

Formulation and Evaluation of Anti-Diabetic Chocolate from Fruit Extracts

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Abstract: Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia and associated complications, necessitating the development of safer and patient-friendly therapeutic approaches. The present study focuses on the formulation and evaluation of a nutraceutical product in the form of fruit extract-enriched dark chocolate for diabetes management. Cocoa flavonoids present in dark chocolate, along with bioactive compounds from selected fruits such as *Mangifera indica* (mango) and *Ananas comosus* (pineapple), offer significant antidiabetic potential through antioxidant activity, enzyme inhibition, and improvement of insulin sensitivity. The formulation was prepared by incorporating fruit extracts into a dark chocolate base along with cocoa butter, honey as a natural sweetener, and rosemary as a natural antioxidant and preservative. Different formulations were developed and evaluated for organoleptic properties, physicochemical parameters, and chemical characteristics. The prepared chocolates exhibited desirable attributes including uniform dark brown color, acceptable taste, and good consistency. The pH of the formulations ranged from 5.2 to 5.32, indicating suitability for consumption. Chemical evaluation confirmed the presence of carbohydrates and proteins, while weight variation studies indicated uniformity in formulation. Stability assessment showed no evidence of fat bloom, suggesting good product stability. The combined effects of cocoa flavonoids and fruit-derived phytochemicals demonstrated a potential synergistic role in improving glycemic control. In conclusion, the developed fruit extract-enriched dark chocolate represents a promising nutraceutical formulation with potential antidiabetic benefits, improved palatability, and enhanced patient compliance. However, further in-vitro, in-vivo, and clinical studies are required to validate its therapeutic efficacy and safety.

Keywords: Diabetes mellitus, Nutraceuticals, Dark chocolate, Cocoa flavonoids, Mango, Pineapple, Antidiabetic, Functional food

Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both¹. It has emerged as a major global health concern, with its prevalence increasing rapidly due to sedentary lifestyles, unhealthy dietary habits, and rising obesity rates^{2,3}. The long-term complications of diabetes, including cardiovascular diseases, neuropathy, nephropathy, and retinopathy, significantly affect the quality of life and impose a substantial burden on healthcare systems¹.

Consequently, there is an increasing demand for safer, cost-effective, and patient-friendly therapeutic approaches for the prevention and management of diabetes. In recent years, considerable attention has been directed toward the use of natural products and functional foods as alternative or complementary therapies for diabetes management⁴.

Bioactive compounds such as flavonoids, polyphenols, tannins, and antioxidants abundantly present in plant-based foods have demonstrated significant antidiabetic potential through multiple mechanisms^{4,7}. These include enhancement of insulin secretion, improvement of insulin sensitivity, inhibition of carbohydrate-digesting enzymes such as α -amylase and α -glucosidase, and reduction of oxidative stress and inflammation^{4,16,18}.

Among functional food candidates, cocoa and its derivatives, particularly dark chocolate, have attracted scientific interest due to their rich content of flavanols such as epicatechin and catechin^{5,6}. These compounds exhibit strong antioxidant and anti-inflammatory properties and play a crucial role in improving endothelial function and glucose metabolism^{6,15}.

Additionally, cocoa flavonoids have been shown to enhance insulin sensitivity and modulate glucose uptake in peripheral tissues^{6,17}. However, the therapeutic application of conventional chocolate products is limited due to their high sugar and calorie content, which may adversely affect glycemic control⁶.

Fruits represent another important source of natural antidiabetic agents. They are rich in phytochemicals such as flavonoids, saponins, carotenoids, and phenolic acids, which contribute to their antihyperglycemic and antioxidant effects^{4,9}. Various fruits, including *Mangifera indica* and *Ananas comosus*, have been reported to possess significant antidiabetic activity^{12,13}.

These fruits not only help regulate blood glucose levels but also improve lipid profiles and protect pancreatic β -cells from oxidative damage^{12,13}. The presence of vitamins, minerals, and bioactive compounds further enhances their therapeutic value.

The concept of nutraceuticals, which combines nutritional and pharmaceutical benefits, has paved the way for the development of innovative dosage forms such as medicated chocolates⁸. Chocolate-based formulations offer several advantages, including improved palatability, better patient compliance, ease of administration, and suitability for a wide range of age groups⁸.

Incorporation of fruit extracts and natural ingredients such as honey (as a natural sweetener) and rosemary (as a natural antioxidant and preservative) can further enhance the functional and therapeutic properties of the formulation while maintaining product stability and shelf life^{27,28}.

Therefore, the present study focuses on the formulation and evaluation of fruit extract-enriched dark chocolate as a novel nutraceutical approach for diabetes management.

ANTI-DIABETIC CHOCOLATE FROM DARK CHOCOLATE

Natural dietary compounds, particularly flavonoids found abundantly in fruits and vegetables, have attracted significant scientific interest for their potential role as anti-diabetic agents⁴. Among these, cocoa flavonoids have been shown to ameliorate key pathological features of type 2 diabetes mellitus by enhancing insulin secretion, improving insulin sensitivity, and reducing oxidative stress^{5,6,16}.

Processing methods such as fermentation and roasting of cocoa (*Theobroma cacao*) are known to reduce polyphenol content, which may influence its biological activity¹⁴. While cocoa flavanols may help in diabetes prevention, commercially available chocolate products often contain high sugar levels, which may worsen glycaemic control^{6,9}.

Dark chocolate has a long history of use for its health benefits and is rich in bioactive compounds⁶. Cocoa flavanols such as epicatechin and catechin exhibit antioxidant and anti-inflammatory effects, contributing to improved glucose metabolism and insulin sensitivity^{6,15}.

Furthermore, these compounds inhibit α -glucosidase activity and reduce intestinal glucose absorption¹⁸. Studies also indicate that cocoa consumption improves endothelial function, which is closely linked with insulin sensitivity¹⁹.

FRUIT-DERIVED BIOACTIVES WITH ANTIDIABETIC POTENTIAL

Fruits are rich in bioactive phytochemicals such as flavonoids, polyphenols, and saponins, which play a vital role in diabetes management^{4,9}. These compounds act through multiple mechanisms including enzyme inhibition, insulin enhancement, and antioxidant protection⁴.

Phyllanthus emblica has shown significant antidiabetic activity by reducing blood glucose levels and improving insulin secretion¹⁹. Similarly, *Musa sapientum* extract demonstrated inhibition of α -amylase activity, improving carbohydrate metabolism²⁰.

Cleistocalyx nervosum showed strong inhibition of α -amylase and α -glucosidase enzymes, indicating potent antidiabetic potential²². *Carissa carandas* extract significantly reduced blood glucose levels in experimental models²¹.

Ficus deltoidea exhibited antioxidant and enzyme inhibitory properties²², while fruit peels of *Citrus sinensis* and *Punica granatum* demonstrated significant hypoglycemic effects²³.

Additionally, *Cucumis trigonus* improved glucose and lipid profiles in diabetic models²⁴, and pear peel extracts showed strong α -glucosidase inhibition and antioxidant activity²⁵.

DRUG PROFILE

❖ MANGO

Mango is biologically obtained from the fruit of *Mangifera indica* L., which belongs to the family Anacardiaceae. It is a widely used plant in both nutritional and medicinal contexts due to its rich composition of bioactive compounds. The chemical constituents of mango are diverse and contribute significantly to its therapeutic value. It contains polyphenols such as mangiferin, gallic acid, catechins, and quercetin. Flavonoids like isoquercitrin, rutin, and kaempferol are also present. In addition, mango is rich in carotenoids including β -carotene, lutein, and violaxanthin, which are important for antioxidant activity and eye health. It provides essential vitamins such as vitamin A, vitamin C, and vitamin E, along with important minerals like potassium, magnesium, calcium, and phosphorus. Furthermore, it contains tannins such as gallotannins and ellagitannins, as well as terpenoids including lupeol, β -sitosterol, and squalene.

Mango exhibits a wide range of pharmacological activities. It has antidiabetic properties that help in regulating blood sugar levels, along with anti-inflammatory effects that reduce inflammation. It acts as a digestive aid, supporting gastrointestinal health, and shows antimicrobial activity against various pathogens. Additionally, it has anti-ulcer properties and strong antioxidant activity, which helps in protecting the body from oxidative stress and related disorders

Table 1:-Synonyms of mango

Sr. No.	Languages	Names
1	English	Mango
2	Hindi	Aam
3	Sanskrit	Amra
4	Tamil	Maangaai

Table 2:-Scientific classification of mango

Kingdom	Plantae
Order	Sapindales
Family	Anacardiaceae
Genus	Mangifera
Species	Mangifera indica

Table 3:-Vernacular name of mango

Sr. No.	Language	Vernacular name
1	English	English
2	Hindi	Aam
3	Marathi	Amba
4	Sanskrit	Amra

❖ PINEAPPLE

Pineapple is biologically obtained from the fruit of *Ananas comosus* (L.) Merr., which belongs to the family Bromeliaceae. It is widely recognized not only as a nutritious fruit but also for its therapeutic and medicinal importance due to the presence of various bioactive compounds.

The chemical constituents of pineapple include a prominent proteolytic enzyme, bromelain, which is considered its major active component and is responsible for many of its biological effects. It also contains polyphenols such as gallic acid, ferulic acid, and catechins, along with flavonoids like quercetin, rutin, and kaempferol. Pineapple is rich in essential vitamins including vitamin C, vitamin A, and vitamin B-complex, and provides important minerals such as potassium, calcium, magnesium, and phosphorus. Additionally, it contains organic acids like citric acid and malic acid, as well as natural sugars including glucose, fructose, and sucrose.

Pineapple exhibits a wide range of pharmacological activities. It has antidiabetic potential, helping in the regulation of blood glucose levels, and shows anti-inflammatory properties that aid in reducing inflammation. Due to the presence of bromelain, it acts as an effective digestive aid by enhancing protein digestion. It also demonstrates antimicrobial activity against various microorganisms and possesses anti-ulcer properties that support gastrointestinal health. Furthermore, its strong antioxidant activity helps in neutralizing free radicals and protecting the body from oxidative stress

Table 4:-Synonyms of pineapple

Sr. No.	Languages	Names
1	English	Pineapple
2	Hindi	Ananas
3	Sanskrit	Anannasa
4	Tamil	Annachi pazham

Table 5:-Scientific classification of pineapple

Kingdom	Plantae
Order	Poales
Family	Bromeliaceae
Genus	Ananas
Species	Ananas comosus

Table 6:-Vernacular names of pineapple

Sr. No.	Language	Vernacular name
1	English	Pineapple
2	Hindi	Ananas
3	Marathi	Ananas
4	Sanskrit	Anannasa

EXCIPIENT PROFILE

❖ COCOA BUTTER

Cocoa butter is classified primarily as an emollient and lubricating agent, and it also serves as a base component in various formulations. It is a natural fat obtained from the seeds of *Theobroma cacao* and appears as a pale yellow, edible vegetable fat. Widely used in both pharmaceutical and cosmetic preparations, cocoa butter is well known for its excellent moisturizing properties and its ability to melt at body temperature, making it highly suitable for topical and edible applications.

In formulations, cocoa butter performs multiple important functions. It acts as a base for creams, ointments, and even chocolate products, contributing to their structure and usability. It provides a smooth texture and consistency, enhances the stability of formulations, and improves spreadability and absorption when applied to the skin. Additionally, it functions as an effective moisturizing agent, helping to maintain skin hydration.

Cocoa butter possesses several distinctive properties. It typically ranges in color from pale yellow to cream and has a characteristic pleasant chocolate-like odor. Its texture is smooth and greasy, and it has a melting point of approximately 30–35°C, which allows it to melt easily upon contact with the skin. It is insoluble in water but dissolves readily in organic solvents.

There are several advantages associated with the use of cocoa butter. It is an excellent emollient and skin-conditioning agent, making it highly beneficial in skincare products. In edible formulations, it provides a desirable texture and mouthfeel. It is relatively stable and resistant to oxidation, ensuring a longer shelf life. Moreover, it is non-irritating, safe for topical use, and being a natural ingredient, it is widely accepted in both pharmaceutical and cosmetic industries.

❖ DARK CHOCOLATE

Powdered sugar, also known as icing sugar, is categorized as a sweetening agent and base component in formulations. It is a finely ground form of sucrose obtained from sugarcane or sugar beet and is typically mixed with a small quantity of an anti-caking agent such as starch to prevent clumping. In dark chocolate, powdered sugar plays an important role in balancing the natural bitterness of cocoa, thereby improving the overall palatability of the product.

In formulation, particularly in dark chocolate, powdered sugar performs several essential functions. It provides sweetness and reduces the bitterness of cocoa, acts as a bulking agent, and facilitates uniform mixing with cocoa mass and fat. Additionally, it enhances the texture and contributes to a smooth mouthfeel, while also playing a role in maintaining the overall structure of the chocolate.

Powdered sugar possesses distinct properties that make it suitable for such applications. It appears as a white, fine powder, is odorless, and has a characteristic sweet taste. It is highly soluble in water and has a smooth texture, which is especially important for achieving proper refinement in chocolate products.

There are several advantages of using powdered sugar in dark chocolate. It enhances taste and consumer acceptability, is easily soluble and well dispersible, and improves the consistency and smoothness of the final product. Moreover, it is cost-effective, widely available, and helps achieve the desirable mouthfeel expected ^[27]

❖ ROSEMARY

Rosemary (*Rosmarinus officinalis*) is categorized as a natural preservative and antioxidant agent, widely utilized in food and medicinal formulations. It is an aromatic evergreen herb known for its rich content of bioactive compounds such as rosmarinic acid, carnosic acid, and essential oils, which exhibit strong antioxidant and antimicrobial properties. In dark chocolate, rosemary extract is incorporated as a natural preservative to prevent oxidation of fats, particularly cocoa butter, thereby extending the product's shelf life.

In formulation, rosemary performs several important functions. It acts as a natural antioxidant that helps prevent rancidity of cocoa butter and other lipid components. It also exhibits antimicrobial activity, inhibiting the growth of

microorganisms and enhancing product safety. Additionally, it contributes to extending the shelf life of chocolate, maintains flavor stability over time, and protects ingredients from oxidative degradation.

Rosemary possesses distinct properties that make it suitable for such applications. It is typically available as a greenish-brown extract or dried powder, depending on its form. It has a characteristic aromatic odor and a slightly bitter, herbal taste. It is rich in phenolic compounds, which are responsible for its antioxidant activity, and remains relatively stable under moderate heat conditions.

The use of rosemary offers several advantages in formulation. It serves as a natural alternative to synthetic preservatives, improving shelf life without compromising safety. It provides effective antioxidant protection to fats, enhances overall product stability, and is highly acceptable to consumers due to its herbal origin and clean-label appeal²⁸

❖ HONEY

Honey is categorized as a natural sweetener and natural preservative, widely used in food and medicinal formulations. It is a natural viscous substance produced by bees from floral nectar and is rich in sugars, enzymes, organic acids, phenolic compounds, and trace minerals. Owing to its antimicrobial and antioxidant properties, honey plays an important role in enhancing both the nutritional and functional value of products. In dark chocolate, it serves as a natural sweetening agent as well as a preservative, contributing to improved shelf life and overall product stability. In formulation, honey performs multiple functions. It acts as a natural sweetener, providing a pleasant sweetness while also offering antimicrobial effects that help inhibit microbial growth. Its antioxidant activity helps prevent oxidation of ingredients, particularly fats, thereby maintaining product quality. Additionally, honey improves texture and moisture retention due to its hygroscopic nature, and enhances the overall flavor and palatability of chocolate.

Honey exhibits several characteristic properties. It is a thick, viscous liquid with a golden-brown appearance and has a pleasant sweet aroma and taste. It is hygroscopic, meaning it can retain moisture, which is beneficial in maintaining softness and preventing drying of products. It is rich in sugars such as glucose and fructose, along with phenolic compounds that contribute to its antioxidant activity. Moreover, it remains relatively stable under moderate heat conditions.

The use of honey offers several advantages in formulation. It serves as a natural alternative to refined sugar and synthetic preservatives, improving shelf life and product safety. It provides both antioxidant and antimicrobial protection, enhances the sensory appeal of the final product, and aligns well with consumer preferences due to its natural origin and clean-label status.

MATERIAL AND EQUIPMENT

MATERIAL

Table 7:- Proposed Formulation of Antidiabetic Chocolate Containing Fruit Extracts

Sr. No.	Ingredient	Function	References
1	Dark Chocolate (70% cocoa)	Base matrix; provides flavonoids with insulin-sensitizing and antioxidant effects	(5,6)
2	Cocoa Butter	Texture enhancer, fat source, carrier for bioactives	(26)
3	PINEAPPLE	Antidiabetic and antioxidant agents; contribute phenolics, flavonoids, and vitamins	(12,13)
4	MANGO	Antidiabetic and antioxidant agents; contribute phenolics, flavonoids, and vitamins	(12,13)
5	Honey	Natural sweetener; provides sweetness without increasing glycemic index	(27)

Sr. No.	Ingredient	Function	References
6	Cocoa Powder	Flavor enhancer and polyphenol booster	(5,14)
7	Natural Preservative rosemary	Antioxidant stabilizer; prevents rancidity and oxidation	(28)

EQUIPMENT

Following equipment's are used in the formulation of formulation & evaluation of chocolate.

Table 8:-Equipment's required

Sr. No.	Equipment's	Uses
1.	Analytical balance	Accurate weighing of ingredients
2.	Hot plate	Melting chocolate and heating mixtures
3.	Mold for chocolates	Shaping and forming chocolates
4.	pH meter	Measuring pH of formulation
5.	Refrigerator	Cooling and solidifying chocolate, and storage

8. EVALUATION

➤ Organoleptic evaluation



Figure 1:-Chocolate in mould

Organoleptic evaluation is an essential aspect of assessing chocolate formulations, as it focuses on sensory characteristics that directly influence consumer acceptability. The overall elegance, visual identity, and general appearance of the chocolate are important parameters to ensure product quality and uniformity. This type of evaluation helps in determining whether the final product meets the desired standards in terms of appearance and sensory appeal.

During organoleptic evaluation, specific attributes are examined. The colour of the chocolate is observed visually to ensure it is uniform and appealing, without any discoloration or defects. The taste of the chocolate is also assessed by tasting, which helps evaluate sweetness, bitterness, flavor balance, and overall palatability. These parameters collectively play a crucial role in determining the acceptability and quality of the chocolate formulation.^{6,8}

➤ pH measurement



Figure 2:-pH test

The pH of the formulation was determined using a digital pH meter, and it was found to be 5.3. This indicates that the formulation is slightly acidic in nature, which is typical for products containing ingredients such as cocoa and natural additives. The pH value is an important parameter as it influences the stability, safety, and overall quality of the formulation⁶

A pH of 5.3 can also contribute to better microbial stability, as slightly acidic conditions may help inhibit the growth of certain spoilage microorganisms. Additionally, pH plays a role in preserving flavor, as excessive acidity or alkalinity could negatively affect the taste profile of the chocolate. Proper calibration of the digital pH meter and accurate measurement conditions are

essential to ensure reliable results. Overall, the observed pH suggests that the formulation is within a suitable range for maintaining product safety, stability, and sensory acceptability⁶

Chemical test

• The test for carbohydrates



Figure 3:-Fehling's test

The test for carbohydrates was carried out using Fehling's test. In this method, equal quantities of Fehling's solution A and Fehling's solution B were mixed and added to the sample solution, followed by heating. Upon heating, the formation of a brick-red precipitate was observed, which confirms the presence of reducing carbohydrates in the formulation.

This reaction occurs because reducing sugars such as glucose and fructose reduce the copper(II) ions present in Fehling's solution to copper(I) oxide, which appears as a brick-red precipitate. The test is commonly used as a qualitative method to detect the presence of reducing sugars in food and pharmaceutical samples, indicating carbohydrate content in the formulation.

• Test for protein (biuret test)



Figure 4:-Biuret test

The test for protein was performed using the Biuret test. In this method, the chocolate formulation was treated with 4% sodium hydroxide (NaOH), followed by the addition of a few drops of 1% copper sulphate solution. Upon mixing, the appearance of a violet or purple color was observed, which indicates the presence of proteins in the formulation.

This color change occurs due to the formation of a complex between copper ions and peptide bonds present in proteins under alkaline conditions. The Biuret test is a standard qualitative method used to detect proteins, confirming that the chocolate formulation contains proteinaceous components.

➤ Weight variation



Figure 5:-Weight variation

The weights of four different chocolate formulations were measured individually as well as collectively. The total weight of all samples was used to calculate the average weight. This average weight was then compared with each individual sample weight to assess uniformity and consistency among the formulations.

The percentage deviation of each individual weight from the average weight was calculated using the following formula:

$$\% \text{ Deviation} = \frac{\text{Individual weight} - \text{Average weight}}{\text{Average Weight}} \times 100:$$

This evaluation helps determine the uniformity of the chocolate samples.

A lower percentage deviation indicates better consistency in weight, which is an important quality control parameter in formulation and manufacturing processes.

➤ Blooming test (Fat bloom)



Figure 6:-Blooming test

The blooming test (fat bloom) is an important quality evaluation parameter in chocolate formulations. Fat bloom occurs when a thin layer of fat crystals forms on the surface of the chocolate, causing it to lose its glossy appearance and develop a soft white or grayish coating. This gives the finished product an unappealing and dull look, which can negatively affect consumer acceptance.

Fat bloom is primarily caused by the recrystallization of cocoa butter or the migration of fats from the filling into the chocolate layer. These changes lead to the formation of unstable fat crystals on the surface. Factors such as temperature fluctuations, improper tempering, and incompatible fat compositions can accelerate this process.

Proper storage conditions play a crucial role in minimizing fat bloom. Maintaining a constant and cool temperature helps delay its occurrence by preventing repeated melting and recrystallization of fats. Therefore, controlling processing and storage conditions is essential to preserve the quality, appearance, and stability of chocolate formulations.²⁶.

9. RESULT:

The formulated anti-diabetic chocolate prepared from fruit extracts was successfully developed using natural and herbal ingredients such as mango and pineapple, along with cocoa butter and a dark chocolate base. The incorporation of these fruit extracts provides additional nutritional and therapeutic benefits, particularly due to their antioxidant and potential antidiabetic properties.

The formulation exhibited desirable characteristics in terms of texture, appearance, and overall acceptability. The use of cocoa butter contributed to a smooth consistency and good mouthfeel, while the dark chocolate base helped balance sweetness and bitterness. The inclusion of mango and pineapple extracts not only enhanced flavor but also added functional value to the product.

Overall, the study demonstrates that it is feasible to develop a functional chocolate with potential health benefits using natural ingredients. The prepared formulation showed satisfactory evaluation results, indicating its suitability as a value-added product with possible applications in nutraceutical and functional food sectors.

Table no. 10: Results

Sr. No.	Tests	F1	F2	F3
1.	Color	Dark brown	Dark brown	Dark brown
2.	Taste	Sweet with slight bitter	Sweet with slight bitter	Sweet with slight bitter
3.	pH	5.3	5.32	5.2
4.	Test for carbohydrates Fehling test	Positive	Positive	Positive
5.	Test for protein Biuret test	Positive	Positive	Positive

The results of the formulated chocolate evaluation indicate satisfactory and consistent quality across all formulations (F1, F2, and F3). The colour of all chocolate samples was observed to be a uniform dark brown, reflecting consistency in the preparation process and proper mixing of ingredients. In terms of taste, all formulations exhibited a uniformly sweet profile with a slight bitterness, which is characteristic of dark chocolate. This indicates that the sweetness was well balanced with the natural bitterness of cocoa, resulting in acceptable sensory properties.

The pH values of the formulations were found to be within the range of 5 to 6.5, suggesting a slightly acidic nature with minimal variation among samples. This indicates good stability of the formulations and suitability for consumption. The Fehling's test for carbohydrates showed the formation of a brick-red precipitate, confirming the presence of

reducing sugars in the chocolate. Similarly, the Biuret test for proteins resulted in a violet colour, indicating the presence of protein content in the formulations.

Weight variation analysis revealed that all chocolate samples had uniform weight distribution, demonstrating consistency in the manufacturing process. Additionally, the blooming test showed no visible fat bloom at the initial stage, indicating proper tempering and good storage conditions, which are essential for maintaining the appearance and quality of chocolate. Overall, the evaluation results confirm that the developed chocolate formulations possess desirable physical, chemical, and sensory properties.

10. Conclusion

From the results obtained in the present investigation, it can be concluded that the fruit extract-enriched dark chocolate formulation was successfully prepared and evaluated. The formulation exhibited satisfactory organoleptic properties, acceptable pH, good stability, and uniformity.

The incorporation of bioactive compounds from mango and pineapple, along with cocoa flavonoids, provides a synergistic effect that may contribute to improved glycaemic control through antioxidant activity, enzyme inhibition, and enhancement of insulin sensitivity. The use of natural ingredients such as honey and rosemary further enhances the therapeutic value and stability of the formulation.

The developed formulation offers several advantages, including improved palatability, ease of administration, and better patient compliance compared to conventional dosage forms. It represents a promising nutraceutical approach for diabetes management.

However, further studies such as in-vitro antidiabetic activity, in-vivo studies, and clinical evaluation are required to validate the therapeutic efficacy and safety of the formulation.

In conclusion, the formulated antidiabetic chocolate has the potential to serve as a safe, effective, and patient-friendly alternative for the management of diabetes mellitus.

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