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ASSESSMENT OF AQUEOUS EXTRACT OF *SORGHUM BICOLOR* AND *PENNISETUM GLAUCUM* SEEDS IN AMELIORATING DIABETES IN ALLOXAN-INDUCED HYPERGLYCEMIC WISTAR RATS

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ABSTRACT

Background: To the best of our knowledge, there is a lack of scientific data on the traditional folkloric use of Sorghum bicolor and Pennisetum glaucum at dosages of 750 and 1000 mg/kg body weight by individuals with diabetes, which motivated the present investigation.

Aim: To evaluate the antidiabetic potentials of aqueous extract of *Sorghum bicolor* and *Pennisetum glaucum* seed in alloxan-induced hyperglycemic rats.

Materials and Methods: Forty nine albino rats of both sexes were divided into seven groups (A-G) of 7 rats each. Animals in group A (control) received distilled water while those in groups B-G which were induced into hyperglycemia by intraperitoneal injection of alloxan monohydrate (150 mg/kg body weight) received distilled water, 25 mg/kg body weight of glibenclamide (reference antidiabetic drug), 750 mg/kg body weight of *S. bicolor*, 1000 mg/kg body weight of *S. bicolor*, 750 mg/kg body weight of *P. glaucum* and 1000 mg/kg body weight of *P. glaucum* respectively. Extract administration of 0.5 ml was done once daily for 21 days after which blood glucose level, selected biochemical parameters and pancreatic histology were determined.

Results: *S. bicolor* and *P. glaucum* contains alkaloids, tannins, saponins, carbohydrates, phenols and glycosides. Triterpenes and steroids are present in *P. glaucum* only while cardiac glycosides are present in *S. bicolor* only. The proximate composition of *S. bicolor* and *P. glaucum* in '%' are moisture content (6.57±0.09; 12.03±0.15), crude protein (11.27±0.15; 7.81±0.15), ash content (0.30±0.01; 2.20±0.11), crude fibre (3.32±0.02; 2.10±0.15), fat (3.27±0.15; 3.93±0.04), carbohydrates (75.23±1.19; 71.90±0.21) respectively. The amino acid content of *S. bicolor* and *P. glaucum* in 'g/100g protein' are (leucine: 13.72; 9.80), (lysine: 2.36; 3.70), (isoleucine: 4.00; 4.40), (phenylalanine 4.80; 5.15), (tryptophan: 1.21; 1.97); (valine: 5.40; 5.55), (methionine: 1.95; 2.46), (proline: 9.14; 6.50), (arginine: 4.82; 5.33), (tyrosine: 3.95; 3.44), (histidine: 2.17; 2.55), (cysteine: 2.20; 2.50), (alanine: 9.29; 7.75), (glutamate: 20.74; 19.68), (glycine: 3.18; 3.85), (threonine: 3.19; 3.83), (serine: 4.40; 4.60), (aspartate: 7.50; 8.00) respectively. Alloxan induction significantly ($p<0.05$) increased the levels of blood glucose (BG), feed intake (FI), as well as activities of glucose-6-phosphatase, α-amylase. Administration of alloxan significantly ($p<0.05$) decreased the levels of insulin, total protein (TP), body weight (BW), as well as the activities of hexokinase, catalase (CAT), superoxide dismutase (SOD) and phosphofructokinase (PFK) in the serum of the animals. However, when compared with the distilled water treated diabetic animals, treatment of hyperglycaemic/diabetic animals with the aqueous extract of both *S. bicolor* and *P. glaucum* seed at 750 and 1000 mg/kg body weight which significantly ($p<0.05$) decreased the levels of BG, FI,

as well as activities of glucose-6-phosphatase, α-amylase, increased insulin, TP, BW, HDLC as well as activities of hexokinase, and PFK in the serum of the animals, in a manner comparable with the glibenclamide treated diabetic animals.
Conclusion: This study revealed that *S. bicolor* and *P. glaucum* seed exhibited antidiabetic activity against alloxan-induced diabetes and scientifically validated the folkloric use of the plant in the management of diabetes with the best effect at 1000 mg/kg body weight of *P. glaucum* seed. It could also be explored in the control of some of the metabolic dysfunctions normally associated with diabetes. Alkaloids, tannins, saponins, essential amino acids: lysine, valine, leucine, methionine, isoleucine, arginine, histidine might have acted singly or synergistically to produce the desired pharmacological effects.
Keywords: *Sorghum Bicolor, Pennisetum Glaucum,* Hyperglycemia, Alloxan-Induced Diabetes.

1.0 INTRODUCTION

Diabetes mellitus (DM) is often called a "silent" disease because it can progress for years before clinical detection, and it now represents one of the fastest-growing threats to public health worldwide. The global burden of diabetes has risen markedly over the past decade: recent estimates indicate that roughly **589 million adults (ages 20–79)** are living with diabetes, with further increases projected in coming decades if preventive measures are not scaled up. A substantial proportion of people with diabetes remain undiagnosed, contributing to delays in care and higher risk of complications (International Diabetes Federation [IDF], 2024; World Health Organization [WHO], 2024).

Diabetes is not a single disease but a group of metabolic disorders characterized by chronic hyperglycemia and related clinical features such as polydipsia, polyuria, unexplained weight loss, and—in severe cases—ketonemia/ketonuria. Long-term hyperglycemia causes microvascular and macrovascular complications including coronary artery disease, stroke, neuropathy, nephropathy (which can progress to renal failure), diabetic retinopathy (which can lead to visual impairment and blindness), and increased risk of lower-limb amputations. Diabetes is also commonly accompanied by metabolic abnormalities such as hypertension, dyslipidemia (elevated triglycerides and LDL cholesterol), and increased oxidative stress; these metabolic derangements contribute to tissue damage across organ systems. The pathophysiology that links chronic hyperglycemia to organ damage involves oxidative stress, inflammation, and formation of advanced glycation end products (AGEs). (Magliano *et al*., 2021; Yeh *et al*., 2016; Umpierrez & Pasquel, 2017).

There is growing interest in identifying novel, affordable therapies and functional foods that may help prevent or manage diabetes, and cereal grains are an important area of study. **Sorghum bicolor L. Moench** is among the world's major cereals and provides both food and feed in many regions. Sorghum grain and flour are rich in phytochemicals—tannins, phenolic acids, anthocyanins and other polyphenols, phytosterols, and policosanols—that have documented antioxidant, hypocholesterolemic, and potential antidiabetic properties. Several animal and cell studies have reported that sorghum extracts can improve insulin sensitivity and reduce fasting

glucose and serum lipids; systematic reviews of sorghum phytonutrients also highlight antioxidant and metabolic benefits, although human evidence remains limited and heterogeneous. These data suggest that sorghum phytochemicals may contribute to improved glycemic control and cardiovascular risk profiles when incorporated into diets or when concentrated extracts are used in experimental settings (Park *et al*., 2012; de Oliveira *et al*., 2024; Olawole *et al*., 2018).

Pennisetum glaucum (pearl millet) is widely cultivated in arid regions of Africa and Asia. Millet seed coats and whole grains contain substantial amounts of phenolics, flavonoids, polymeric tannins and anthocyanins, as well as phytates and minerals. Experimental studies show that millet polyphenols and related compounds can inhibit carbohydrate-digesting enzymes—pancreatic α-amylase and intestinal α-glucosidase—thereby slowing starch digestion and reducing postprandial glycemic excursions. Traditional millet-based foods are associated with lower glycemic responses and greater satiety compared with many refined cereal products, making them promising dietary components for glycemic management (Chethan & Malleshi, 2007; Jacob *et al*., 2024; Vidhyalakshmi, 2024).

Dietary polyphenols and phytates reduce carbohydrate digestibility through enzyme inhibition and by forming complexes with starches; they also exhibit antioxidant activity and can interfere with AGE formation—mechanisms that are plausibly protective against diabetes-related oxidative damage. While preclinical and some human studies are encouraging, more randomized clinical trials are needed to define effective doses, preparations (whole grain vs. bran vs. extract), and long-term safety and efficacy for diabetes prevention and management (Ayua *et al*., 2021; Yeh *et al*., 2016).

DM remains an accelerating global public-health challenge, and cereal grains such as sorghum and pearl millet—rich in polyphenols and other bioactive components—are promising candidates for dietary strategies or nutraceutical development aimed at reducing diabetes risk and ameliorating metabolic complications. However, while mechanistic and animal data are strong, well-designed human studies are still required to translate these findings into clinical practice and public-health recommendations.

Thus, this study will investigate the hypothesis that a Sorghum extract and millet extract has antidiabetic effects through a mechanism that improves insulin sensitivity.

2.0 MATERIALS AND METHODS

2.1 Plant materials and authentication

Plant materials were collected by the researcher at Karu Nasarawa state Nigeria and were sent to National Cereals Research Institute (NCRI) Badegi, Bida, Niger State Nigeria for authentication.

2.2 Experimental animals

Adult Wistar rats (*Rattus norvegicus*) were purchased from NVRI Vom Plateau State Nigeria. They were kept under laboratory conditions before being used in experiments. The Wistar rats

were housed in laboratory cages fed with pellets and were watered *ad libitums*. The animals were allowed a 14-day period of acclimatization.

2.3 Assay kits, chemicals and drugs

The assay kits for the determination of liver function, kidney function, lipid profile, selected biomolecules and carbohydrates metabolizing enzymes were products of Randox Laboratory Ltd, Co-Atrim, UK. Alloxan monohydrate (1, 3-diazinane-2, 4, 5, 6- tetrone) and glibenclamide were products of Kemei Laboratories Ltd., Mumbai, India and May and Bayer Ltd., Dagenham, England respectively. Other chemicals include: Normal saline**,** glacial acid, o'toludine reagent**,** sulphuric acid**,** catalyst mixture**,** distilled water**,** sodium hydroxide**,** boric acid**,** hydrochloric acid**,** petroleum ether**,** trichloroaceatic acid**,** glacial acetic acid**,** nitric acid**,** absolute ethanol**,** chloroform/ethanol mixture**,** acetate buffer**,** ethanol**,** ammonium thiocyanate**,** iron chloride solution**,** potassium permanganate**,** oxalic acid**,** methyl red indicator**,** calcium chloride.

2.4 Glucometer and test strips

One Touch Blood Glucose Monitoring System (glucometer) and On-Call-Redi Blood Glucose Test Strips were products of Schiffgraben Diagnostic, Hannover, Germany and Acon Laboratories Inc., San Diego, USA respectively.

2.5 Preparation of aqueous extract of *Sorghum bicolor* and *Pennisetum glaucum* seed

The plants were grounded first into coarse form using a pestle and mortar and then reduced to a powdery form using a mill. The powdery plant materials (150g) were separately soaked in 500ml of distilled water each for 6hours with constant stirring. The extracts were centrifuged and the supernatant were concentrated using a water bath. The concentrated extracts were dried under room temperature. The extracts were weighed, stored in specimen jars and used in the preparation of the stock extract for administration.

2.6 Screening of aqueous extract of *Sorgum bicolor* and *Pennisetum glaucum* for secondary metabolites

2.6.1 Phytochemical Screening

Phytochemical screening of the plant extracts was carried out to assess the concentration of each plant sample using standard methods (Harborne, 1989; Trease and Evans, 1989: Sofowora, 1993).

Determination of proximate content

The proximate content was carried out using AOAC (2005) procedures in the Central Services Laboratory, National Cereals Research Institute Badeggi Niger State Nigeria.

2.6.2 Determination of amino acid content

The Amino Acid profile in the known sample was determined using methods described by Benitez (1989). The known sample was dried to constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator and loaded into the Applied Biosystems PTH Amino Acid Analyzer.

2.7 Induction of hyperglycemia and antidiabetic study of aqueous extract treated diabetic animals

Hyperglycemia was induced in Wistar albino rats by single intraperitoneal injection of freshly prepared alloxan monohydrate solution (150 mg/kg of body weight) in physiological saline after overnight fasting for 12 hrs.

2.8 Confirmation of hyperglycemia

The development of hyperglycemia in rats was confirmed by plasma glucose estimation 72 hrs post alloxan injection. The rats with fasting plasma glucose level of 360-590mg/dl were used for this experiment.

2.9 Animal grouping and extract administration

Group A: Control (consist of rats that will be given normal water+ feed)

Group B: Diabetic + Distilled water

Group C: Diabetic + Glibenclamide

Group D: Diabetic + 750mg/kg body weight of Sorghum extract

Group E: Diabetic + 1000mg/kg body weight of Sorghum extract

Group F: Diabetic + 750mg/kg body weight of Millet extract

Group G: Diabetic + 1000mg/kg body weight of Millet extract

2.10 Determination of body weight and feed intake of animals

Rats were weighed during cage changes once a week, using a 3s average function of a laboratory scale (Mettler Toledo PB3002-S FACT; Mettler-Toledo AG, Greifense, Zurich Switzerland).

Food consumption was determined by subtracting the left over weight of feed from the initial weight of feed that was given and then dividing by the number of rats in the cage. This was done 3 times in a week and the overall mean was used.

2.11 Collection of blood, preparation of Serum and tissue supernatant.

After 21 days of treatment, body weight was measured and blood was collected from the eyes (venous pool) by sino-ocular puncture in plain serum tubes for the estimation of the biochemical

assays and organs were harvested for histopathology. The blood was centrifuged and serum was collected in a plain serum bottle. The harvested organ was kept in formol saline.

2.12 Determination of selected biochemical parameters

Determination of Serum insulin

Insulin was assayed in rat serum using Mercodia Ultrasensitive Rat Insulin ELISA kits provided by IMMUNOTECH Company (Burgi *et al*., 1988; Lygren *et al*., 2014). Briefly, all reagents and samples were brought to room temperature before use. The required amount of enzyme conjugates 1X and wash buffer solution was prepared. The samples, insulin control solutions, and calibrators were also prepared as well as sufficient microplate wells to accommodate calibrators and samples in duplicate. A recommended plate plan which includes: Cal 0-5: calibrator solutions (standards); insulin control low (ICL), Insulin control high (ICH) and sample (S) were prepared. 25 µL each of calibrators was pipetted into appropriate wells and 100 µL of enzyme conjugate 1X solution added into each well and incubated on a plate shaker at 2000 rpm for 2 hours at room temperature. Each well was washed six times with wash buffer 1X solution and reaction volume discarded by inverting the micro plate over a sink. Wash solution of 350 µL was added into each well and the wash solution discarded and tapped firmly several times against absorbent paper to remove excess liquid. This was repeated five times to avoid prolonged soaking during washing procedure. 200 µL substrate 3,3',5,5'-tetramethylbenzidine (TMB) was then added into each well. This was incubated for 15 minutes at room temperature (18-25 ^{0}C) and 50 µL stop solutions were added to each well. The plate was placed on the shaker at 280 rpm for 5 minutes to ensure mixing. The absorbance was read at 450 nm within 30 minutes. Absorbance was then extrapolated from the insulin calibration curve (Figure 38) to obtain pancreatic insulin concentration.

Determination of serum total protein

The protein concentration in the serum of the animals was assayed, using Biuret reagent as described by Gornall *et al* (1949). The assay mixture which included 1.0ml of sample and 4.0ml biuret reagent was mixed thoroughly by shaking and left undisturbed for 30 minutes at room temperature for colour development. The blank was constituted by replacing the sample with 1.0 ml distilled water. The absorbance was read against the blank at 540 nm. The concentration of the protein, present in the sample was calculated by comparing them with those on the calibration curve for egg albumin depicted in the appendix. The curve was obtained by plotting the absorbance against varying concentration of egg albumin (1-10 mg/ml) as depicted in Table 3.1. The concentration of protein in the sample was extrapolated from the calibration curve of the egg albumin, using the expression:

Protein concentration (mg/ml) = $C_s \times F$

Where: C_s= corresponding protein concentration from the calibration

F= dilution factor

2.13 Determination of Serum carbohydrate metabolizing enzyme activity

Determination of hexokinase activity

Hexokinase activity was assayed using the procedure described by Brandstrup *et al* (1969). The total volume of reaction mixture of 5.3 ml contained the following: 1 ml of 0.005M glucose solution, 0.5 ml of 0.072M adenosine triphosphate (ATP) solution, 0.1 ml of 0.05M magnesium chloride solution, 0.4 ml of 0.0125M potassium dihydrogen phosphate, 0.4 ml of 0.1M potassium chloride, 0.4 ml of 0.5M sodium fluoride and 2.5 ml of Tris-HCl buffer (0.01 M, pH 8.0). The mixture was pre-incubated at 37 ^{0}C for 5 minutes. The reaction was initiated by the addition of 2 ml of liver supernatant. One millilitre of the reaction mixture was immediately transferred into the tubes containing 1 ml of 10% trichloroacetic acid (TCA) that was considered as zero time. A second aliquot was removed and deproteinised after 30 minutes of incubation at 37 ^{0}C. The protein precipitate was removed by centrifugation and the residual glucose in the supernatant was estimated by the method of Trinder (1969): the initial absorbance was read immediately the cuvette was inserted into the spectrophotometer at 340 nm and at exactly 1 minute after another absorbance was read. Liver hexokinase activity is calculated using the expression:

$$\text{Hexokinase (Units/g protein)} = \frac{\Delta \text{ Absorbance/min x DF}}{2 \text{ x TPC}}$$

Δ Absorbance/min = Absorbance of the sample at 1 minute – Initial absorbance of the sample
DF = Dilution factor
2 = Volume of liver supernatant
TPC = Total protein concentration (mg/ml)

2.14 Determination of phosphofructokinase activity

Phosphofructokinase activity was determined by a procedure adapted from Hengartner & Harris (original description in Rypniewski & Evans, 1989). The following reaction mixture were prepared and 3.00 mL of the reaction mixture was pipetted into a cuvette.

Solution Ⅰ 27.33 mL Solution Ⅵ 0.06 mL
Solution Ⅱ 0.30 mL Solution Ⅶ 0.60 mL
Solution Ⅲ 0.39 mL Solution Ⅷ 0.06 mL
Solution Ⅳ 0.60 mL Solution Ⅸ 0.06 mL
Solution Ⅴ 0.60 mL

It was the Incubated at 30 °C for about 3 minutes. 0.01mL of enzyme solution was added into the cuvette and mix. absorbance change at 340 nm per minute (ΔAbs340) in the linear portion of curve was read.

Calculation

$$\text{Volume activity (U/mL)} = \frac{(\Delta\text{Abs340}) \text{ X } (3.00 + 0.01)}{6.22 \text{ X } 0.01} \text{ X d.f.}$$

$$\text{Specific activity (U/mg protein)} = \frac{\text{Volume activity (U/mL)}}{\text{Protein concentration (mg/mL)}}$$

2.15 Determination of glucose-6-phosphatase activity

Glucose-6-phosphatase activity was determined by the procedure described by Koide and Oda (1959). Incubation mixture contained 0.7 ml of citrate buffer (0.1 M, pH 6.5), 0.3 ml of 0.01M substrate and 0.3 ml of serum. The reaction mixture was incubated at 37 ^{0}C for 15 minutes. Addition of 1 ml of 10% trichloroacetic acid to the reaction tubes terminated the reaction of the enzyme. The suspension was centrifuged at 5000 g for 10 minutes and the inorganic phosphate content of the supernatant was determined by the procedure described by Fiske and Subbarow (1925). 2 ml of the supernatant was pipetted into a test tube. To this, 1 ml of ammonium molybdate was added followed by 0.4 ml of amino naphthol sulphonic acid. The blue colour developed after 20 minutes was read at 680 nm. Glucose-6-phosphatase activity was calculated by the expression:

$$\text{Glucose-6-phosphatase (U/mg protein)} = \frac{\text{Pi x 2 x DF}}{\text{1000 x TPC}}$$

Pi = Concentration of inorganic phosphate released
2 = Factor introduced to obtain the amount of inorganic phosphate released
DF = Dilution factor
1000 = Factor introduced to convert inorganic phosphate SI unit to the mg equivalent
TPC = Total protein concentration (mg/ml)

2.16 Determination of α- amylase activity

The α -amylase activity was determined by the procedure described by Rinderknecht *et al*., (1967). 10 µL of the sample was transferred to a 1.5ml well labelled Eppendorf tubes. 190 µL of the substrate was added and vortexed to mix and incubate for 5min. A blank control was prepared, using 10 µL water plus 190 µL Substrate and 80 µL Stop Reagent. 80 µL Stop Reagent was added to each sample tube to terminate the reaction. It was then Vortexed to mix and centrifuge for 5min at 14,000 rpm. Carefully transfer 200 µL of the supernatant was transferred into wells of a clear bottom 96-well plate. 200 µL water and 200 µL Calibrator was transferred in separate wells.it was Read on an OD_{595nm} (580 to 600nm) on a plate reader.

Calculation: α -amylase activity is calculated as follows,

$$\text{Activity} = \frac{OD_{SAMPLE} - OD_{BLANK}}{OD_{CAL} - OD_{H20}} \text{ X n X 550 (U/L)}$$

where OD_{SAMPLE} and OD_{BLANK} are the OD_{595nm} values of the sample and blank, respectively. OD_{CAL} and OD_{H2O} are the OD_{595nm} values of the Calibrator and water. n is the dilution factor. The number "550" is the equivalent activity (U/L) of the calibrator under the assay conditions.

2.17 Data analysis

The data was analyzed using SPSS (Version 29: 2022). The data was expressed as Mean ± Standard Error of Mean (SEM) of seven determinations. The group means was compared by Newman-Keuls multiple range test (NKMRT). Values was considered statistically significant at $p<0.05$.

3.0 RESULTS AND DISCUSSION

3.1 Results

3.1.1 Secondary metabolite constituents of aqueous extract of *Sorghum bicolor* and *Pennisetum glaucum* seed

Table 1: Phytochemical constituents of *Sorghum bicolor* and *Pennisetum glaucum* seed

Active Components	*Pennisetum glaucum*	*Sorghum bicolor*
Glycoside	+	+
Cardiac Glycoside	-	+
Carbohydrate	+	+
Triterpenes	+	-
Steroids	+	-
Saponins	+	+
Tanins	+	+
Alkaloids	+	+
Phenols	+	+

Key:

+ = positive

- = Negative

Sorghum bicolor tested positive for glycoside, cardiac glycoside, carbohydrate, saponins, tanins, phenols and alkaloids (Table 1). *Pennisetum glaucum* tested positive for glycoside, carbohydrate, tritepenes, steroids, saponins, tanins, phenols and alkaloids (Table 1).

3.1.2 Amino acid profile of *Sorghum bicolor* and *Pennisetum glaucum* seed

Table 2: Amino acid profile of *Sorghum bicolor* and *Pennisetum glaucum* seed (g/100g protein)

Amino Acid	*S. bicolor*	*P. glaucum*	FAO/WHO 1990 Standard
Leucine	13.72	9.80	6.60
Lysine	2.36	3.70	5.80
Isoleucine	4.00	4.40	2.80
Phenylalanine	4.80	5.15	6.30
Norleucine	-	-	-
Tryptophan	1.21	1.97	1.40

Valine	5.4	5.55	5.00
Methionine	1.95	2.46	2.50
Proline	9.14	6.50	10.70
Arginine	4.82	5.33	5.20
Tyrosine	3.95	3.44	1.10
Histidine	2.17	2.55	2.55
Cysteine	2.20	2.50	3.00
Alanine	9.29	7.75	6.10
Glutamic acid	20.74	19.68	14.70
Glycine	3.18	3.85	2.20
Threonine	3.19	3.83	3.40
Serine	4.40	4.60	7.70
Aspartic acid	7.50	8.00	7.70

Data are mean ± SEM of two determinations

A total of eighteen amino acids out of the twenty known amino acid were present in *Sorghum bicolor* seed. Asparagine and glutamine were absent. Leucine, isoleucine, methionine, arginine, tyrosine, alanine, glutamate and glycine were found to be above the set limit approved by FAO/WHO 1990 while lysine, phenylalanine, tryptophan, valine, proline, cysteine, serine and aspartate were below the FAO/WHO 1990 standard. Histidine and threonine fell within the FAO/WHO 1990 standard (Table 2).

Amino acid content analysis of *P. glaucum* seed revealed the presence of eighteen amino acids out of the twenty known amino acid. Asparagine and glutamine were conspicuously absent. The amino acid found to be above the FAO/WHO 1990 standard are leucine, tryptophan, histidine, alanine, glutamate, glycine and aspartate while those that were below the set limit are lysine, isoleucine, phenylalanine, proline, cysteine and serine. The amino acids that were within the FAO/WHO 1990 reference value for daily intake include valine, methionine, arginine and threonine (Table 2).

3.1.3 Proximate composition of *Sorghum bicolor* and *Pennisetum glaucum* seed

Table 3: Proximate composition of *Sorghum bicolor* and *Pennisetum glaucum* seed (%)

Proximate Composition	*S. bicolor*	*P. glaucum*
Moisture Content	6.57±0.09	12.03±0.15
Crude Protein	11.27±0.15	7.81±0.15
Ash Content	0.30±0.01	2.20±0.11
Crude Fibre	3.32±0.02	2.10±0.15
Fat	3.27±0.15	3.93±0.04
Carbohydrate	75.23±1.19	71.90±0.21

Data are mean ± SEM of three determinations

Sorghum bicolor contains about 75.23% carbohydrate, 3.27% fat, 3.32% crude fiber, 11.27% crude protein, 6.57% moisture and 0.3% ash (table 3). *Pennisetum glaucum* contains about 71.9% carbohydrate, 3.93% fat, 2.1% crude fiber, 7.81 crude protein, 12.03% moisture and 2.2% ash (Table 3).

3.1.4 Blood glucose level of alloxan-induced hyperglycemic rats following oral administration of aqueous *Sorghum bicolor* and *Pennisetum glaucum* seed

Table 4: Blood glucose level (mg/dL) of alloxan-induced diabetic rats following oral administration of aqueous extract (750 and 1000mg/kg body weight) of *Sorghum bicolor* and *Pennisetum glaucum*

			Treatment Days			
Treatment Group	Basal BG Prior to Treat.	BG Day 4	Day 8	Day 12	Day 14	Day 18	Day 21
A	83.42±0.42[a]	75.27±0.12[a]	82.48±0.02[a]	78.56±0.23[a]	70.68±0.75[a]	72.36±0.46[a]	86.24±0.34[a]	80.05±0.89[a]
B	92.38±0.75[b]	413.67±1.88[b]	441.02±1.58[b]	507.45±2.58[b]	513.04±2.16[b]	529.47±2.78[b]	547.23±3.05[b]	599.34±3.87[b]
C	82.84±0.37[a]	491.42±2.58[c]	416.13±1.34[c]	325.46±1.87[c]	274.17±1.56[c]	163.58±1.89[c]	103.67±0.56[c]	72.13±0.96[c]

D	81.35±0.03[a]	366.67±0.83[d]	316.53±1.75[d]	278.49±1.34[d]	223.14±1.72[d]	155.67±1.25[d]	121.53±0.36[d]	96.03±0.86[d]
E	85.46±0.56[c]	425.67±1.46[e]	339.04±1.58[e]	281.53±1.68[e]	202.45±1.73[e]	171.68±2.06[e]	124.67±1.52[e]	87.16±0.74[e]
F	72.94±0.79[d]	302.96±0.83[f]	261.48±0.28[f]	215.76±1.74[f]	172.38±1.36[f]	154.89±2.73[f]	129.73±0.14[f]	99.05±0.35[d]
G	76.39±0.84[d]	405.83±1.38[g]	314.17±1.75[g]	281.63±1.62[e]	188.45±1.35[g]	145.32±2.86[g]	115.38±0.67[g]	81.32±0.78[a]

A = Control; **B** = Diabetic rats + Distilled water; **C =** Diabetic rats + Glibenclamide; **D** = Diabetic rats + 750mg/kg body weight of *Sorghum bicolor* Extract; **E =** Diabetic rats + 1000 mg/kg body weight of *Sorghum bicolor* Extract; **F =** Diabetic rats + 750 mg/kg body weight of *Pennisetum glaucum* Extract; **G** = Diabetic rats + 1000 mg/kg body weight of *Pennisetum glaucum* Extract.

Data are mean ± SEM of seven determinations. Test values with superscript different from their respective control down the column for each day are significantly different (p<0.05)

The results showed that all the animals treated with 150 mg/kg body weight of alloxan became diabetic after 72 hours with blood glucose level ranging from 302.96±0.83 to 491.42±2.58 mg/dL (Table 4). The fasting blood glucose level of the animals administered with alloxan and distilled water significantly ($p< 0.05$) increased from 92.38±0.75 to 599.34±3.87 mg/dL. Administration of the aqueous extract of *Sorghum bicolor* and *Pennisetum glaucum* seed both at the doses of 750 and 1000 mg/kg body weight significantly ($p< 0.05$) reduced the blood glucose levels progressively up till the end of the treatment period. While the reduction in fasting blood glucose of alloxan-induced diabetic animals administered 1000 mg/kg body weight of *Pennisetum glaucum* aqueous extract produced values that compared ($p> 0.05$) well with the distilled water treated non-diabetic animals on day 21, the fasting blood glucose level of alloxan-induced diabetic animals administered 750 and 1000 mg/kg body weight of both *Sorghum bicolor* and *Pennisetum glaucum* aqueous extract, although, reduced, did not compare well with the distilled water treated non-diabetic animals from Day 1 to Day 21 (Table 4).

3.1.5 Body weight and feed intake of animals following oral administration of aqueous extract of *Sorghum bicolor* and *pennisetum glaucum* seed

Table 5: Body weight of alloxan-induced hyperglycemic rats following oral administration of aqueous extract (750 and 1000mg/kg body weight) of *Sorghum bicolor* and *Pennisetum glaucum* seed

		Body Weight (g)			
Treatment Group	Initial Weight	Week 1	Week 2	Week 3	Week 4
A	118.64±1.05[a]	120.45±1.22[a]	131.02±1.02[a]	148.72±1.32[a]	169.75±1.53[a]
B	110.45±1.23[b]	107.02±1.04[b]	102.68±1.56[b]	98.24±0.36[b]	86.52±0.06[b]
C	94.87±0.87[c]	99.48±1.24[c]	113.68±1.56[c]	131.53±1.78[c]	142.70±1.28[c]
D	83.59±0.74[d]	88.46±0.46[d]	93.56±0.20[d]	98.29±0.02[d]	107.85±1.45[d]
E	89.26±0.65[e]	95.19±0.79[c]	98.73±0.97[e]	102.85±1.78[e]	117.93±1.84[e]
F	81.37±0.82[c]	85.42±0.89[d]	90.45±0.36[d]	98.37±0.56[d]	106.79±1.16[d]
G	103.94±0.96[d]	112.98±1.47[e]	115.22±1.78[f]	121.72±1.06[f]	127.30±1.67[f]

Data are mean ± SEM of seven determinations. Test values with superscript different from their respective control down the column for each week are significantly different (p<0.05)
A = Control; **B** = Diabetic rats + Distilled water; **C =** Diabetic rats + Glibenclamide; **D** = Diabetic rats + 750mg/kg body weight of *Sorghum bicolor* Extract; **E =** Diabetic rats + 1000 mg/kg body weight of *Sorghum bicolor* Extract; **F =** Diabetic rats + 750 mg/kg body weight of *Pennisetum glaucum* Extract; **G** = Diabetic rats + 1000 mg/kg body weight of *Pennisetum glaucum* Extract.

Throughout the treatment period (21 days), there was progressive decrease in body weight of non-diabetic animals when compared with the distilled water treated non-diabetic animals (Table 5). However, administration of glibenclamide as well as *Sorghum bicolor* and *Pennisetum glaucum* aqueous extract at both doses (750 and 1000 mg/kg body weight) to diabetic animals significantly (p< 0.05) increased the body weight of the animals when compared with the non-diabetic animals. The 1000 mg/kg body weight of *Sorghum bicolor* seed extract produced body weight values that compared (p> 0.05) well with the glibenclamide treated diabetic animals at week 1 (Table 5).

3.1.6 Effect of aqueous extract of *Sorghum bicolor* and *Pennisetum glaucum* seed on selected biomolecules (Insulin and total protein) of alloxan-induced hyperglycemic rats

Administration of alloxan significantly (P<0.05) decreased serum insulin concentration when compared with Distilled water treated control animals. Administration of glibenclamide to hyperglycemic animals significantly (P<0.05) increased serum insulin concentration activity when compared with distilled water treated hyperglycemic animal. Administration of aqueous extract of *Sorghum bicolor and Pennisetum glaucum* at 750 and 1000mg/kg body weight to hyperglycemic animals significantly (P<0.05) increased serum insulin concentration when compared with distilled water treated hyperglycemic animals (Figure 1).

Administration of alloxan significantly (P<0.05) decreased serum total protein concentration when compared with Distilled water treated control animals. Administration of glibenclamide to hyperglycemic animals significantly (P<0.05) increased serum total protein concentration activity when compared with distilled water treated hyperglycemic animal. Administration of aqueous extract of *Sorghum bicolor and Pennisetum glaucum* at 750 and 1000mg/kg body weight to hyperglycemic animals significantly (P<0.05) increased serum total protein concentration when compared with distilled water treated hyperglycemic animals (Figure 2).

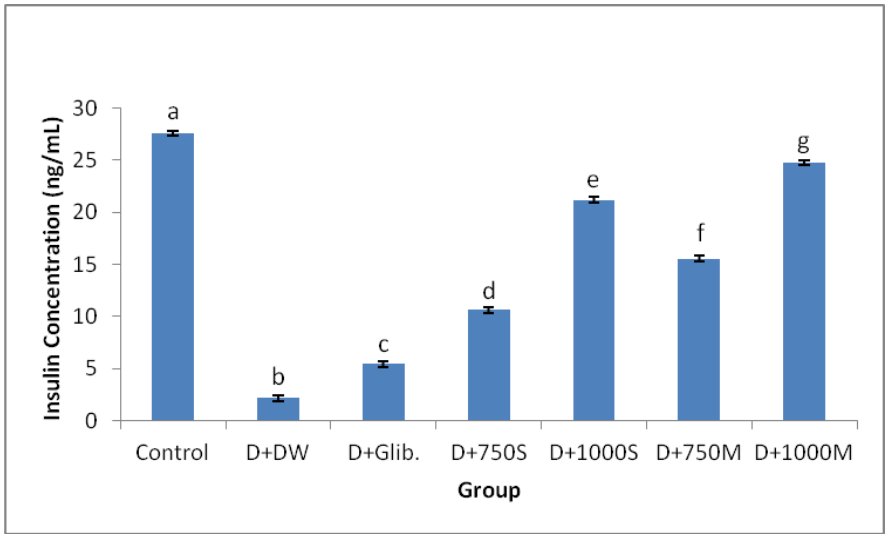

Figure 1: Effect of aqueous extract of *Sorghum bicolor* and *Pennisetum glaucum* on serum insulin concentration in alloxan-induced hyperglycemic rats

D = Diabetic rats + Distilled water; **D + Glib.** = Diabetic rats + Glibenclamide; **D + 750S**= Diabetic rats + 750 mg/kg body weight of *Sorghum bicolor* Extract; **D + 1000S** = Diabetic rats + 1000 mg/kg body weight of *Sorghum bicolor* Extract; **D + 750M** = Diabetic rats + 750 mg/kg body weight of *Pennisetum glaucum* Extract; **D + 1000M** = Diabetic rats + 1000 mg/kg body weight of *Pennisetum glaucum* Extract

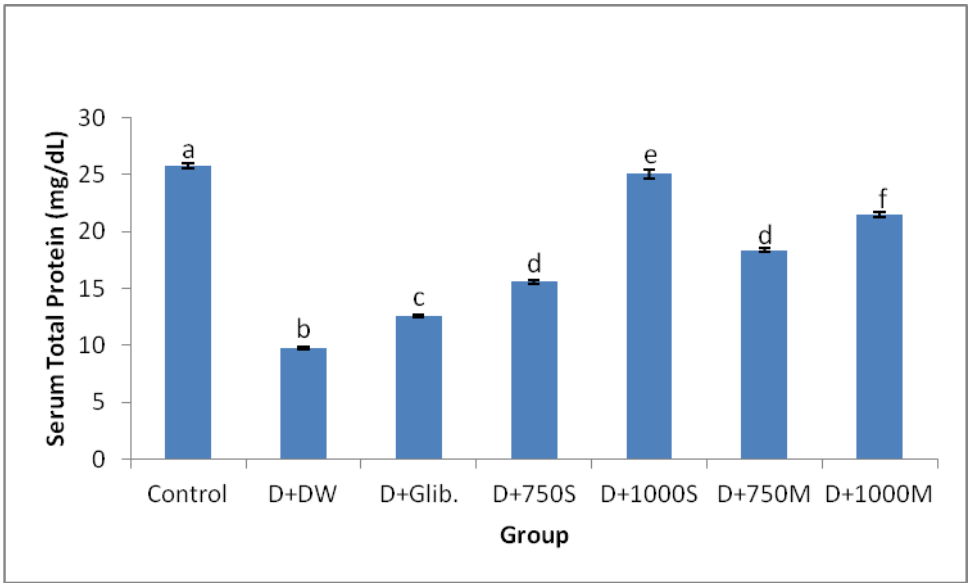

Figure 2: Effect of aqueous extract of *Sorghum bicolor* and *Pennisetum glaucum* on serum total protein concentration in alloxan-induced hyperglycemic rats

D = Diabetic rats + Distilled water; **D + Glib.** = Diabetic rats + Glibenclamide; **D + 750S**= Diabetic rats + 750 mg/kg body weight of *Sorghum bicolor* Extract; **D + 1000S** = Diabetic rats + 1000 mg/kg body weight of *Sorghum bicolor* Extract; **D + 750M** = Diabetic rats + 750 mg/kg body weight of *Pennisetum glaucum* Extract; **D + 1000M** = Diabetic rats + 1000 mg/kg body weight of *Pennisetum glaucum* Extract

3.1.7 Serum carbohydrate metabolizing enzyme activities of alloxan-induced hyperglycemic rats following oral administration of aqueous extracts of *Sorghum bicolor* and *Pennisetum glaucum* seed

Table 6: Serum Carbohydrate Metabolizing Enzyme Activity of Alloxan-induced Diabetic Rats Following Oral Administration of Aqueous Extract of *Sorghum bicolor* and *Pennisetum glaucum* Seed

Treatment Group	Alpha Amylase (mg/mL)	Glucose-6-Phosphatase (mg/mL)	PFK (mg/mL)	Hexokinase (mmol/L)
A	15.63±0.09^{a}	9.88±0.02^{a}	15.36±0.12^{a}	12.56±0.16^{a}
B	62.15±0.69^{b}	62.53±1.58^{b}	8.54±0.06^{b}	3.27±0.02^{b}
C	30.75±0.85^{c}	15.67±0.03^{c}	20.98±0.16^{c}	16.40±0.18^{c}
D	27.15±0.72^{d}	35.98±0.16^{d}	32.37±0.20^{d}	26.03±0.29^{d}
E	34.12±0.89^{c}	20.38±0.09^{c}	57.60±0.29^{e}	21.28±0.26^{e}
F	42.72±1.20^{e}	43.64±1.08^{e}	45.69±0.25^{f}	18.43±0.19^{c}
G	55.63±1.28^{f}	52.73±1.76^{f}	38.65±0.23^{g}	32.68±0.32^{f}

Data are mean ± SEM of seven determinations. Test values with superscript different from their respective control down the column are significantly different (p<0.05)

A = Control; **B** = Diabetic rats + Distilled water; **C =** Diabetic rats + Glibenclamide; **D** = Diabetic rats + 750mg/kg body weight of *Sorghum bicolor* Extract; **E =** Diabetic rats + 1000 mg/kg body weight of *Sorghum bicolor* Extract; **F =** Diabetic rats + 750 mg/kg body weight of *Pennisetum glaucum* Extract; **G** = Diabetic rats + 1000 mg/kg body weight of *Pennisetum glaucum* Extract.

Administration of alloxan significantly (P<0.05) reduced serum hexokinase activity when compared with Distilled water treated animals. Administration of glibenclamide to diabetic animals significantly (P<0.05) increased serum hexokinase activity when compared with distilled water treated hyperglycemic animal. Administration of aqueous extract of *Sorghum bicolor and Pennisetum glaucum* at 750 and 1000mg/kg body weight to hyperglycemic animals significantly (P<0.05) increased serum hexokinase activity when compared with distilled water treated hyperglycemic animals (Table 6).

Administration of alloxan significantly (P<0.05) reduced serum phosphofructokinase activity when compared with Distilled water treated control animals. Administration of glibenclamide to hyperglycemic animals significantly (P<0.05) increased serum phosphofructokinase activity when compared with distilled water treated hyperglycemic animal. Administration of aqueous

extract of *Sorghum bicolor and Pennisetum glaucum* at 750 and 1000mg/kg body weight to hyperglycemic significantly (P<0.05) increased serum phosphofructokinase activity when compared with distilled water treated hyperglycemic animals (Table 6).

Administration of alloxan significantly (P<0.05) increased serum glucose-6-phosphatase activity when compared with Distilled water treated control animals. Administration of glibenclamide to hyperglycemic animals significantly (P<0.05) decreased serum glucose-6-phosphatase activity when compared with distilled water treated hyperglycemic animal. Administration of aqueous extract of *Sorghum bicolor and Pennisetum glaucum* at 750 and 1000mg/kg body weight to hyperglycemic animals significantly (P<0.05) decreased serum glucose-6-phosphatase activity when compared with distilled water treated hyperglycemic animals (Table 6).

Administration of alloxan significantly (P<0.05) increased serum α-amylase activity when compared with Distilled water treated control animals. Administration of glibenclamide to hyperglycemic animals significantly (P<0.05) decreased serum α-amylase activity when compared with distilled water treated hyperglycemic animal. Administration of aqueous extract of *Sorghum bicolor and Pennisetum glaucum* at 750 and 1000mg/kg body weight to hyperglycemic animals significantly (P<0.05) decreased serum α-amylase activity when compared with distilled water treated hyperglycemic animals (Table 6).

3.2 Discussion

3.2.1 Secondary metabolite contents of aqueous extract of *Sorghum bicolor* and *Pennisetum glaucum* seed

The aqueous extract of *Sorghum bicolor* and *Pennisetum glaucum* seeds contains appreciable amounts of secondary metabolites, including glycosides, cardiac glycosides (in sorghum), carbohydrates, triterpenes (in millet), steroids (millet), saponins, tannins, alkaloids, and phenols. These phytochemical constituents are known to underlie many of the medicinal activities of plants; specifically, bioactive classes such as alkaloids, glycosides, saponins, tannins, and flavonoids are often responsible for pharmacological effects (Tran, Barnes, & Gao, 2020).

Antidiabetic effects of plants have frequently been associated with these agents: alkaloids, flavonoids, phenolics, and saponins (Elekofehinti, 2015). For example, saponins may lower glucagon secretion, enhance insulin release, and promote glucose utilization (Elekofehinti, 2015). They may also exert antioxidant and antiglycation effects, which help counteract diabetes-related oxidative stress (Lee, Noh, Lim, & Kim, 2021). Flavonoids, meanwhile, can stimulate insulin secretion by acting on pancreatic β-cells (Al-Ishaq, 2019).

Alkaloids may reduce blood glucose by inhibiting intestinal enzymes such as α-amylase and α-glucosidase (Lee et al., 2021). These compounds have also been shown to increase glucose uptake in β-cells (Lee et al., 2021). Tannins are thought to aid cellular glucose uptake from blood, contributing to glycemic control (Tran et al., 2020).

3.2.2 Amino acid profile

Of all the food nutrients, requirements for protein are very crucial for diabetics without which life would be impossible (Brain and Allan, 1977a). The presence of essential amino acids (indispensable amino acids) in *S. bicolor* seed (leucine, isoleucine, methionine) and *P. glaucum* seed (leucine, tryptophan, histidine), which are higher than the FAO/WHO 1990 reference value for daily intake, might serve as an alternative (new) source of high protein quality. This is because essential amino acids are amino acids that cannot be synthesized in human body but can only be obtained through the diets (Taylor *et al.*, 1998). According to Yadkin and Holford (1998), the end products of metabolism of these essential amino acids are oxoglutarate, succinyl CoA and acetyl CoA which are important substrates in important biochemical processes such as ATP (carrier of chemical energy) and nucleic acids (important components of genetic material) synthesis. The high amino acid content, particularly essential amino acid content, for *S. bicolor* and *P. glaucum* of the seed may not be unconnected with the high crude protein (11.27±0.15%; 7.81±0.15%) in its proximate composition. The amino acid rich nature of the seed made it proteinous and may perform the nutritional roles of many proteinous foods such as structural, hormonal, enzymatic, antibody, transport, regulation and metabolic (Yudkin and Holford, 1998). The low quantity of proline in both *S. bicolor* and *P. glaucum* seed, which was below FAO/WHO 1990 reference value for daily intake, would probably make it more digestible, thus releasing all the amino acids in it into the amino acid pools of the body. These amino acids serve as raw materials for the synthesis of many other cellular products, including hormones, enzymes and pigments. In addition, several of these amino acids are key intermediates in cellular metabolism (Murray *et al.*, 2000). The detection of essential (indispensable) amino acids in high amounts in the extract agrees with the report of Alabi (2008) on soya bean amino acids profile. Similarly, *Van-Loon et al* (2003) reported that amino acid ingestion strongly enhances insulin secretion in patients with long-term type 2 diabetes.

3.2.3 Proximate composition

The crude protein content for *S. bicolor and P. glaucum* seed is 11.27±0.15% and 7.81±0.15% respectively. This value showed that the seeds have appreciable amount of protein which are good for growth and repair of worn out tissues. This would equally indicate retention of nitrogen for synthesis of new tissue protein during growth and tissues repair with an increase in total body pool of protein (Barbosa-Silva, 2008). The low moisture content of *S. bicolor and P. glaucum* seed (6.57±0.09%; 12.03±0.15%) indicates its low perishability. The low fat content obtained (3.27±0.15%; 3.93±0.04%) showed that *S. bicolor and P. glaucum* seed contained minute amount of oil. The value obtained for carbohydrate (75.23±1.19%; 71.90±0.21%) for *S. bicolor and P. glaucum* seed indicate that the seed was high in calorific value, and the carbohydrate content, if digestible could serve as a source of energy (ATP) (Abdullahi *et al*., 1999). The moderate value of crude fibre (3.32±0.02%; 2.10±0.15%) for *S. bicolor and P. glaucum* seed obtained in the present study may contribute to reduce the risk of cardiovascular diseases and diabetes (Serna-Saldivar, 2003) as well as prevention of colorectal cancer and constipation (Bingham *et al*., 2003).

3.2.4 Blood glucose

Diabetic individuals are at high risk of developing common metabolic complications which result in morbidity and mortality (Elhefnawy *et al*., 2022). Alloxan, a beta cytotoxin, damages

β- cells of islets of Langerhans of pancreas resulting in a decrease in endogenous insulin secretion and paves ways for the decreased utilization of glucose by body tissues (Ighodaro *et al*., 2024). It results in elevation of blood glucose level, decreased protein content, increased levels of serum cholesterol and triacylglycerols (Aluwong *et al*., 2016). Therefore, the determination of concentration of glucose content in the blood of diabetic laboratory animals induced with alloxan is a useful quantitative index of diabetes. Glibenclamide, a well-known oral hypoglycaemic drug belongs to the family of the sulfonylureas a first generation anti-diabetic drug; elicits its hypoglycaemic effect mainly by acting on ATP sensitive potassium channel in pancreatic beta-cells.

These hypoglycemic effects were consistent with the results of a recent study that found that SE rich tannins at dosages of 0.25-0.5 g/kg of body weight significantly decreased serum glucose concentration in STZ-induced diabetic rats (Chung *et al*., 2011) and mice fed a high fat diet (Park *et al*., 2012). Recent in vitro studies confirm that sorghum phenolic extracts, especially 3-deoxyanthocyanidins, strongly inhibit α-glucosidase and α-amylase activities, suggesting a mechanism for post-prandial glucose control (Zhou et al., 2025; Authors, 2023). Moreover, meta-analyses of randomized controlled trials show that consumption of whole grains (which include sorghum) significantly lowers fasting blood glucose and insulin resistance in humans (Zheng, Kan, & Du, 2024; Smith et al., 2023).

Studies have also reported that polyphenols from cocoa extract (Ruzaidi *et al*., 2005) and *Salacia reticulate* extract (Yoshino *et al*., 2009) reduce serum glucose levels in type 1 diabetic rats.

The blood glucose lowering effect of *Pennisetum glaucum* and the possible mechanism involved in the hypoglycemic action of *Pennisetum glaucum* may be stimulation of insulin secretion by the pancreas or/and enhance insulin sensitivity in various organs due to its high amount of phenols.

3.2.5 Body weight and feed intake of hyperglycemic animals

Weight loss in untreated alloxan-diabetic animals is likely due to poor glycemic control, leading to increased gluconeogenesis and muscle protein breakdown via the ubiquitin–proteasome pathway (Szkudelski & Goldberg, 1996; isolated hepatocyte studies, 1975). The observed increase in body weight in treated diabetic animals may result from improved glycemic control and reversal of muscle wasting (Sureka et al., 2021)

3.2.6 Selected biomolecules

Insulin deficiency promotes a catabolic state characterized by increased muscle protein breakdown and reduced hepatic protein synthesis, resulting in lower serum total protein; this is driven in part by accelerated amino acid release and gluconeogenesis (Tessari, 2024; James et al., 2022). The increase in serum protein concentration following treatment of diabetic rats with glibenclamide and the extract (*S. bicolor and P. glaucum*) at 750 and 100 mg/kg body weight suggests that both extract promote normal protein metabolism probably by enhancing insulin synthesis and its release.

Insulin is a peptide hormone secreted by pancreatic β-cells in response to elevated blood glucose, and it promotes glucose uptake in liver, muscle, and adipose tissue. When insulin is lacking or present at very low levels, glucose uptake by these peripheral tissues falls, leading to hyperglycemia (Rorsman & Ashcroft, 2017; StatPearls, 2025). In chemically induced

diabetes (e.g., using alloxan), the reduction in serum insulin results from selective β-cell cytotoxicity, which impairs endogenous insulin production and thereby contributes to sustained high blood glucose (Raza et al., 2022; Mechanisms of alloxan-induced β-cell death, 1997). The increase in serum insulin concentration may be attributed to ability of the extract (*S. bicolor* and *P. glaucum*) at 750 and 1000 mg/kg body weight as well as glibenclamide to increase insulin secretion by the pancreas possibly from the regenerated β-cells.

3.2.7 Carbohydrate metabolizing enzyme activity

Glycolysis and gluconeogenesis are two complementary metabolic pathways that help maintain glucose balance in the body under different nutritional conditions. Insulin plays a critical role in this regulation by promoting glycolysis and suppressing gluconeogenesis (Leavens & Birnbaum, 2021). In particular, insulin stimulates key glycolytic enzymes, including **hexokinase** and **phosphofructokinase-1 (PFK-1)**, thereby increasing the conversion of glucose to glucose-6-phosphate and facilitating downstream glycolytic flux. Under insulin-deficient states (such as in diabetes), the activity of hexokinase and PFK-1 is reduced, which contributes to impaired glycolysis and decreased glucose utilization (Wasserman, 2021; Silva et al., 2012). However, the increase in hexokinase and PFK activities following treatment of diabetic rats with the aqueous extract of *Sorghum bicolor* and *Pennisetum glaucum* seed both at 750 and 1000 mg/kg body weight as well as glibenclamide may be adduced to ability of the extract to stimulate insulin secretion, which would activate hexokinase and PFK activities, thereby increasing hepatic glucose utilization for energy production, and consequently decrease hepatic glucose levels.

Glucose-6-phosphatase is one of the key regulatory enzymes in gluconeogenesis. In the present study, the increase in serum activity of glucose-6-phosphatase in the diabetic untreated animals, after alloxan induction, may be adduced to insulin insufficiency. Insulin reduces gluconeogenesis by decreasing the activities of key enzymes such as glucose-6-phosphatase and alpha amylase (Cherrington, 2015). The increase may also be due to activation or increased synthesis of the enzymes which was responsible for the increased glucose production during diabetes in the serum of the animals. α-amylase catalyzes the hydrolysis of polysaccharide (starch) to oligosaccharide (dextrin). Increase in α-amylase activity following alloxan induction favours forward reaction in carbohydrate hydrolysis pathway, thereby increasing blood glucose pool, which may result in hyperglycaemia. However, the decrease in serum enzyme activity of glucose-6-phosphatase upon treatment of diabetic rats with the aqueous extract of *Sorghum bicolor* and *Pennisetum glaucum* seed both at 750 and 1000 mg/kg body weight as well as glibenclamide may be due to increased insulin secretion, which is responsible for the repression of the gluconeogenic key enzymes. The increase in serum α-amylase activity by both extract at 750 and 1000 mg/kg body weight as well as glibenclamide may imply inhibition in enzyme activity, thereby reducing the serum glucose pool of the animals.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The following conclusions could be made:

The extracts exhibited antidiabetic activity with the best at 1000mg/kg b.w of millet. The extract also restored histological damage and alterations in biomolecules of the diabetic animals. Therefore, the extracts may be relatively 'safe' as oral remedy at the doses investigated in this study. Alkaloids, tannins, saponins, essential amino acids: lysine, valine, leucine, methionine, isoleucine, arginine, histidine might have acted singly or synergistically to produce the desired pharmacological effects.

The possible mode of action by the extract are:

i. Facilitating pancreatic insulin secretion
ii. Stimulating glucose utilization by peripheral tissues
iii. Increasing insulin sensitivity

4.2 Recommendations

Based on the results obtained in this study, the following are recommendd:

i. Administration of phytoconstituents implicated in the present study. Solvent extraction of plants.
ii. Bioassay-guided fractionation/identification of antidiabetic principles in 1000 mg/kg body weight of *P. glaucum* seed.
iii. Isolation and investigation of mechanism of action of the isolated antidiabetic bioactive principle.
iv. Formulation of the antidiabetic bioactive agent into useful antidiabetic drug is recommended.

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