Formulation and Evaluation of Herbal Sugar-Free Antidiabetic Chocolate

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***Abstract*—The present study focuses on the formulation and evaluation of a herbal sugar-free antidiabetic chocolate using cocoa powder, cocoa butter, stevia, and selected medicinal plant extracts. Diabetes mellitus is a chronic metabolic disorder of increasing global prevalence. Herbal ingredients including Psidium guajava (guava leaves), Gymnema sylvestre, Trigonella foenum-graecum (fenugreek), and Cinnamomum verum (cinnamon) were incorporated into a sugar-free chocolate base sweetened with Stevia rebaudiana. The chocolate was prepared by the melt and mix method and evaluated for organoleptic, physicochemical, and in-vitro antidiabetic parameters. Results showed acceptable appearance, smooth texture, pH 6.4, melting point 110–120°C, weight variation −1.2%, and viscosity 4200–4800 cP. In-vitro α-amylase and α-glucosidase inhibition assays demonstrated significant dose-dependent enzyme inhibitory activity. No blooming was observed. The formulation represents a novel, patient-friendly nutraceutical dosage form for diabetes management.**

***Index Terms*—Antidiabetic chocolate, Diabetes mellitus, Gymnema sylvestre, Guava leaf extract, Nutraceutical, Postprandial hyperglycemia, Stevia, Sugar-free formulation.**

I. INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion,
insulin action, or both. According to WHO, its global burden has risen dramatically, with developing countries like India significantly affected [1]. Type 2 diabetes mellitus (T2DM) accounts for approximately 90–95% of all cases and is associated with insulin resistance and
impaired pancreatic β-cell function [2]. Chronic hyperglycemia leads to neuropathy, nephropathy, retinopathy, and cardiovascular complications [3].

Conventional antidiabetic therapies are often associated with adverse effects, risk of hypoglycemia, and poor patient compliance [4]. Herbal medicines

such as Gymnema sylvestre, fenugreek, guava leaves, and cinnamon have shown antidiabetic activity through enzyme inhibition, insulin sensitization, and antioxidant effects [5]. Chocolate serves as an excellent carrier for bioactive herbal compounds due to its palatability, thereby improving patient compliance [9]. The present study formulates a herbal sugar-free antidiabetic chocolate using stevia as a non-caloric natural sweetener, combining therapeutic benefits with consumer acceptability [10, 11].

II. AIM AND OBJECTIVES

Aim: To formulate and evaluate a herbal sugar-free antidiabetic chocolate containing selected plant extracts and natural sweeteners as a patient-friendly, effective nutraceutical dosage form for diabetes management.

Objectives:

- Formulate a sugar-free chocolate base using cocoa powder, cocoa butter, and stevia.
- Incorporate herbal extracts of guava leaf, Gymnema sylvestre, fenugreek, and cinnamon.
- Optimize formulation for texture, taste, homogeneity, and stability.
- Evaluate physicochemical parameters: pH, melting point, thickness, weight variation, and viscosity.
- Assess organoleptic properties including taste, aroma, mouthfeel, and acceptability.
- Perform in-vitro antidiabetic activity by α-amylase and α-glucosidase inhibition assays.
- Conduct stability studies under different temperature and humidity conditions.

III. PLANT PROFILE

1. Psidium guajava (Guava Leaves) – Family Myrtaceae. Constituents: flavonoids (quercetin, guaijaverin), tannins, saponins, polyphenols. Mechanism: inhibits α-glucosidase, reduces postprandial glucose, improves insulin sensitivity [1].
2. Gymnema sylvestre (Gurmar) – Family Apocynaceae. Constituents: gymnemic acids, saponins, flavonoids. Mechanism: regenerates pancreatic β-cells, enhances insulin secretion, reduces intestinal glucose absorption [2].
3. Trigonella foenum-graecum (Fenugreek) – Family Fabaceae. Constituents: trigonelline, galactomannan, saponins. Mechanism: delays gastric emptying, reduces glucose absorption, improves insulin sensitivity [5].
4. Cinnamomum verum (Cinnamon) – Family Lauraceae. Constituents: cinnamaldehyde, eugenol, polyphenols. Mechanism: mimics insulin activity, enhances glucose uptake, improves insulin receptor function [4].
5. Stevia rebaudiana (Natural Sweetener) – Family Asteraceae. Constituents: stevioside, rebaudioside A. Non-caloric; does not raise blood glucose; enhances insulin secretion. Ideal sugar substitute for diabetic formulations [1, 3].

IV. MATERIALS AND METHODS

A. Materials

Table I: Material List

Sr.	Material	Category	Supplier
1	Cocoa Powder	Base material	Cadbury / Local
2	Cocoa Butter	Base material	Merck
3	Stevia	Sweetener	Himedia Labs
4	Guava Leaf Ext.	Herbal extract	Auth. supplier
5	Gymnema Ext.	Herbal extract	Himedia Labs
6	Fenugreek Ext.	Herbal extract	Local supplier
7	Cinnamon Ext.	Herbal extract	Local supplier
8	Ethanol	Solvent	Loba Chemie
9	Distilled Water	Solvent	Lab supply

B. Extraction Method

Each herbal drug was shade-dried, powdered, and extracted by boiling 10–20 g in 100–200 mL distilled water at 90–100°C for 30–45 min. Decoctions were filtered through muslin cloth and Whatman No.1 filter paper and stored at 4°C [1, 4, 8].

C. Formulation Composition

Table II: Formulation Composition

Ingredient	Function	Qty (%)
Cocoa Butter	Base	40
Cocoa Powder	Flavor/Antioxidant	30
Stevia	Sweetener	5
Guava Leaf Ext.	Antidiabetic	5
Gymnema Ext.	Antidiabetic	5
Fenugreek Ext.	Antidiabetic	5
Cinnamon Ext.	Antidiabetic	5
Total	—	100%

D. Preparation Method

Cocoa butter was melted at 40–50°C in a water bath. Cocoa powder was gradually blended in with continuous stirring. Stevia was incorporated uniformly, followed by the four standardized herbal extracts. The mixture was homogenized until lump-free, degassed, poured into pre-lubricated molds, refrigerated until solidification, de-molded, and stored in airtight containers under cool and dry conditions.

V. EVALUATION TESTS

A. Organoleptic & Physical Evaluation

Samples were examined by a trained sensory panel for color, odor, taste, texture, surface smoothness, glossiness, and absence of air bubbles.

B. Physicochemical Parameters

Melting point: water bath with thermometer. pH: 1 g crushed chocolate in 50 mL phosphate buffer (pH 6.8) measured by pH meter. Thickness: Vernier caliper. Weight variation: 10 chocolates weighed individually; formula = (Individual − Average) / Average × 100%. Viscosity: Brookfield Viscometer at 40–45°C.

C. Stability Testing

Samples stored at 25°C ± 2°C (RT), 4°C ± 2°C (refrigerated), and 40°C ± 2°C (elevated). Appearance, texture, and odor observed at days 1, 3, 7, and 14 [5].

D. Blooming Test

Fat bloom and sugar bloom were assessed by visual inspection of the chocolate surface for whitish or grayish discoloration under controlled storage conditions [7, 8].

E. In-Vitro Antidiabetic Activity

α-Amylase inhibition: enzyme incubated with starch and test sample at 37°C for 10–15 min; DNS reagent added; absorbance at 540 nm. α-Glucosidase inhibition: p-nitrophenyl glucopyranoside as substrate; absorbance at 405 nm. Acarbose used as standard in both assays [12].

VI. RESULTS AND DISCUSSION

A. Organoleptic & Physical Evaluation

Table III: Organoleptic & Physical Evaluation

Parameter	Observation
Color	Dark brown
Odor	Pleasant chocolate aroma
Taste	Sweet with mild herbal taste
Texture	Smooth and uniform
Appearance	Glossy and acceptable
Surface	Smooth, no air bubbles
Break property	Good snap

B. Physicochemical Parameters

Table IV: Physicochemical Evaluation Results

Sr.	Parameter	Result
1	Melting Point	110–120°C
2	pH	6.4
3	Thickness	2.4 mm
4	Weight Variation	−1.2% (within limits)
5	Viscosity	4200–4800 cP
6	Stability	Stable at RT & below RT
7	Fat Bloom	Absent
8	Sugar Bloom	Absent

C. α-Amylase Inhibition Assay

Table V: α-Amylase Inhibition (n=3)

Conc. (µg/mL)	Acarbose % Inh.±SD	Herbal Choc. % Inh.±SD
25	39.21±0.52	28.45±0.45
50	53.15±0.48	41.32±0.41
75	68.32±0.62	55.48±0.49
100	82.65±0.71	69.73±0.58

D. α-Glucosidase Inhibition Assay

Table VI: α-Glucosidase Inhibition (n=3)

Conc. (µg/mL)	Acarbose % Inh.±SD	Herbal Choc. % Inh.±SD
25	38.65±0.44	26.31±0.36
50	52.48±0.53	38.76±0.42
75	66.81±0.67	51.62±0.48
100	80.92±0.74	64.83±0.55

The herbal chocolate demonstrated significant dose-dependent inhibition of both α-amylase and α-glucosidase enzymes. While inhibition was lower than acarbose, the polyherbal synergy across four extracts provides comprehensive glycemic control. pH 6.4, weight variation −1.2%, and absence of blooming confirm physicochemical acceptability and adequate formulation stability.

VII. CONCLUSION

The herbal sugar-free antidiabetic chocolate was successfully formulated and evaluated. The formulation exhibited acceptable organoleptic properties, satisfactory physicochemical parameters, and significant in-vitro antidiabetic activity through α-amylase and α-glucosidase inhibition. It offers improved patient compliance over conventional dosage forms. The developed chocolate serves as an effective functional food and nutraceutical approach for diabetes management combining therapeutic

benefits with consumer acceptability. Further clinical evaluation and long-term stability studies are recommended.

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