Research Article

Formulation and Evaluation of Polyherbal Antidiabetic Cookies

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ABSTRACT

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycaemia, requiring effective and safe management strategies. The present study focuses on the formulation and evaluation of polyherbal antidiabetic cookies aimed at providing a palatable, functional food alternative to conventional dosage forms. A combination of antidiabetic medicinal plants including *Gymnema sylvestre* (Gudmar), *Catharanthus roseus* (Sadaphuli), *Costus igneus* (Insulin plant), *Moringa oleifera*, *Tridax procumbens* (Kudkudi), and *Psidium guajava* (Guava leaves) were used for their synergistic hypoglycemic potential. Natural sweeteners such as *Stevia rebaudiana*, *Glycyrrhiza glabra* (Liquorice), and *Cinnamomum zeylanicum* (Cinnamon) were incorporated to enhance taste and maintain glycaemic safety. The cookies were prepared using wheat flour and finger millet (nachani) flour as the base, with the addition of orange zest for flavour enhancement. The prepared formulations were evaluated for organoleptic properties, physicochemical parameters (weight variation, hardness, moisture content), in vitro antidiabetic activity (α-amylase inhibition assay), and stability. Results demonstrated acceptable physical and sensory characteristics with notable α-amylase inhibition, indicating promising antidiabetic efficacy. This study suggests that polyherbal cookies could serve as a convenient and effective dietary supplement for diabetic individuals, combining therapeutic efficacy with improved patient compliance.

Keywords: Antidiabetic cookies, Hyperglycaemia, Hypoglycaemia, Alpha-amylase inhibition, Sensory evaluation.

INTRODUCTION

Diabetes is a common, non-communicable metabolic disorder that often affects young individuals and is linked to other health problems such as kidney and heart diseases. It happens when the pancreas either doesn't produce enough insulin or the body cannot use it effectively. According to a WHO report, around 422 million adults worldwide were living with diabetes in 2014, with the global rate increasing from 4.7% to 8.5%. Diabetes mellitus is a long-term condition characterized by high blood sugar levels, high fat levels in the blood, loss of nitrogen, sugar in the urine, and sometimes the presence of ketones. There are mainly three types of diabetes, one of which is Type 1 diabetes, also known as insulin-dependent or juvenile-onset diabetes. This type is usually caused by the immune system attacking the insulin-producing beta cells in the pancreas.

The polyherbal anti-diabetic cookies developed in this study are made using a combination of herbs and cereals. The herbal ingredients include *Gymnema sylvestre* (Gudmar), Finger millet, *Catharanthus roseus*, Guava leaves, Tridax procumbens, Moringa leaves, Liquorice, Costus igneus, Betel leaves, and Stevia leaves, along with wheat flour as the cereal base. This special mix creates a tasty and healthy snack that helps naturally manage blood sugar levels. Using herbal components also reduces the chances of side effects, making the cookies safe for diabetic people of all ages. This study supports the World Health Organization's 2016 goal of promoting natural food products to help control or lower blood sugar as part of its plan to fight non-communicable diseases.[1]

The cookies developed in this study are made from a mix of herbs and cereals, offering a natural and effective way to help manage diabetes. *Gymnema sylvestre* (Gudmar) helps by reducing sugar absorption in the intestines, boosting insulin release, and supporting glucose metabolism.[2] Finger millet is high in fibre, which slows down sugar absorption and helps control blood sugar after meals.[3] Catharanthus roseus (Madagascar periwinkle) contains compounds that increase insulin production, enhance sugar uptake, and have antioxidant effects.[4] Guava leaves help lower blood sugar by blocking certain enzymes and encouraging insulin release.[5] Tridax procumbens has antioxidant and anti-inflammatory properties that support blood sugar control.[6] Moringa leaves improve insulin sensitivity and sugar uptake through activation of AMPK enzymes.[7] Liquorice reduces cortisol levels by blocking a specific enzyme, which in turn helps improve the body's response to insulin.[8] Stevia leaves contain natural sweeteners that not only replace sugar but also help trigger insulin release and increase glucose uptake.[9] The insulin plant (Costos igneus) plays a helpful role by promoting insulin secretion and improving how the body uses glucose.[10] Wheat flour, used as the cereal base, provides long-lasting energy because of its complex carbohydrates. Together, these ingredients help regulate blood sugar, increase insulin efficiency, and reduce inflammation and oxidative stress, making the cookies a healthy option for diabetic individuals.

Diagnosis of diabetes mellitus:

Diabetes diagnosis relies heavily on analysing blood sugar levels. In healthy individuals, normal blood sugar levels

range from 80 mg/dl when fasting to up to 160 mg/dl after consuming a meal (postprandial state). To diagnose diabetes, various laboratory tests are employed, including:

The finger prick blood sugar test, which provides instant results

Fasting blood sugar (FBS) test, measuring blood glucose after an overnight fast

Glucose tolerance test (GTT), assessing the body's ability to regulate blood sugar levels after consuming a sugary drink

Glycohemoglobin (HbA1c) test, measuring average blood glucose control over the past 2-3 months

These tests help healthcare professionals diagnose and monitor diabetes, enabling timely interventions and effective management strategies.

Normal Blood Sugar Levels:

- Fasting: 80 mg/dl

- Postprandial (after meals): up to 160 mg/dl

- HbA1c: less than 5.7%

Abnormal Results:

- Fasting: 126 mg/dl or higher (diabetes)

- Postprandial: 200 mg/dl or higher (diabetes)

- HbA1c: 6.5% or higher (diabetes)

Early detection and diagnosis are crucial for preventing diabetes-related complications and improving patient outcomes.[11]

Pathophysiology of diabetes mellitus:

Oxidative stress plays a pivotal role in the pathophysiology of diabetes, resulting from an imbalance between the production of reactive oxygen species (ROS) and the capacity of enzymatic or non-enzymatic antioxidants. ROS comprises free radicals, including superoxide, hydroxyl, peroxyl, and hydroperoxyl, as well as non-radical species like hydrogen peroxide. Antioxidants, such as superoxide dismutase, glutathione reductase, vitamins A, C, and E, carotenoids, glutathione, and trace elements, counteract ROS.

In diabetes, ROS oxidizes low-density lipoprotein cholesterol, leading to its uptake by scavenger cells and the formation of foam cells and arterial sclerosis plaques. ROS stimulates damaging pathways, including the glucosamine pathway, sorbitol aldose reductase pathway, electron transport chain, and protein kinase C stimulation. Activation of these pathways contributes to: Atherosclerosis, Programmed cell death (apoptosis), Lipid peroxidation, Advanced glycation end-product (AGE) formation, Amylin deposition, Pancreatic β-cell dysfunction and failure

Research has identified a key cellular defence mechanism against oxidative stress, involving the sequence-specific DNA binding factor (Nuclear Factor Erythroid Derived 2 Like 2, Nrf2) and its negative regulator (Kelch-like ECH-associated protein 1, Keap1). This pathway plays a crucial role in protecting cells from oxidative damage.

Understanding the mechanisms of oxidative stress and antioxidant defences provides valuable insights into diabetes pathophysiology and potential therapeutic strategies. Targeting oxidative stress and enhancing antioxidant defences may help mitigate diabetes-related complications and improve patient outcomes [11].

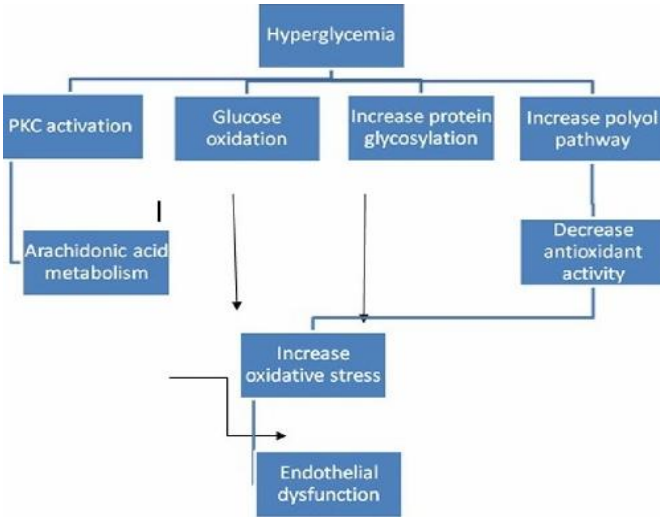


Figure 1: Pathophysiology of diabetes mellitus

MATERIALS AND METHODS

Collection of samples:

The herbal and natural ingredients used in the formulation of the polyherbal anti-diabetic cookies were carefully sourced to ensure quality and effectiveness. Medicinal plants such as *Gymnema sylvestre* (Gudmar), *Catharanthus roseus*, *Psidium guajava* (Guava leaves), *Tridax procumbens*, *Moringa oleifera* (Moringa leaves), and Insulin plant leaves were collected from the village hills and cultivated areas on our farm, shade dried and finely powdered. Additional ingredients, including orange zest, *Cinnamomum* (cinnamon) powder, *Glycyrrhiza glabra* (liquorice), stevia powder, vanilla essence, butter, milk, baking soda, baking powder, and salt, were procured from the local market in Satara.

Figure 2: All herbal plant materials.

Cereals such as finger millet (*Eleusine coracana*) and wheat flour were also purchased locally to serve as the base of the

cookie formulation. This combination of freshly collected herbs and locally sourced ingredients was selected to ensure both the therapeutic value and palatability of the final product.

Authentication: All herbal plants are authentified and certified from Yashwantrao Chavan Institute of science and Technology, Satara.

METHOD OF PREPARATION:

Different compositions of polyherbal antidiabetic cookies were developed using varying ratios of ingredients to optimize taste, texture, and health benefits. The primary cereal ingredients included *Eleusine coracana* (finger millet) and *Triticum aestivum* (wheat flour). The herbal components consisted of powdered leaves from the following plants: *Gymnema sylvestre*, *Catharanthus roseus*, *Psidium guajava* (guava), *Moringa oleifera*, *Costus igneus* (insulin plant) and Tridax procumbens.

Additional ingredients used in the formulation included:

- **Dairy and Fats**: Milk and butter
- **Flavouring Agents**: Vanilla essence, orange zest, and *Cinnamomum* (cinnamon) powder
- **Leavening Agents**: Baking powder and baking soda
- **Sweetener**: Natural sugar substitute (*Stevia rebaudiana*)
- **Functional Additives**: *Glycyrrhiza glabra* (liquorice) and salt.

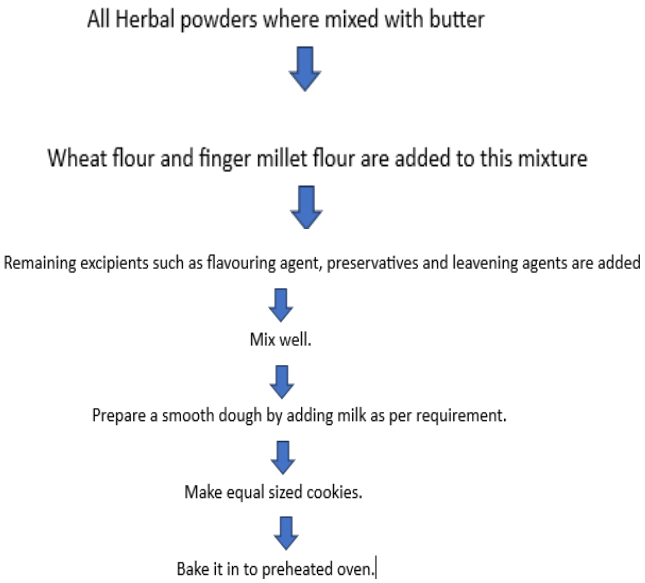


Figure 3: Flow chart for preparation of plyherbal cookies

Various combinations were prepared and evaluated for their **palatability** and **visual appeal**. Based on these sensory characteristics, the most acceptable formulation was selected for **sensory evaluation** and **nutritional value analysis**.

These are ingredients and their quantities of batch which was selected for sensory evaluation and nutritional analysis.

Table 1: Preliminary batches of polyherbal cookies**.**

Ingredients	Quantity	Role
Wheat Flour	100gm	Binder
Finger millet flour	50gm	Binder
Gymnema sylvestre	60mg	Antidiabetic
Psidium guajava (Guava)	200mg	Antidiabetic
Catharanthus roseus	60mg	Antidiabetic
Tridax procumbens	100mg	Antidiabetic
Chamaecostus Cuspidatus (insulin plant)	150mg	Antidiabetic
Moringa oleifera	200mg	Antidiabetic
Stevia powder	4 tsp	Natural Sweetener
Cinnamon powder	100mg	Antioxidant / Preservative
Liquorice powder	200mg	Sweetener / Preservative
Orange zest	1 tsp	Flavouring agent
Baking powder	200mg	Leavening agent
Baking soda	50mg	Leavening agent
Salt	A pinch	Taste enhancer
Butter	15gm	Binder
Milk	50ml	Bider
Vanila essence	5ml	Flavouring agent

Figure 4: Polyhedral cookies formulated.

EVALUATION OF POLYHERBAL COOKIES:

A] Phyto chemical Properties of Cookies:

1] Moisture content:

The moisture content of the cookies was measured using the standard method described in *Chemical Analysis of Food* [10]. A known weight of the cookie sample was placed in a moisture dish and heated in a hot air oven at 105°C for about 2 hours. After heating, the sample was cooled and weighed again. This process of heating for 30 minutes, cooling, and reweighing was repeated until the difference between two consecutive weights was less than 0.001 grams. The final moisture content was calculated using the standard formula provided in the reference method.

$$\mu = \frac{(\text{weight before} - \text{weight after})}{\text{weight after}} \times 100 = \text{moisture content in \%}$$

2] Ash value:

The total ash content of the prepared cookies was determined using the standard procedure described in *Chemical Analysis of Food* [10]. About 1 gram of the cookie sample was placed in a pre-weighed (tarred) crucible and heated over a Bunsen burner until all the organic matter (carbon) was completely burned off. The sample was then allowed to cool and weighed. This process of heating, cooling, and weighing was repeated until a constant weight was obtained. The total ash content was then calculated using the formula provided below.

% Ash = Weigh of ash / Weight of original sample × 100

B] Nutritional analysis:

1] Protein estimation:

Protein content in the cookies was estimated using the standard method described in the DGHS Manual. About 200–300 mg of cookie powder was placed into four test tubes. To each tube, 3 grams of a catalyst mixture (potassium sulfate and copper sulfate) and 10 ml of concentrated sulfuric acid (H_2SO_4) were added. The samples were then digested for 3 to 4 hours to break down the organic matter. After digestion, the mixture was distilled using boric acid, potassium permanganate, and 40% sodium hydroxide. The resulting solution was titrated with acid and neutralized using ammonia. The percentage of protein was then calculated using a standard formula.[12]

2] Fat content:

To estimate the fat content, 2 grams of the cookie sample were placed in a Soxhlet apparatus and extracted using a 1:1 mixture of diethyl alcohol and petroleum ether for 6 hours. After extraction, the ether was removed by distillation, and the remaining sample was dried in a hot air oven at 110 ± 1°C. Once dried, the sample was cooled and weighed. The residue was then washed with 2–3 ml of diethyl ether, and the process was repeated until a constant weight was obtained. The final weight was used to calculate the fat content in the sample.[12]

% of fat content = (M1 - M2) *100/ weight of the sample

Where,

M1 =Weigh of Round bottom flask with fat;

M2 = Weigh of the Round bottom flask.

3] Carbohydrate estimation:

Carbohydrate content was estimated using the method described in the DGHS Manual. For this, 2 grams of cookie powder were taken in a 200 ml volumetric flask. Then, 50 ml of lead acetate and 6 ml of 0.5 N hydrochloric acid (HCl) were added. The mixture was heated on a hot water bath to help break down the carbohydrates. (Heating step is not for calculating reducing sugar before inversion. It is essential for calculating reducing sugar after inversion.) After heating, the solution was cooled and neutralized with 6 ml of 0.5 N sodium hydroxide (NaOH). The final volume was made up to 200 ml using distilled water.

To measure the invert sugar (a form of simple sugar), the Lane and Eynon method was used. In this method, 10 ml of mixed Fehling's A and B solutions were taken in a conical flask, and the sample solution was added gradually during titration, completed within 3 minutes. A 1% aqueous methylene blue solution was used as the indicator.[12]

Reducing sugar % before inversion = F*10/C*R

Reducing sugar % after inversion = F*10/C*R

Where, C = concentration;

R = Reading;

F =Factor of Fehling solution Total invert sugar % after inversion

C=concentration;

Total carbohydrate% = Reducing sugar % after inversion – reducing sugar %before inversion * 0.95

4] Total Energy:

Total energy was calculated based on the carbohydrate, protein, and fat content of the cookie sample. Total energy was calculated by using following formula,[12]

Total energy = carbohydrate * 4 + Protein * 4 + Fat * 9

C] In Vitro Evaluation:

Alpha Amylase Inhibition test for Antidiabetic cookies is done by BIOCYTE RESEARCH AND DEVELOPMENT, SANGALI, MAHARASHTRA. For this test sample of cookies was send and test is performed.

Table 2: Alpha Amylase Inhibition Test

Sr. No.	Sample code	Conc.	OD			Mean	Percent
1	Control	-	0.89	0.88	0.85	0.87	
2	**Standard**	250	0.25		0.24	0.23	72.90
		500	0.21	0.19	0.18	0.19	77.86
		1000	0.15	0.12	0.11	0.12	**85.49**
3	**Sample-Antidiabetic**	250	0.58	0.57	0.59	0.58	33.58
		500	0.45	0.48	0.42	0.45	48.47
		1000	0.38	0.35	0.37	0.36	**58.01**

After inhibition test it was concluded that the alpha-amylase inhibition assay indicates that the test sample of cookies exhibits dose-dependent antidiabetic activity, as evidenced by increasing percent inhibition at higher concentrations. At 250, 500, and 1000 µg/mL, the sample showed 33.58%, 48.47%, and 58.01% inhibition, respectively.

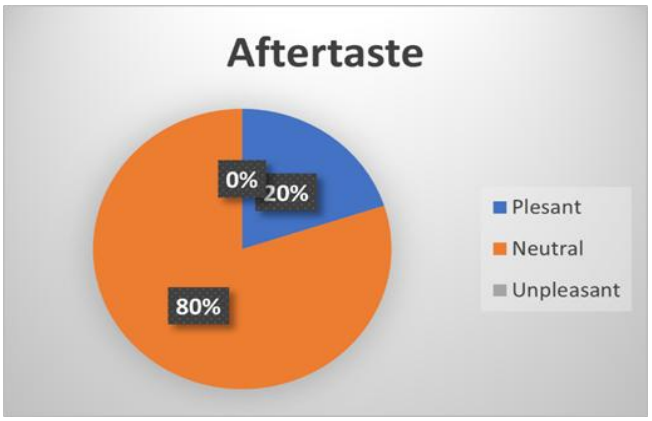
RESULT AND DISCUSSION

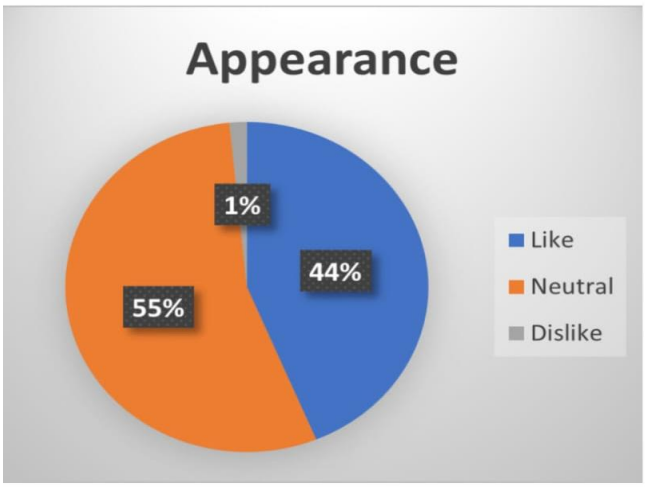
Phytochemical Properties of Cookies:

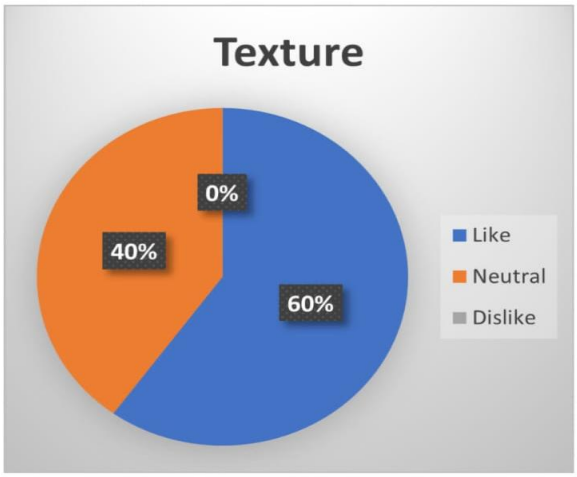
Table 3: Chemical and physiochemical parameter

Parameters	Results
Moisture content	42.23%
Ash value	10%
Protein content	8.5%
Fat content	18.66%
Carbohydrate estimation	63.415%
Total energy	455.541 kcal
Alpha Amylase Inhibition	58.01%

Sensory Evaluation:







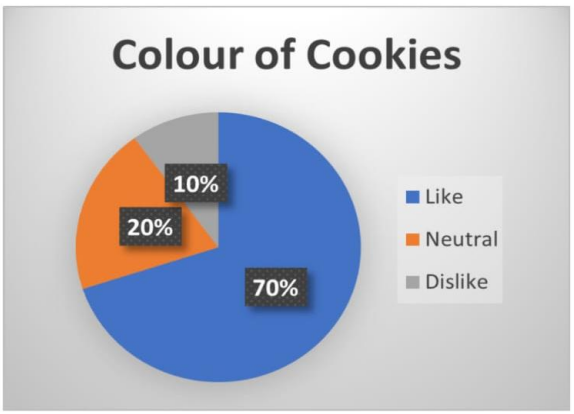


Figure 5: Sensory evaluation of polyherbal cookies

CONCLUSION

Based on the current results, the formulated antidiabetic cookies were found to be nutritionally rich, with controlled levels of fat and carbohydrates and a high protein content. This makes them suitable for people suffering from Diabetes. Add on benefits are suitable for health-conscious individuals, growing children, and malnutrition. Sensory evaluation showed that the addition of orange zest and vanilla essence enhanced the flavour and overall appeal of the cookies. The selected cookie formulation was well accepted, with an approval rate of about 90–96%, indicating good potential for large-scale production. Overall, the cookies showed acceptable results in terms of nutritional value, physicochemical properties, taste.

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