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Development and characterization of antioxidant-rich mango leaf tea for diabetes management

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Abstract

Diabetes mellitus (DM) is a growing global health concern, necessitating innovative dietary interventions. This study explores the development of a functional tea incorporating *Mangifera indica* L. (mango) leaves and anti-diabetic spices to enhance glucose regulation and antioxidant benefits. Mango leaves are rich in bioactive compounds such as mangiferin and polyphenols, known for their insulin-sensitizing properties. The tea was formulated using mango leaves, tea leaves, ginger, cinnamon, cardamom, and black pepper, with honey as a natural sweetener. Sensory evaluation by 30 panelists indicated high acceptability, particularly for Mixture B. Nutritional analysis confirmed high polyphenol (139 mg/100 g) and vitamin C (537 mg/100 g) content, supporting its functional potential. Microbiological testing validated its safety, with a stable shelf life of 30 days. This study highlights the potential of mango leaf-based tea as a natural dietary intervention for diabetes management, warranting further clinical research.

Keywords: Mango leaves, functional tea, polyphenols, diabetes management, antioxidants

1. Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by hyperglycemia due to defects in insulin secretion, insulin action, or both (American Diabetes Association, 2010a) [1]. The global prevalence of diabetes is rapidly increasing, with Type 2 diabetes affecting approximately 4% of the world's adult population, a figure projected to nearly double by 2025 (International Diabetes Federation, 2006) [2]. India, recognized as the "Diabetes Capital of the World," currently harbours the largest population of diabetics, with estimates indicating a sharp rise from 19 million to nearly 69.9 million by 2025 (International Diabetes Federation, 2006) [2]. This surge is largely attributed to urbanization-induced lifestyle changes, including sedentary habits and dietary shifts (Ganeshpurkar *et al.*, 2017) [3].

Given the limitations of conventional diabetes management, functional foods and medicinal plants have gained attention for their therapeutic potential. Among these, *Mangifera indica* L. (mango) leaves are emerging as a promising natural remedy due to their rich bioactive profile, including flavonoids, phenols, and mangiferin, which exhibit anti-diabetic, antioxidant, and anti-inflammatory properties (Zhang *et al.*, 2019; Pan *et al.*, 2018) [4, 5]. Mangiferin has been shown to enhance insulin sensitivity, modulate glucose metabolism, and inhibit intestinal glucose absorption, offering a multifaceted approach to diabetes management (Ganeshpurkar & Saluja, 2017) [6].

Tea, a widely consumed beverage, is known for its polyphenol content and associated health benefits, including antioxidative and anti-inflammatory properties (Khizar Hayat *et al.*, 2015) [7]. The incorporation of mango leaves into tea formulations presents an innovative approach to developing a functional beverage that supports diabetes prevention. Furthermore, spices such as cinnamon, ginger, and cardamom, known for their glucose-lowering effects, could enhance the tea's efficacy (Xinyan Bi *et al.*, 2017; Al-Suhaimi *et al.*, 2011; Li *et al.*, 2012) [8, 9, 10].

This study aims to develop a mango leaf-based tea enriched with anti-diabetic spices, optimize its processing to retain bioactive compounds, and evaluate its sensory characteristics, consumer acceptance, and nutritional composition. Additionally, microbial safety and stability assessments will ensure product quality (Chen *et al.*, 2013) [11]. By offering a simple and health-promoting beverage, this research contributes to the growing field of functional foods, addressing the increasing global burden of diabetes. Additionally, the simplicity of the recipe makes it a convenient and health-promoting beverage option,

addressing the growing demand for functional foods. This project contributes to public health initiatives and lays the foundation for further research on natural dietary interventions for diabetes prevention and management.

2. Materials and Methods

The research methodology comprised two phases: product development and sensory evaluation to assess the acceptability and nutritional properties of the formulated tea. The study was conducted in Coimbatore, Tamil Nadu, India, known for its diverse population and accessibility to locally sourced ingredients. Mango Leaves (*Mangifera indica* L.) fresh young mango leaves were collected from home-grown plants in Erode. The leaves were washed thoroughly, dried using a carbon sheet method to preserve bioactive compounds and ground into a fine powder. Tea Leaves (*Camellia sinensis*) fresh tea leaves were collected from Valparai, Coimbatore. The leaves were washed, dried, and ground into a fine powder. Ginger (*Zingiber officinale*) sourced from a supermarket in Coimbatore, ginger was washed, peeled, and dried before being ground into powder. Spices (Cinnamon, Cardamom, Black Pepper) were purchased from a local supermarket, the spices were cleaned and ground before being incorporated into the tea formulation. Commercially available honey was used as a natural sweetener.

2.1 Development of Tea Powder with Mango Leaves and Spices

Tea formulations were developed using a combination of mango leaves, tea leaves, and spices to optimize flavour, aroma, and health benefits. Three different formulations were prepared and analyzed for sensory acceptability. The selected formulation underwent further laboratory analysis. The collected mango leaves, tea leaves, and spices were cleaned and dried to remove moisture. Each ingredient was ground into a fine powder and sieved to achieve uniformity. The powders were blended in predetermined ratios to ensure optimal taste and bioactive retention. The mixture was brewed in hot water (95-100 °C) for 3-5 minutes before being filtered and cooled. Samples were stored in airtight containers and sent for sensory evaluation and nutritional analysis.

2.2 Analysis of Nutritive Value and Microbial Analysis

The nutritional composition of the developed tea was analyzed using standardized methods to ensure accuracy and reliability. Moisture content was measured following IS 3077:1992, while ash content was determined through incineration using the same standard. Fat content was assessed through solvent extraction based on AOAC 950.4. Protein levels were estimated using the Kjeldahl method as per IS 7219. Carbohydrate content was evaluated through

hydrolysis following IS 1657, and the energy content was calculated using the EFLT/SOP/03/05 method. Dietary fiber was measured using enzymatic digestion as per ISO 6541. Vitamin C content was determined through redox titration according to IS:5838-1970. Additionally, polyphenols were quantified using the Folin-Ciocalteu colorimetric method to ensure the presence of bioactive compounds beneficial for health. These analyses provided a comprehensive overview of the tea's nutritional value, ensuring its potential as a functional beverage. The microbiological analysis of the developed tea was conducted to ensure its safety and suitability for consumption.

2.3 Shelf-Life Assessment

The developed tea was stored in airtight flasks to prevent bacterial contamination and maintain quality. Sensory attributes were monitored over time to determine the optimal shelf life.

2.4 Sensory Evaluation

The sensory evaluation of the developed mango leaf tea was conducted with a panel of 30 trained judges using a 9-point hedonic scale to assess various quality attributes. The appearance of the tea, including colour, clarity, and overall presentation, was evaluated to determine its visual appeal. The results of the sensory evaluation provided valuable insights into consumer acceptance and helped identify areas for potential improvement, ensuring the development of a well-balanced and appealing tea formulation.

3. Results and Discussion

3.1 Nutritional Analysis of Developed Tea Powder

The nutritional analysis of the developed tea powder formulated with mango leaves and spices revealed a composition rich in essential nutrients and bioactive compounds beneficial for diabetic individuals. The analysis showed that the developed tea powder had a moisture content of 3.32%, ensuring good shelf stability. The carbohydrate content was found to be 82.39%, contributing to an energy value of 470.13 kcal per 100 g, making it a nutrient-dense beverage option. The protein content was moderate at 1.03%, while fat content was 6.24%, indicating a balanced macronutrient profile.

The polyphenol content was measured at 139 mg/100 g, which is significant in combating oxidative stress and improving insulin sensitivity in diabetic individuals. Additionally, the vitamin C content was 537 mg/100 g, further enhancing the tea's antioxidant properties. The fiber content was 11.3%, supporting digestive health and helping regulate blood sugar levels. These results align with previous studies suggesting that mango leaves and spices contribute to the prevention and management of diabetes through their bioactive compounds.

Table 1: List of four formulated mixtures

S.no	Mixture	Combination	Ingredients
1	A	Tea leaves Powder + 20% Mango leaves powder	20% of mango leaves powder+ 20% Tea leaves powder + 5% honey + 10%Spices
2	B	Tea leaves Powder + 25% Mango leaves powder	25% of mango leaves powder+ 15% Tea leaves powder + 5% honey + 10%Spices
3	C	Tea leaves Powder + 30% Mango leaves powder	30% of mango leaves powder+ 10% Tea leaves powder + 5% honey + 10%Spices

Table 2: Nutrient content and microbiological analysis of tea powder from selected mixture B

S.no	Nutrients	Values/100 g
1	Moisture	3.32%
2	Ash	6.14%
3	Fat	0.12%
4	Protein	1.03%
5	Carbohydrate	82.39%
6	Energy	470.13 Kcal
7	Fiber	11.3%
8	Vitamin C	537.0 mg
9	Polyphenols	139.0 mg
10	Shelf life	30 days
11	TPC	3×10^2 CFU/ml
12.	<i>E. coli</i>	Absent
13	<i>Bacillus</i> sp.	Absent
14	<i>Pseudomonas</i> sp.	Absent
15	<i>Streptococcus</i> sp.	Absent

3.2 Sensory Evaluation

A sensory evaluation was conducted with 30 semi-trained panelists using a 9-point hedonic scale to assess the acceptability of the developed tea. The evaluation focused on key attributes such as appearance, taste, flavour, texture, and overall acceptability. Among the three formulations tested (Mixture A, Mixture B, and Mixture C), Mixture B was rated the highest across all sensory attributes. The

results demonstrate that the developed tea was well-received and has strong potential for market acceptance.

Table 3: Organoleptic evaluation of the judging panel

Attributes	Control	Variation A	Variation B	Variation C
Appearance	7.4±1.2	7.5±0.9	8.6±0.6	6.9±1.2
Flavour	7.7±1.2	7.2±0.8	8.5±0.5	6.8±1.3
Taste	7.5±1.3	6.8±1.2	8.4±0.6	6.5±1.3
consistency	7.4±1.3	7.0±1.4	8.5±0.5	6.6±1.4
Overall acceptability	7.5±1.3	7.1±0.8	8.7±0.5	6.8±1.1

3.3 Microbiological Stability and Shelf-Life

The shelf-life analysis of the developed tea powder revealed that it remained stable for 30 days at room temperature (22 °C) without significant changes in quality. Sensory scores showed a gradual decline over time but remained within acceptable limits. The total plate count was initially 3×10^2 CFU/ml, which remained within safe limits over the storage period, confirming the microbiological safety of the product. The absence of harmful microbial contaminants such as *E. coli*, *Bacillus* sp., and *Pseudomonas* sp. further established its safety for consumption. Proper storage conditions were found to be essential in maintaining the tea's stability. The overall developed product acceptability is significant at $p < 0.001$.

Table 4: One-way ANOVA for the sensory attributes of the developed tea powder

		Sum of Squares	Df	Mean Square	F	Sig.
Appearance	Between Groups	44.692	3	14.897	13.003	<.001*
	Within Groups	132.900	116	1.146		
	Total	177.592	119			
Flavour	Between Groups	50.167	3	16.722	14.807	<.001*
	Within Groups	131.900	116	1.129		
	Total	181.167	119			
Taste	Between Groups	63.225	3	21.075	15.302	<.001*
	Within Groups	159.767	116	1.377		
	Total	222.992	119			
Consistency	Between Groups	61.767	3	20.589	12.610	<.001*
	Within Groups	189.400	116	1.633		
	Total	251.167	119			
Overall acceptability	Between Groups	60.300	3	20.100	18.093	<.001*
	Within Groups	128.867	116	1.111		
	Total	189.167	119			

*Significant at $p < 0.001$

3.4 Functional Benefits and Implications

The high polyphenol content of the developed tea powder suggests strong antioxidant potential, which plays a critical role in reducing oxidative stress and managing diabetes. Studies have indicated that polyphenols can improve insulin sensitivity, reduce inflammation, and protect against neurodegenerative diseases. Additionally, the presence of vitamin C further supports its functional role in reducing oxidative damage. The combination of mango leaves and spices contributes to the tea ability to regulate blood sugar levels, making it an effective dietary intervention for individuals with diabetes.

While the developed tea powder demonstrated promising nutritional, sensory, and functional properties, further research could focus on optimizing processing techniques to enhance its shelf-life and flavour stability. Exploring alternative natural sweeteners or additional plant-based ingredients could further improve consumer acceptance.

Additionally, clinical studies could be conducted to validate the tea's efficacy in managing blood sugar levels among diabetic individuals.

4. Conclusion

The developed tea powder, formulated with mango leaves and spices, presents a novel functional beverage with significant nutritional and health benefits. It provides a rich source of antioxidants, dietary fiber, and essential nutrients while maintaining a well-balanced flavour profile. Sensory evaluation results indicate high acceptability and microbiological analysis confirms its safety for consumption. The tea aligns well with dietary recommendations and offers a promising alternative for individuals with diabetes or those seeking a health-conscious beverage. Future studies on formulation enhancement and long-term stability could further improve its commercial viability.

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