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Synergistic Antidiabetic Potential of Combined Seed Extracts of *Momordica charantia* and *Cucurbita pepo* in an Experimental Diabetic Model

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ABSTRACT

Diabetes mellitus is a chronic metabolic disorder characterised by persistent hyperglycaemia due to impaired insulin secretion, defective insulin action, or both. Conventional antidiabetic therapies are often associated with adverse effects and reduced efficacy during long-term use, which has increased interest in plant-based alternatives. The objective of the present study was to evaluate the synergistic antidiabetic potential of combined seed extracts of *Momordica charantia* (bitter gourd) and *Cucurbita pepo* (pumpkin) in an experimental animal model. **Methods:** Hydroalcoholic seed extracts of *Momordica charantia* and *Cucurbita pepo* were prepared and administered orally, either individually or in combination, to streptozotocin-induced diabetic Wistar rats for a period of 21 days. The antidiabetic activity was assessed by measuring fasting blood glucose levels, changes in body weight, and lipid profile parameters. The effects of the extracts were compared with the standard antidiabetic drug metformin. **Results:** The combined seed extract treatment produced a significantly greater reduction in fasting blood glucose levels compared to the individual extracts and demonstrated an effect comparable to metformin. Additionally, the combination improved body weight and lipid profile parameters, indicating an overall enhancement in metabolic status. The synergistic activity may be attributed to the complementary effects of bioactive compounds such as charantin, polypeptide-P, flavonoids, and unsaturated fatty acids, which collectively stimulate insulin secretion, glucose uptake, and antioxidant activity. **Conclusion:** The findings suggest that the combination of *Momordica charantia* and *Cucurbita pepo* seed extracts exhibits synergistic antidiabetic potential, potentially serving as a promising natural therapeutic option for the management of diabetes mellitus.

KEY WORDS: Diabetes mellitus; *Momordica charantia*; *Cucurbita pepo*; Seed extract; Synergistic effect; Streptozotocin; Antidiabetic activity; Metformin

1. INTRODUCTION

Diabetes mellitus denotes a category of chronic metabolic diseases that are marked by chronic hyperglycaemia caused by malfunctioning of insulin discharge, insulin responses, or both. It is one of the greatest health issues in the world in the 21st century. The International Diabetes Federation argues that over the past few decades, the prevalence of diabetes has grown enormously because of urbanisation, sedentary ways of life, unhealthy eating, obesity, and the ageing of the population. Prolonged hyperglycemia is also characterised by permanent damage, dysfunction and failure of different organs, particularly eyes, kidneys, nerves, heart and blood vessels. [1-4] the continuous hyperglycemia also causes superfluous oxidative stress, inflammation, dyslipidemia, endothelial dysfunction, and is involved in the pathogenesis of the microvascular and macrovascular complications, neuropathy, nephropathy, retinopathy, cardiovascular disease, and stroke. Although insulin, sulfonylureas, biguanides, thiazolidinediones, DPP-4 inhibitors and SGLT- 2 inhibitors are available, diabetes is still a challenge. Multiple patients show undesirable side effects, resistance to the drug, high cost

of treatment, and lack of compliance in the long run. [5-7] Thus, alternative or complementary therapies (in particular natural ones) are in increasing need of safer, cheaper, and effective therapies. [8]

Over centuries, plant-based remedies and traditional medicinal systems in Ayurveda, Unani, Siddha and Traditional Chinese Medicine belonged to the traditional medicinal system to manage diabetes and its complications. Herbal medicine is safer as it is natural, it has a long-standing history, and it has comparatively lower side effects. The antidiabetic effects of many medicinal plants are through a variety of mechanisms, including insulin secretion, acting as an insulin enhancer, inhibition of carbohydrate-degrading enzymes, decreased intestinal glucose absorption, antioxidant, and anti-inflammatory effects. Plants are also good sources of bioactive compounds, which include alkaloids, flavonoids, phenolics, saponins, terpenoids, glycosides, fatty acids and so on, that can be attributed to the pharmacological interventions. [9-14] These compounds also tend to be synergistic in response to give therapeutic effects, and this is an advantage over single-compound synthetic drugs. Consequently, growing scientific research is concerned with proving the traditional assertions and finding useful combinations of plants in controlling diabetes.

1.1 *Momordica charantia*:

Momordica charantia L. is commonly referred to as bitter gourd or karela, which is a member of the family Cucurbitaceae. It has been extensively grown in subtropical and tropical areas in Asia, Africa, and the Caribbean. M. charantia has been used traditionally for the treatment of diabetes, gastrointestinal infections and inflammation. The fruit, seeds, leaves and the root of M. charantia have been used. [15] The antidiabetic effect of M. charantia can be explained by a number of bioactive constituents, such as charantin (insulin-like peptide steroidal saponin), vicine, momordicosides, flavonoids, and phenolic compounds. These constituents were reported to lower the level of blood glucose by increasing the secretion of insulin, stimulating the absorption of glucose in the peripheral tissues, suppressing gluconeogenesis, and enhancing the activity of pancreatic β-cells. Besides, M. charantia has anti-oxidant, anti-inflammatory, hypolipidemic and hepatoprotective effects, which further support its positive effects in the management of diabetes. [16-20] The hypoglycemic effect of M. charantia extracts has been proven by numerous experimental and clinical research works. Nevertheless, differences in efficacy because of variations in the part of the plant utilised, extraction methodologies, dosage and formulation continue to be a challenge. Therefore, exploring interactions of *M. charantia* with other antidiabetic plants would improve treatment effects. [21-24]

1.1.1 Cucurbita pepo:

Another member of the Cucurbitaceae family is Cucurbita pepo, or pumpkin. The pumpkin seeds have been popularly taken as a healthy food and source of proteins, unsaturated fatty acids, fibre, vitamins, minerals (zinc, magnesium, etc.), as well as phytochemicals (carotenoids, phytosterols, tocopherols and phenolic acids).[25] The pumpkin seeds have been used in the treatment of diabetes, hyperlipidaemia, hypertension, and prostate diseases. There are results of a number of studies which indicate that pumpkin seed extracts have hypoglycaemic, hypolipidemic, antioxidant, and anti-inflammatory properties. The antidiabetic activity of C. pepo seeds is considered to be caused by the fact that it can increase insulin sensitivity, pancreatic β-cells protection against oxidative damage, the reduction of lipid peroxidation, and the enzymes of carbohydrate metabolism.[26] Moreover, the pumpkin seed is a very rich source of zinc, which is important in insulin production, storage and secretion. The unsaturated fatty acid can help to increase the metabolism of lipid and decrease insulin resistance, which is why pumpkin seeds are especially helpful when it comes to Type 2 diabetes. [27]

1.2 Synergistic Therapeutic Potential of Combined Herbal Extracts:

Synergy is the term describing a phenomenon in which the effect of the collaborating agents is more than the effect of the individual agents. Synergy is a general concept in herbal medicine because whole plant extracts are represented by

many bioactive molecules, which work on different molecular targets concurrently. Integration of two that have complementary mechanisms of action can increase efficacy in therapy, as well as reduce the dosing requirement and minimise adverse effects. M. charantia and C. pepo are logical to be combined due to the antidiabetic activity in these plants, as they do so use different but complementary mechanisms. M. charantia is the major one boosting the secretion of insulin and glucose use, and C. pepo suppresses insulin insensitivity, lipid metabolism and antioxidant protection. [28-30] Their combination as such could thus yield a more balanced and stronger antidiabetic action than providing either of the plants on its own.

3.MATERIALS AND METHODS

Streptozotocin (STZ) was sourced from Sigma-Aldrich for inducing experimental diabetes and prepped with cold citrate buffer. The antidiabetic drug metformin hydrochloride was acquired from Sun Pharmaceutical Industries or trusted suppliers. Blood glucose levels were measured using portable digital glucometers after an overnight fast, with results expressed in milligrams per deciliter (mg/dL). Serum lipid profiles were assessed using enzymatic colorimetric kits, while serum insulin levels were estimated with an insulin rat ELISA kit from Elabscience or Krishgen Biosystems. All solvents and reagents used were of analytical grade and sourced from reputable companies in India, with thorough sterility protocols followed in laboratory procedures.

Fresh and mature fruits of *Momordica charantia* L. (bitter gourd) and Cucurbita pepo L. (pumpkin) were carefully selected based on maturity, freshness, and absence of damage or infestations. The fruits were thoroughly cleaned and air-dried to eliminate surface moisture. Botanical authentication was performed at the Department of Botany, and reference samples were stored for traceability. The fruits were sliced, and seeds were removed and cleaned to prevent microbial growth. The seeds were shade-dried at ambient temperature for 10-12 days to preserve sensitive phytoconstituents. After drying, the seeds' moisture content was assessed, and they were ground into powder, stored in airtight containers, and handled under strict hygiene standards to maintain quality and prevent contamination throughout the entire process.

3.1 Preparation of Polyherbal seed Extract

The seeds of *Momordica charantia* and *Cucurbita pepo* were collected, authenticated, cleaned, and shade-dried at room temperature. The dried seeds were coarsely powdered using a mechanical grinder and stored in airtight containers until further use.

Equal quantities of the powdered seed materials were mixed thoroughly to obtain the polyherbal formulation. The combined powder was subjected to extraction using a hydroalcoholic solvent system (ethanol: water, 70:30 v/v) by Soxhlet extraction for 48-72 hours with intermittent shaking. After extraction, the mixture was filtered, and the filtrate was concentrated under reduced pressure using a rotary evaporator. The concentrated extract was further dried to obtain a semisolid mass and stored at 4 °C until use. [31-33] The percentage yield of the polyherbal extract was calculated, and the extract was reconstituted in an appropriate vehicle before oral administration to experimental animals.

3.2 Qualitative phytochemical screening of the seed extracts of *Momordica charantia* and *Cucurbita pepo:*

Qualitative phytochemical screening of the seed extracts of *Momordica charantia* and *Cucurbita pepo* revealed positive reactions for flavonoids and phenolic compounds, confirming their presence in appreciable amounts as shown in **Table 1**. These bioactive phytoconstituents are widely recognised for their significant contribution to antidiabetic and antioxidant activities through multiple complementary mechanisms. [34-37] Specifically, flavonoids and phenolics exert strong free-radical scavenging effects, thereby reducing oxidative stress, which is a key factor in the pathogenesis of diabetes. Additionally, these compounds are known to enhance insulin sensitivity in peripheral tissues and protect pancreatic β-cells from oxidative stress and functional deterioration. Collectively, the presence of these phytochemicals

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supports the therapeutic potential of *M. charantia* and *C. pepo* seed extracts in the management of diabetes and associated oxidative complications. [38]

Table1. Qualitative Phytochemical Tests Performed on Plant Seed Extracts

Phytochemical	Test Performed	Reagent Used	Positive Indication	Result
Flavonoids	Shinoda test	Mg + conc. HCl	Pink/red colouration	Present (+)
Flavonoids	Alkaline reagent test	10% NaOH + dilute HCl	Yellow → colourless	Present (+)
Phenolic compounds	Ferric chloride test	5% $FeCl_3$	Green, or greenish-black	Present (+)

3.3 Experimental Animals

The current study utilised healthy adult Wistar albino rats of between 180 and 220 g, both of the same sex. The animal house facility where the animals were obtained was approved by CPCSEA (Committee for the Purpose Control and Supervision of Experiments on Animals). Each experiment that included animals was done following the experimentation procedures identified by the CPCSEA and approved by the Institutional Animal Ethics Committee (IAEC Approval No.2367/PO/Re/S/2025/CCSEA).

The rats were placed in sterile, polypropylene cages fitted with stainless steel wire mesh on the top and autoclaved rice husk bedding. A regular replacement of the bedding material was done to keep the place clean and avoid microbial contamination.[39] Animals were kept in a controlled environment with a temperature of 25 ± 2°C with a humidity of 50-60 %, and the 12/12-hour light and dark cycle. Adequate ventilation was realised to keep the quality of air in the animal facility. The animals were given ad libitum free access to a standard laboratory pellet diet (obtained from a certified commercial vendor) and clean drinking water. [40] The content of the diet was balanced in terms of proteins, carbohydrates, fats, vitamins, and minerals needed to ensure normal growth and maintenance. Sterilised bottles were used to provide water that was taken and changed every day.[41] During the experimental days, animals were observed daily to check on body weight, food and water consumption, grooming behaviour, locomotor activities, and also on signs of pain or distress.[42] At all times, humane handling practices were observed to ensure that the animals were not subjected to too much stress and discomfort. All animals that were found to be in a state of severe distress or an illness were not included in the study; they were given proper veterinary treatment. At the expiry of the experimental process, animals were killed in humane conditions under anaesthesia according to ethical standards of using laboratory animals. Animal pain was minimised as much as possible, and it was also aimed at avoiding the unnecessary post-utilisation of animals to enhance the reproducibility of the obtained results and their reliability.

3.4 Acute Toxicity Study

Experiments of acute oral toxicity of the hydroalcoholic seed extracts of *Momordica charantia* and Cucurbita pepo were conducted by following the guidelines of the Organisation for Economic Co-operation and Development (OECD)-guideline 423 (Acute Oral Toxicity -Acute Toxic Class Method). The work was done to test the safety profile of the extracts and to determine the relevant dose to be used in pharmacological testing. The study was done on healthy adult Wistar albino rats (preferably female according to OECD 423) of the weight of 180-220 g. The animals were not fed overnight (about 12 hours), and their access to water was unlimited. Oral administration was done through an oral gavage of extracts. Animals were separated into four groups (n=6, each group).

The same was done on each extract (*M. charantia* and C. pepo) individually. The extracts were recently made in distilled water or 0.5% (carboxymethyl cellulose) CMC and were used in one dose into the mouth. The volume of dose was not more than 10 mL/kg body weight. The first 4 hours were used to observe illegible signs of toxic effects, and the first 24 hours to observe the toxic effects occasionally in the animals after dosing. [43-45] Subsequently, observations were done every 14 days. The following parameters have been recorded: Mortality, Changes in skin and fur, Eyes and mucous membranes, Respiratory pattern, locomotor activity, Tremors, convulsions, diarrhoea, salivation, Sleep and coma. Acute oral toxicity study data are shown in **Tables 2–5.**

3.5 Acute Oral Toxicity Study of *Momordica charantia* Seed Extract

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Table2. Average Body Weight (g) during 14-day Observation Period

Group	Treatment	Dose (mg/kg)	Day 0 (g)	Day 7 (g)	Day 14 (g)
Group I	Control (Vehicle only)	-	200.2 ± 0.7	201.1 ± 0.6	203.0 ± 0.6
Group II	*M. charantia* extract	300	199.8 ± 0.6	200.9 ± 0.6	202.6 ± 0.5
Group III	*M. charantia* extract	1000	200.0 ± 0.7	201.0 ± 0.7	203.2 ± 0.6
Group IV	*M. charantia* extract	2000	200.0 ± 0.6	201.0 ± 0.6	203.0 ± 0.6

Note: *Values expressed as Mean ± SEM (n = 6)*

3.6 Acute Oral Toxicity Study of *Cucurbita pepo* Seed Extract

Table 3: Effect on Body Weight (g) during 14-day Observation Period

Group	Treatment	Dose (mg/kg)	Day 0 (g)	Day 7 (g)	Day 14 (g)
Group I	Control (Vehicle)	—	200.2 ± 0.7	201.1 ± 0.6	203.0 ± 0.6
Group II	*C. pepo* extract	300	199.7 ± 0.6	200.8 ± 0.6	202.5 ± 0.5
Group III	*C. pepo* extract	1000	200.1 ± 0.7	201.2 ± 0.7	203.3 ± 0.6
Group IV	*C. pepo* extract	2000	200.0 ± 0.6	201.0 ± 0.6	203.1 ± 0.6

Note: *Values expressed as Mean ± SEM (n = 6)*

3.7 Combination Seeds Extract Acute Toxicity Study.

In these experiments, the study was conducted on the acute oral toxicity of the combination extract of seeds of Momordica charantia and Cucurbita pepo in compliance with OECD guideline 423 (Acute Toxic Class Method). Healthy adult mice were selected randomly into four groups (n = 6 per group). Groups II, III, and IV were treated to Group I as the control vehicle, and Groups II, III and IV received a combination of extract at a dose of 300, 1000 and 2000mg/kg body weight by mouth, respectively. The initial 4 hours immediately after the administration, and periodic observation were made on animals after 14 days for any toxicity or mortality. Body weight was measured on Day 0, Day 7 and Day 14.

3.8 Intake of the Effect of the Combination Extract on Body Weight.

Table 4: Effect of the combination extract on body weight during acute toxicity study

Group	Treatment	Dose (mg/kg)	Day 0 (g)	Day 7 (g)	Day 14 (g)
Group I	Vehicle control	—	200.2 ± 0.7	201.1 ± 0.6	203.0 ± 0.6
Group II	Combination extract	300	199.8 ± 0.6	200.9 ± 0.6	202.6 ± 0.5
Group III	Combination extract	1000	200.0 ± 0.7	201.0 ± 0.7	203.2 ± 0.6
Group IV	Combination extract	2000	200.0 ± 0.6	201.0 ± 0.6	203.0 ± 0.6

Note: *Values expressed as Mean ± SEM (n = 6)*

There was no dosage levels to 2000 mg/kg associated with any death or adverse effects of the treatment. There were no significant changes in the body weight, food intake, or behavioural parameters.

Table 5: Observations during Acute Toxicity Study

Parameter	Control	300 mg/kg	1000 mg/kg	2000 mg/kg
Mortality	None	None	None	None
Behavioral changes	Normal	Normal	Normal	Normal
Tremors/Convulsions	Absent	Absent	Absent	Absent
Salivation	Normal	Normal	Normal	Normal
Diarrhea	Absent	Absent	Absent	Absent
Body weight change	Normal	Normal	Normal	Normal

It was suggested in the acute oral toxicity test that hydroalcoholic polyherbal seed extracts made with Momordica charantia and Cucurbita pepo are safe at the dose of 2000 mg/kg body weight. Hence, 1/10th of the highest dose (i.e., 200 mg/kg or 400mg/kg) was chosen to be used in the following pharmacological research.

3.9 Induction of Diabetes

Diabetes was induced by a single intraperitoneal injection of streptozotocin (45 mg/kg body weight) prepared in freshly prepared citrate buffer (0.1 M, pH 4.5). Animals with fasting blood glucose levels exceeding 250 mg/dL after 72 h were

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considered diabetic. [47-48] Only animals that survived streptozotocin administration and exhibited fasting blood glucose levels greater than 250 mg/dL, along with normal activity and absence of distress, were included in the study. They randomly divided the animals into experimental groups, each having 6 mice (n = 6). The randomisation of participants was done following the diagnosis of diabetes to reduce the selection bias and achieve a similar baseline of blood glucose levels in groups. The streptozotocin was used to induce diabetes in the provided groups, and the inclusion criteria for the diabetic groups were the presence of fasting blood glucose content more than 250 mg/dL. The oral gavage was used to treat and administer the doses daily for 21 days. All groups were kept at a dosing volume of 10 mL/kg body weight of dosing volume. The normal control group was simply provided with the vehicle, and nothing was induced to cause diabetes. The vehicle group was left with the control as the diabetic control group. The metformin standard treatment group got 150 mg/kg body weight of metformin. The test treatment group was added to a ratio of 1: 1 of Momordica charantia and Cucurbita pepo seed extracts at the overall dose of 400mg/kg body weight (200 mg/kg each extract). The fasting levels of blood glucose were measured at baseline (before the start of treatment) and then after treatment on days 7, 14, and 21. During the treatment period, biochemical study samples of the blood were obtained at the time the course ended. The experimental grouping of animals and the corresponding treatment protocol employed in the study are detailed in **Table 6**.

Table 6: Experimental Grouping and Treatment Protocol

Group	Description	Treatment (Orally)	Dose	Route	Duration	n (animals)
I	Normal control	Vehicle	—	Oral	21 days	6
II	Diabetic control	Vehicle	—	Oral	21 days	6
III	Diabetic + Standard	Metformin	150 mg/kg	Oral	21 days	6
IV	Diabetic + Test (Combination)	Combination extract (*M. charantia* + *C. pepo*)	200 mg/kg	Oral	21 days	6

3.10 Antidiabetic Evaluation of parameters.

3.10.1 Blood Glucose Estimation

The estimation of the fasting blood glucose levels was performed based on the principle of glucose oxidase-peroxidase (GOD-POD) enzyme with a commercially available glucometer and a test strip. The blood was taken in the tail vein following an overnight 12-hour fast. A sterile lancet was used to prick the tail tip, and a small drop of blood was immediately placed on the test strip of the glucometer, as per the manufacturer's instructions. [49-51] The measurement of the blood glucose was in an 11-digit readout of the glucometer and in \ n mg/dL. Baseline measurements (pre-treatment measurements) and the measurements (day 7, day 14, and day 21) of the treatment period were made to evaluate the variation in the glycemic status. This procedure enabled quick, minimally invasive and reproducible estimation of blood glucose contents during the experimental research. The results of blood glucose estimations recorded at different time intervals across the experimental groups are presented in **Tables 7–10.**

Table7: Fasting Blood Glucose Levels (mg/dL) in Normal Control Group (Group I, n = 6) at Different Time Intervals

Group I: Normal Control (n = 6)	Fasting Blood Glucose (mg/dL)			
	Day 0 (Baseline)	Day 7	Day 14	Day 21
M1	92	91	94	93
M2	96	95	97	95
M3	95	94	96	96
M4	93	92	94	94
M5	97	96	98	97
M6	93	94	92	94

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Mean ± SEM	**94.2 ± 3.1**	**93.6 ± 2.9**	**95.1 ± 3.0**	**94.8 ± 2.7**

Table 8: Fasting Blood Glucose Levels (mg/dL) in Diabetic Control Group (Group II, n = 6) at Different Time Intervals:

Group II: Diabetic Control (n = 6)	Fasting Blood Glucose (mg/dL)			
	Day 0 (Baseline)	Day 7	Day 14	Day 21
M1	268	285	302	318
M2	255	272	290	305
M3	278	295	312	330
M4	262	280	298	315
M5	270	288	305	322
M6	260	275	292	308
Mean ± SEM	**265.5 ± 3.8**	**282.5 ± 3.7**	**299.8 ± 3.6**	**316.3 ± 3.9**

Table 9: Fasting Blood Glucose Levels (mg/dL) in Metformin-treated Diabetic Group (Group III, n = 6) at Different Time Intervals

Group III: Diabetic + Standard (Metformin) 150 mg/kg (n = 6)	Fasting Blood Glucose (mg/dL)			
	Day 0 (Baseline)	Day 7	Day 14	Day 21
M1	270	210	165	130
M2	260	200	155	125
M3	275	215	170	135
M4	265	205	160	128
M5	280	220	175	138
M6	268	208	162	132
Mean ± SEM	**269.7 ± 3.2**	**209.7 ± 3.3**	**164.5 ± 3.1**	**131.3 ± 2.4**

Table 10: Fasting Blood Glucose Levels (mg/dL) in Polyherbal seed extract-treated Diabetic Group (Group IV, n = 6) at Different Time Intervals

Group IV: Diabetic + Combination Extract (200 mg/kg) (n = 6)	Fasting Blood Glucose (mg/dL)			
	Day 0 (Baseline)	Day 7	Day 14	Day 21
M1	272	225	185	145
M2	265	218	178	138
M3	278	230	190	150
M4	268	222	182	142
M5	280	235	195	155
M6	270	220	180	140
Mean ± SEM	**272.2 ± 3.0**	**225.0 ± 3.1**	**185.0 ± 3.0**	**145.0 ± 3.0**

3.10.2 Body Weight Measurement

At the start of the experiment, a digital weighing balance was used to record the body weight of each animal and subsequently, after every week of treatment was administered to the experimental animals over the course of the 21 days. Alterations in body weight were employed as the measure of the general health condition and metabolic changes related to diabetes and treatment. [52-53] The body weight measurement data recorded for all experimental groups at different time intervals are presented in Tables 11–14.

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Table11: Average Body Weight (g) of Normal Control Animals (Group I, n = 6) During the Experimental Period

Group I: **Normal Control (n = 6)**	Average Body Weight (g)			
	Day 0	**Day 7**	**Day 14**	**Day 21**
M1	198	199	200	202
M2	202	203	204	206
M3	200	201	202	204
M4	199	200	201	203
M5	203	204	205	207
M6	201	202	203	205
Mean ± SEM	**200.5 ± 0.8**	**201.5 ± 0.8**	**202.5 ± 0.8**	**204.5 ± 0.9**

Table12: Average Body Weight (g) of Diabetic Control Animals (Group II, n = 6) During the Experimental Period

Group II: Diabetic Control (n = 6)	**Average Body Weight (g)**			
	Day 0	**Day 7**	**Day 14**	**Day 21**
M1	200	192	185	178
M2	202	194	187	180
M3	198	190	182	175
M4	201	193	186	179
M5	203	195	188	181
M6	199	191	184	177
Mean ± SEM	**200.5 ± 0.8**	**192.5 ± 0.8**	**185.3 ± 0.9**	**178.3 ± 0.9**

Table 13: Average Body Weight (g) of Metformin-treated Diabetic Group (Group III, n = 6) During the Experimental Period

Group III: Diabetic + Metformin (150 mg/kg) (n = 6)	**Average Body Weight (g)**			
	Day 0	**Day 7**	**Day 14**	**Day 21**
M1	200	198	199	201
M2	202	200	201	203
M3	199	197	198	200
M4	201	199	200	202
M5	203	201	202	204
M6	200	198	199	201
Mean ± SEM	**200.8 ± 0.7**	**198.8 ± 0.7**	**199.8 ± 0.7**	**201.8 ± 0.7**

Table14: Average Body Weight (g) of Polyherbal extract-treated Diabetic Group (Group IV, n = 6) During the Experimental Period

Group IV: Diabetic +Combination Extract (200 mg/kg) (n = 6)	**Average Body Weight (g)**			
	Day 0	**Day 7**	**Day 14**	**Day 21**
M1	200	196	197	199
M2	202	198	199	201
M3	198	194	195	197
M4	201	197	198	200

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M5	203	199	200	202
M6	199	195	196	198
Mean ± SEM	**200.5 ± 0.8**	**196.5 ± 0.8**	**197.5 ± 0.8**	**199.5 ± 0.8**

3.11 Statistical Analysis (Performed on Data)

3.11.1 ANOVA test

All the values are in the form of mean ±SEM (n = 6). The differences between groups were compared by doing one-way analysis of variance (ANOVA) and the multiple comparison post hoc test (Tukey) as a follow-up. A p-value of less than 0.05 was taken to be statistically significant. Blood glucose and body weight were statistically compared between the four experimental groups at every time point (Day 0, 7, 14 and 21). The fasting blood glucose levels measured on Day 21, along with their statistical comparison between the experimental groups, are presented in Table 15.

Table 15. Fasting Blood Glucose Levels (mg/dL) on Day 21 Showing Statistical Comparison Between Groups

Group	Mean ± SEM (mg/dL)	Statistical comparison
Normal control	94.8 ± 2.7	-
Diabetic control	316.3 ± 3.9	***p < 0.001 vs Normal
Metformin	131.3 ± 2.4	***p < 0.001 vs Diabetic
Combination extract	145.0 ± 3.0	**p < 0.01 vs Diabetic

Note: *$p < 0.05 \rightarrow$ statistically significant, $p < 0.01 \rightarrow$ very significant, $p < 0.001 \rightarrow$ highly significant*

One-way ANOVA revealed a significant difference in fasting blood glucose levels among the experimental groups on Day 21 ($p < 0.001$). The diabetic control group exhibited a significant increase in blood glucose levels compared to the normal control group ($p < 0.001$). Treatment with metformin resulted in a significant reduction in fasting blood glucose levels compared to the diabetic control ($p < 0.001$). Similarly, the combination extract group also demonstrated a significant decrease in blood glucose levels compared to the diabetic control group ($p < 0.01$), indicating notable antihyperglycemic activity, though slightly less pronounced than metformin.

3.11.2 Tukey's test:

Tukey's multiple comparison test revealed that the diabetic control group exhibited significantly elevated fasting blood glucose levels and reduced body weight compared to the normal control group ($p < 0.001$), confirming the diabetic state. Treatment with metformin resulted in a marked and highly significant reduction in fasting blood glucose levels and prevention of body weight loss when compared with the diabetic control group ($p < 0.001$). Similarly, the combination extract also produced a significant decrease in blood glucose levels and helped maintain body weight relative to diabetic control animals ($p < 0.01$).

However, when compared directly, the combination extract was slightly less effective than metformin in reducing fasting blood glucose levels ($p < 0.05$), indicating comparatively lower antihyperglycemic potency.

4.RESULTS AND DISCUSSION

Streptozotocin administration successfully induced diabetes, as evidenced by a highly significant elevation in fasting blood glucose levels in diabetic control animals compared to normal controls throughout the 21-day experimental period ($p < 0.001$). Normal control animals maintained stable glucose levels during the study. The diabetic control group showed a progressive increase in fasting blood glucose from Day 0 to Day 21 (Figure 1). In contrast, metformin and the combination extract treatments produced a significant, time-dependent reduction in fasting blood glucose levels. Metformin reduced glucose levels from 269.7 ± 3.2 mg/dL at baseline to 131.3 ± 2.4 mg/dL on Day 21 ($p < 0.001$ vs

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diabetic control). Similarly, the combination extracts significantly lowered glucose levels to 145.0 ± 3.0 mg/dL ($p < 0.01$ vs diabetic control), demonstrating strong antihyperglycemic activity, though slightly less potent than metformin. Percentage reduction analysis showed that metformin and the combination extract reduced fasting blood glucose by 51.3% and 46.7%, respectively, indicating that the combination extract achieved a comparable glucose-lowering effect to the standard drug. Although individual plant extracts were not evaluated separately, the marked antihyperglycemic effect observed with the combined Momordica charantia and Cucurbita pepo seed extracts suggests a possible synergistic or additive interaction. Diabetic control animals exhibited a significant loss in body weight over 21 days ($p < 0.001$). Treatment with metformin and the combination extract effectively prevented body weight loss and maintained weights near normal levels ($p < 0.01$ vs diabetic control), reflecting improved metabolic status. Overall, one-way ANOVA demonstrated highly significant differences among experimental groups for fasting blood glucose and body weight at all time points ($p < 0.001$). Tukey's post hoc test confirmed significant differences between diabetic control and normal animals, as well as between treated groups and diabetic controls ($p < 0.01$–0.001).

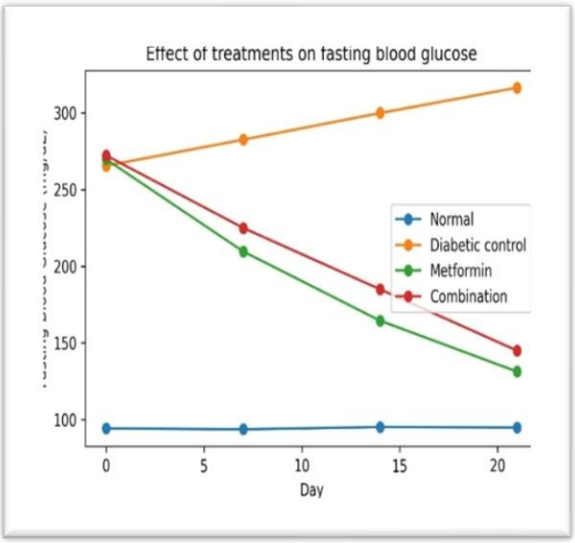

Figure 1: Impact of treatments on the level of fasting blood glucose

5.CONCLUSION

The present study demonstrates that the combined aqueous seed extracts of Momordica charantia and Cucurbita pepo exert a potent antihyperglycemic effect in streptozotocin-induced diabetic rats. The combination therapy produced a significant reduction in fasting blood glucose levels and effectively prevented diabetes-associated body weight loss over the 21-day treatment period, indicating an overall improvement in metabolic status. Notably, the glucose-lowering efficacy of the combination extract was comparable to that of metformin, the standard antidiabetic drug, suggesting that this phytotherapeutic formulation possesses clinically meaningful therapeutic potential. The observed antihyperglycemic activity may be attributed to the presence of bioactive phytoconstituents such as flavonoids and phenolic compounds, which are known to improve insulin sensitivity, enhance peripheral glucose utilization, and protect pancreatic β-cells from oxidative damage. The findings support the concept that integrated phytotherapy using complementary medicinal plants may offer a valuable adjunct or alternative strategy for glycemic control. Such plant-based interventions could be particularly beneficial in resource-limited settings with restricted access to conventional antidiabetic medications or among patients seeking natural therapeutic options with potentially fewer adverse effects. Despite the promising outcomes, further investigations are warranted to elucidate the precise molecular mechanisms underlying the observed effects, identify the active phytoconstituents responsible, and evaluate the long-term safety and efficacy of the

combination extract. Ultimately, well-designed controlled clinical trials will be essential to validate the translational potential of this formulation and establish its role in the management of diabetes mellitus in human subjects.

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