 6 (mmol/L)
Group 1	4.70 ± 0.10	4.90 ± 0.06	5.00 ± 0.17	5.97 ± 0.09·	5.72 ± 0.23·	5.83 ± 0.32*	5.93 ± 0.32·
Group 2	6.93 ± 0.07·	7.13 ± 0.07·	7.83 ± 0.12¬	8.00 ± 0.00·	8.17 ± 0.03¬	8.13 ± 0.07¬	8.27 ± 0.07¬
Group 3	6.23 ± 0.20·	6.63 ± 0.54·	6.10 ± 0.10¬◦	6.40 ± 0.21 ◦	6.27 ± 0.15 ◦	5.97 ± 0.20 ◦	6.00 ± 0.42 ◦
Group 4	6.30 ± 0.11·	6.37 ± 0.12·	5.47 ± 0.12·◦	5.57 ± 0.07·◦	5.23 ± 0.09·◦	5.23 ± 0.09·◦	5.23 ± 0.03·◦
Group 5	5.33 ± 0.35◦	5.43 ± 0.30 ◦	5.83 ± 0.88¬◦	5.67 ± 0.17 ◦	5.90 ± 0.06 φ	6.07 ± 0.22 ◦	5.40 ± 0.32 ◦
Group 6	6.97 ± 0.03·	7.23 ± 0.03·	7.33 ± 0.07¬◦	7.47 ± 0.03¬	7.27 ± 0.07·	7.57 ± 0.19#	5.83 ± 0.17 ◦
Group 7	6.97 ± 0.03·	7.23 ± 0.03·	7.33 ± 0.07¬◦	7.47 ± 0.03¬	7.27 ± 0.07¬	7.56 ± 0.19¬	5.83 ± 0.09◦
Group 8	6.97 ± 0.03#	7.27 ± 0.03·	7.37 ± 0.07¬◦	7.43 ± 0.03¬	7.40 ± 0.00*#	7.40 ± 0.12¬	6.13 ± 0.13·◦
Group 9	7.13 ± 0.09#	7.33 ± 0.09·	7.33 ± 0.09¬◦	7.50 ± 0.12¬	7.30 ± 0.10¬	7.20 ± 0.12¬	5.03 ± 0.03·◦

Table 1: Weekly non-fasting Blood Glucose concentration.

n = 3, Values presented Mean SEM., * = significantly relative to initial value in same group at $P < 0.05$, # = significantly relative to Group 1 in same week at $P < 0.05$, φ = significant relative to Group 2 in same week at $P < 0.05$

3.2. Effect of sun flower seed on plasma insulin levels

Figure 1 shows the effect of sunflower and HFD on plasma insulin levels. The results showed that HFD only, significantly ($P < 0.05$) reduced plasma insulin levels. Rats fed with sunflower seed extract at a dose of 3g / kg body weight after 5 weeks of HFD significantly increased the insulin levels ($P > 0.05$) compared to HFD only fed rats having similar effect to the standard drug metformin**.**

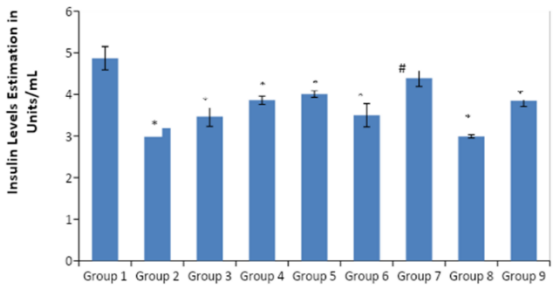

Fig. 2 Transfer Latency Across the Groups
Figure 1: Insulin Levels Estimation n = 3, Values presented Mean SEM., * = significantly relative to Group 1 at P < 0.05, # = significantly relative to Group 2 at P < 0.05

3.3. Effect of sun flower seed on serum glycated haemoglobin (HbA1c).

Figure 2 showed that rats fed on HFD alone hada significant (P < 0.05) increase in HbA1c compared to control. Sunflower seed co-administered with HFD significantly (P < 0.05) reduced the serum HbA1c level. Also, HbA1c levels were significantly lowered in rats that fed sunflower seed powder after 5 weeks of HFD when compared with rats fed with HFD alone.

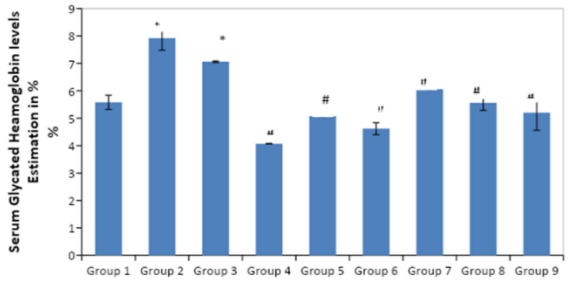

Fig. 2 HbA1c. n = 3, Values presented Mean SEM., * = significantly relative to Group 1 at P < 0.05, # = significantly relative to Group 2 at P < 0.05.

3.4. Effect of sun flower seed on serum glycated albumin levels

Figure 3 showed that the HFD and sunflower seed extract had no effect on serum glycated albumin (P > 0.05) across the groups

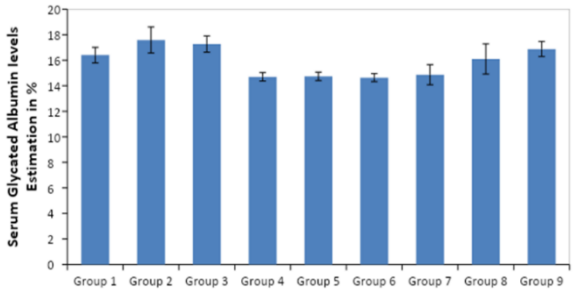

Fig. 3 Glycated Albumin. n = 3, Values presented Mean SEM

3.5. Pancreatic Histology

Effect Of Helianthus annuus seed onsumption On pancreatic histology in HFD fed fats (using a microscope at 40 x and 100 x view by Amure Okonkwo histopathologist UTH- Ibadan, Nigeria**.**

3.6. Histology Scoring System

Was based on pancreatic damage (Tandi et al., 2017).

Score 0 for normal cells size, cell numbers, normal boundaries and shapes

Score 1 for clear cells boundaries but decreased cells numbers and cell degeneration but normal cell shapes

Score 2 for unclear cells boundaries, decreased cells numbers, cell degeneration and abnormal cell shapes.

Score 3 for unclear cells boundaries, decreased cells number, cell necrosis are visible and abnormal cell shapes.

Score 4 for very unclear boundaries, cells number greatly reduce, cell necrosis are visible and abnormal cell shapes.

Two photomicrographs, used to represent each group as follows:

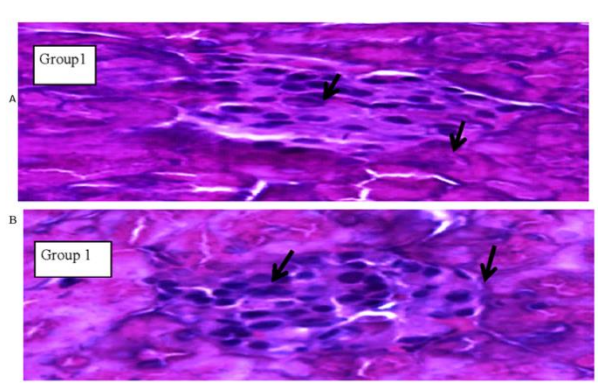

Plate 1 (A&B) Pancreas histology in control group, the rats were fed on rat feeds and water *ad Libitum*. Showing normal islet cells of Langerhans,boundaries, number cells and cells shapes. showed by the short arrows (➔) Score = 0

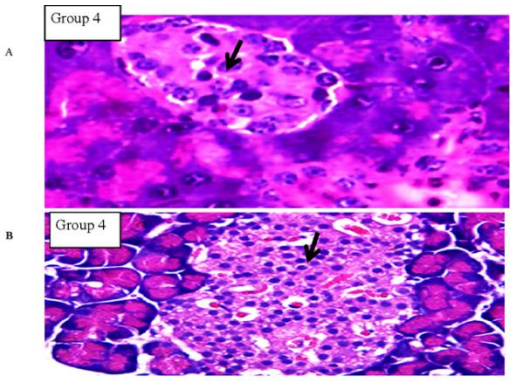

Plate 4 (A&B):Pancreas histology in groups 4 rats, fed with sunflower seed powder 3000mg / kg body wt. along with 20 g / kg of HFD for six weeks, showed normal size of islet cells Langerhans, abnormal boundaries, no necrosis but have normal cells shapes ➔ .Score =1

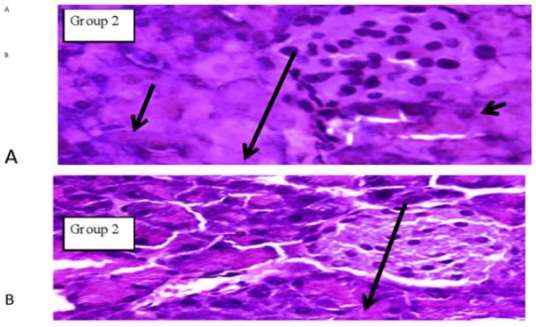

Plate 2 (A&B): Pancreas histology in HFD alone group. Showing areas of Necrosis, with long arrows ⟶ , reduce cells number and abnormal cells boundaries and shapes with short arrow ➔ . Score = 3

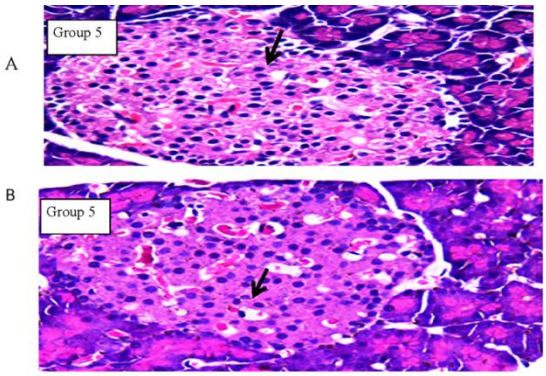

Plate 5 (A&B): Pancreas histology in group 5 rats, fed with sunflower seed powder 2000mg /kg body weight along with 20g / kg of HFD for six weeks, showed normal size of islet cells of Langerhans, abnormal boundaries, no necrosis but have normal cells shapes ➔ . Score =1

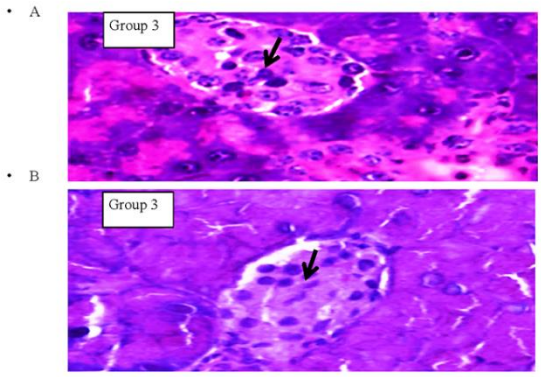

Plate 3 (A&B): Pancreas histology in groups 3 rats, fed with sunflower seed powder 5000mg / kg body wt. along with 20g /kg of HFD for six weeks, showed normal size of islet cells Langerhans, abnormal boundaries, no necrosis but have normal cells shapes , Score =1

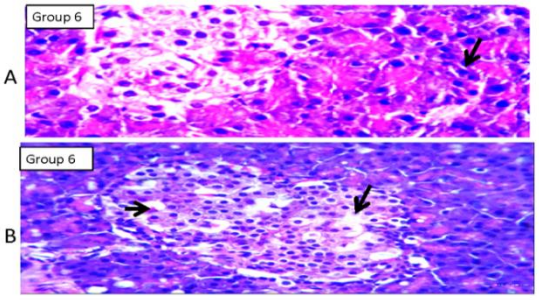

Plate 6 (A&B): Pancreas histology in group 6 rats, fed with sunflower seed powder 5000 mg /kg body weight for a week, after been fed for five weeks with 20 g /kg of HFD, showed cells degeneration, abnormal boundaries ➔ , but normal shapes and no necrosis Score = 2

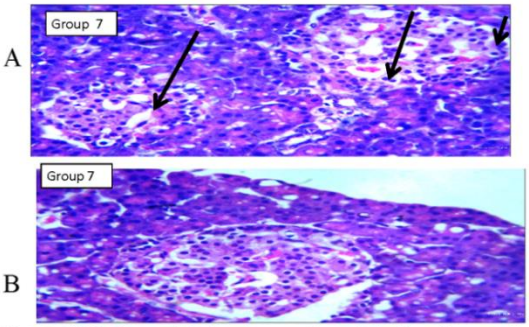

Plate 7 (A&B): Pancreas histology in group 7 rats, fed with sunflower seed powder 300mg / kg body weight after been fed for five weeks with 20g /kg of HFD. showed cells degeneration ↓, abnormal boundaries →, but normal shapes and no necrosis Score = 2

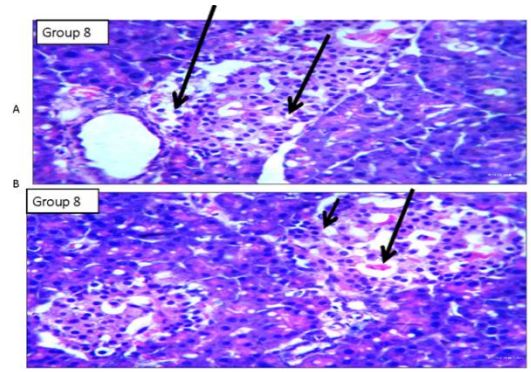

Plate 8 (A& B): Pancreas histology in group 8 rats, fed with sunflower seed powder 2000mg / kg body weight for a week, after been fed for five weeks with 20g /kg of HFD. showed cells degeneration, Showed by long arrow , abnormal boundaries but abnormal shapes and no necrosis. Score = 2

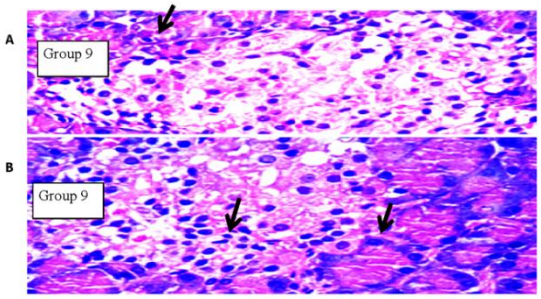

Plate 9 (A&B): Pancreas histology in group 9 rats, were given experimental drug (metformin) 0.07g / kg body weight after been fed for five weeks with 20g /kg of HFD, showing clear boundaries, normal number of islet cells of Langerhans, normal cells shapes at pointed short arrows (➔) above. Score = 0

4. Discussion

In this This study sought to investigate the effect of sunflower seed extract on metabolic parameters in HFD fed rats. Studies have shown that prolonged intake of HFD can cause hyperglycemia (Ikemoto et al., 1996; Abi et al., 2018; Caique et al., 2020; Prasad et al 2022;) This study also showed similar findings. Sunflower seed extracts supplementation at 2 g, 3 gand 5 g / kg body weight for up to six weeks was found to significantly ($P < 0.05$) ameliorate the hyperglycaemia caused by HFD in rats. This effect was similar to the effect of metformin (Table 1). This demonstrates a protective role by the sunflower seed against the deleterios hyperglycemic effect of HFD in experimental rats. This finding agrees with other reports that showed sunflower seed as possessing both anti-glycative and anti-lipid properties in both humans and animals (Sun et al., 2012; Rehman et al 2021). Sunflower seeds inhibit and play a defensive role against advanced glycation end products (AGEs) regeneration when non-enzymatic glycation occurs between sugar and protein. But when advanced glycation end products (AGEs) accumulated, they are the major contributors to diabetes under hyperglycemic condition.

Similarly, sunflower seeds ameliorated the suppressed insulin levels caused by HFD. Feeding the rats with high sunflower seed powder at a dose of 3 g / kg body weight per rat / day after 5 weeks of HFD significantly ($P < 0.05$) increased the plasma insulin levels similar to metformin (Figure 1). This agrees with the work done by Shuangshaug et al. (2017), who demonstrated that sunflower seeds prevent insulin resistance seen in prediabetes and in type 2 diabetes by increasing plasma levels of un-bound insulin and enhancing normoglycemia, Glycated albumin in blood was generally unaffected by sunflower seed in this study. Glycated albumin has been known to be elevated in a case of long standing hyperglycemia, like in the case of diabetes mellitus with constantly chronic elevated blood glucose level.

The impact of sunflower seed on glycated heamoglobin (HbA1c) was also studied in this work. High fat diet was found to significantly elevate HbA1c level in rats. Concurrent administration of sunflower seed significantly ($P < 0.05$) reduced the HbA1c level in the HFD fed rats (Figure 2). The sunflower seed was also found to have a therapeutic benefit as it was found to significantly ($P < 0.05$) lower HbA1c level in the rats after 5 weeks of HFD. This agrees with the work of other researchers who demonstrated that sunflower seeds reduce insulin resistance in

prediabetes and decrease risk of developing type 2 diabetes. This is due to increase in insulin secretion and release of un-bound insulin and prevention of stored glucose inform of HbA1c. Also, sunflower seeds contain chlorogenic acid which is an inhibitor of glucose -6- phosphate translocase (Karamac et al.,2012; Jiang, et al., 2016; Rehman, et al., 2021). Glycated albumin in blood was generally unaffected by sunflower seed in this study (Figure 3).

Animals fed on HFD alone showed significant ($P < 0.05$) necrosis, reduced cells number and abnormal cells boundaries of islet cells (Plate 3) when compared to control (Plate 1), The rats fed with sunflower seeds at a dose of 2000mg, 3000mg and 5000mg / kg body weight per rat / day were found to have a protective role when co-administered with HFD (Plate 4). It helped maintain the normal histology of the islet cells of Langerhans similar to metformin (Plate 2). The administration of sunflower seed after 5 weeks of HFD did not show much benefit in terms of restoration of the islet cells (Plate 5).

This finding agrees with a recent finding by Wijayanti et al. (2023) that showed pancreatic islets cells repair in streptozotocin induced hyperglycemic rats when treated with an enteral formula containing sunflower seed flour. A comparative study by Roche et al. (2014) showed that rats fed on a lifetime diet of sunflower seed oil had significantly higher pancreatic β-cell numbers and insulin production compared to other oils.

5. Conclusion

This Sunflower seed significantly ($P < 0.05$) reduced blood sugar and HbA1c levels in HFD fed rats. This amelioration was attributed to its ability in reducing insulin resistance. Also, sunflower seed was found to largely protect the pancreatic islet cells from the severe necrotic damage induced by the HFD. Even though the protective effect is minimal when sunflower seed is used as a therapeutic agent. These findings provide valuable insights into the potential role of sunflower seed in ongoing quest for pre-diabetes and diabetes management. Sunflower seed research will be valuable in the management of metabolic disorders.

Recommendation

There will be need for gene expression (INS, INRs, GLUT-2 and IGF-1 genes) and possible clinical studies in future research.

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Limitations of the study

Unavailability of resources to study on the phytochemical components of sunflower seeds

Conflicts of Interests

None to report.

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