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RESEARCH ARTICLE

Effect of Palmyra Tuber Powder (*Borassus flabellifer*) on Blood Glucose Level of Type II Diabetic (NIDDM) Patients

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Abstract

Background: Diabetes mellitus is one of the lifestyle illnesses and has become a global burden with an alarming rate of prevalence in recent years. Palmyra tuber is a rich source of many nutrients, especially protein and fiber. It has the potential to reduce weight and blood glucose levels. **Aim:** To study the palmyra tuber powder incorporated recipes for diabetic patients and weight loss. **Methods:** The raw ingredients were procured, processed, and prepared for three standard varieties, namely healthmix, *kollukkattai* mix, and soup mix. Processed palmyra powder was incorporated at the levels of 10 %, 20 %, 30 %, and 40 % into three standard formulas. **Results:** All the prepared variations were evaluated for sensory characteristics using a 5-point Likert scale and compared statistically. The most accepted *kollukkattai* mix variety was chosen for nutrient analysis and finally selected for supplementation to the selected diabetic people. The analysis stated that the palmyra tuber incorporated *kollukkattai* mix variation at 30% level had secured the highest significant overall mean rating score when compared to the other two varieties and was also selected as the best for supplementation to selected diabetic people. The supplementation study revealed the potential benefits of palmyra tuber by showing a significant statistical impact on the reduction of weight, BMI, waist and hip circumference levels, and blood glucose levels among a selected group of people with diabetes. **Conclusion:** Palmyra tuber incorporated *kollukkattai* mix received the highest possible rating in terms of sensory acceptability and was selected for use as a supplement in the diabetic population.

Major Findings: This study indicates that supplements can significantly improve specific health outcomes.

Keywords: Formulation, Incorporation, Novel Food, Nutrient Analysis, Palmyra Tuber, Sensory Evaluation

1. Introduction

Diabetes Mellitus is a major healthcare problem that currently affects people all over the world. The rate of incidence is increasing rapidly in emerging economies. India has the highest population of diabetics worldwide, with an estimated 66.8 million people living with the disease, making it a serious health[1]. Diabetes is mostly caused by the rapid socioeconomic change brought on by industrialization and urbanisation. The epidemic of diabetes in India is still growing and is affecting individuals of all ages, from the wealthy to the impoverished, from rural to urban areas, and from older to younger[2]. It is a metabolic condition identified by hyperglycaemia resulting from deficiencies in insulin secretion, insulin action, or both[3]. People who have diabetes have an increased risk of developing either macrovascular or microvascular complications[4]. The healthcare costs and related consequences place a heavy financial strain on households and the country[5]. The World Health Organisation (WHO) emphasised and recommends traditional remedies to control diabetes because they are safe and inexpensive[6].

Borassus flabellifer is a tall and erect palm with big, fan-shaped leaves that differ from other palms' pinnate foliage[7]. Borassus is derived from a Greek term that describes the fruit's leathery covering, and flabellifer means "fan-bearer". The plant is also known as jaggery

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palm, Palmyra palm, toddy palm, and wine palm. Palmyra palm is an important tree in Cambodia and India. The various parts of the plant are used to cure a variety of ailments, including secondary syphilis, antiperiodic, heart burns, liver and spleen enlargement, and so on[8]. Since ancient times, palm trees have played a significant role in improving human well-being. Various parts of plants and trees, such as roots, stems, leaves, flowers, and seeds, are used as medicine to treat a wide range of diseases[9].

Diabetic patients often avoid Germinated Endosperm of Sugar Palm (GESP) and Elephant Foot Yam Tuber (EFYT) for fear of increasing their hyperglycaemia[10]. But germinated endosperm of sugar palm fruit (*B. flabellifer*) is also widely consumed raw or as a vegetable throughout the Indian subcontinent and Southeast Asia. Nonetheless, many diabetic patients in Bangladesh both urban and rural avoid this GESP because they think it will have a negative effect on their diabetes[11]. However, no empirical data were found to support or disprove these long-standing taboos. Palm tubers contain hypoglycemic effects due to their contents, especially phytochemicals, fibre, sodium, potassium, copper, and zinc[12]. The combination of palm tuber and elephant foot yam tuber showed the most antidiabetic effects[13]. Hence, the present study is planned to formulate palm tuber powder incorporated *kolukkatttai* mix, health mix and soup mix, analyze the nutrient content, supplement the palmyra tuber incorporated recipes to selected diabetic people and evaluate the impact of supplementation on the anthropometric and blood glucose level of diabetic patients.

2. Materials and Methods

2.1 Selection of Ingredients

The ingredients namely palmyra tuber, whole green gram, black gram dhal, black rice, red rice, ragi, pearl millet, foxtail millet, wheat, sorghum, barley, roasted bengal gram dhal, peanut, sago, badam, oats, onion powder, garlic powder, garam masala, cardamom were chosen based on their dietary diversity and on the concept of the combination of cereals, millets, pulses, legumes, nuts and spices to increase the taste and palatability. Suitable specific ingredients from the above list were chosen according to the types of recipes.

2.2 Procurement and Processing of Selected Ingredients

Raw ingredients were procured from the local market in Thanjavur district. The proposed study was carried out in the Department of Nutrition and Dietetics, Sengamala Thayaar Educational Trust Women's College (Autonomous), Mannargudi, Tamil Nadu. Palmyra tubers were collected from the farm and thoroughly cleansed to remove mud and clay. The outer covering of palm tubers was removed and boiled for about 40 minutes. After removing the inner skin, they were cut into little pieces, surface dried in the sun drying method, powdered the dried palm tubers, and sieved to achieve uniformity and avoid lump formation. Similarly, the other ingredients were processed and ground into a fine powder before being stored in an airtight container until future usage.

2.3 Formulation of Palm Tuber Incorporated Recipes

About three palm tuber powder incorporated recipes were developed and coded as Palm Tuber Powder Incorporated Health Mix (PTHM), Palm Tuber Powder Incorporated *Kolukkattai* Mix (PTKM), and Palm Tuber Powder Incorporated Soup Mix (PTSM). Initially, standard formulations were developed using a variety of ingredients for each recipe, and palm tuber powder was incorporated as shown in Table 1.

Table 1. Palmyra tuber incorporated health mix, *kolukkattai* mix and soups mix

S. No.	Ingredients	Level of Incorporation of PalmyraTuberPowder				
		0 %	10 %	20 %	30 %	40 %
1	Palmyra Tuber Powder	-	10 g	20 g	30 g	40 g
2	Health Mix Powder (PTHM)	150 g	140 g	130 g	120 g	110 g
3	*Kolukkatai* Mix (PTKM)	100 g	90 g	80 g	70 g	60 g
4	Soup Mix (PTSM)	100 g	90 g	80 g	70 g	60 g
5	Other Ingredients (Seasoning and Flavour Enhancers)	5 g	5 g	5 g	5 g	5 g

2.4 Sensory Evaluation of Palm Tuber Incorporated Recipes

A scientific approach to analyzing sensory qualities integrates human senses to assess appearance, flavor, color, texture, and taste[14]. The sensory evaluation of the prepared recipes was performed by 50 panel members using a five-point Likert scale, with the maximum score ranging from Excellent (5) to Poor (1). The panel members were instructed about the evaluation technique, and the sensory evaluation sheet was used to obtain score ratings.

2.5 Evaluation of Nutritional Qualities of the Health Mix

Nutrients such as calories, carbohydrate, protein, fat, fiber, folic acid, calcium and iron were analyzed using a standard procedure. Estimation of nutrients such as ash by the incineration method in a muffle furnace at 550ºC, moisture content in hot air circulating oven, crude fat by soxhlet extractor, protein (N X 6.25) in Kjeldahl method (AOAC, 2019), carbohydrate content by difference, potassium by photometer method and magnesium by iodine method (AOAC, 2019) were done. Shelf-life testing of the developed palm tuber incorporated *kolukkattai* mix was also done.

2.6 Supplementation of the Most Accepted Palm Tuber Incorporated Recipe

The palm tuber incorporated *kolukkattai* mix was chosen for supplementation because it received the highest sensory acceptability rating. About 50 grams of palm tuber incorporated *kolukkattai* mix was given to 50 adult diabetic subjects for 90 days with clear instructions on how to make *kolukkattai* out of the given powders. The effect of supplementation of palm tuber powder incorporated *kolukkattai* on the blood glucose level and the anthropometric indices was recorded.

2.7 Statistical Analysis

The values obtained from the study were subjected to statistical analysis by one-way ANOVA using SPSS Software 16.0. The significance of the treatments effect was studied at 5% level of significance.

3. Results and Discussion

3.1 Sensory Acceptability Testing of Palm Tuber Powder Incorporated Recipes

As shown in Table 2, palm tuber powder incorporated into all recipes was highly acceptable and comparable

Table 2. Mean sensory scores of juices incorporated with watermelon rind powder

Palm Tuber Incorporated Food Products	Sensory Qualities	Level of Palmyra Tuber Powder Incorporation (Mean ± SD)				
		0 %	10 %	20 %	30 %	40 %
Palm Tuber Health Mix (PTHM)	Appearance	4.60 ± 0.65	4.82 ± 0.39	4.92 ± 0.27	4.24 ±0.94	3.64± 1.19
	Colour	4.73 ± 0.98	4.78± 0.42	4.94± 0.24	4.18± 0.96	3.76± 1.2
	Flavour	4.95 ± 0.56	4.76± 0.42	4.90± 0.30	4.50± 0.81	4.08± 1.07
	Taste	4.82 ± 0.87	4.62± 0.67	4.70± 0.68	4.12± 0.94	4.12± 1.0
	Consistency	4.54 ± 0.83	4.76± 0.43	4.88± 0.33	4.36± 0.88	3.96± 1.07
Palm Tuber *Kolukkattai*Mix (PTKM)	Appearance	4.97 ± 0.15	4.84± 0.37	4.92± 0.27	4.98± 0.14	4.86± 0.21
	Colour	4.98 ± 0.45	4.81± 0.37	4.90± 0.30	4.98± 0.14	4.96± 0.20
	Flavour	4.85 ± 0.43	4.88± 0.33	4.88± 0.33	4.96± 0.20	4.92± 0.27
	Taste	4.89 ± 0.34	4.72± 0.54	4.70± 0.54	4.88± 0.33	4.90± 0.30
	Consistency	4.90 ± 0.21	4.84± 0.36	4.88± 0.33	4.98± 0.14	4.91± 0.27
Palm Tuber Soup Mix (PTSM).	Appearance	4.11 ± 0.46	4.42± 0.88	3.74± 1.45	3.34± 1.94	2.60± 1.65
	Colour	4.45 ± 1.20	4.24± 0.96	4.30± 1.25	3.92± 1.76	3.54± 1.79
	Flavour	4.12 ± 1.67	4.42± 0.81	4.34± 1.01	4.26± 1.38	3.64± 1.61
	Taste	4.48 ± 1.39	4.38± 0.90	4.28± 1.25	4.01± 1.57	3.20± 1.73
	Consistency	3.98 ± 0.99	4.38± 0.86	4.30± 1.15	4.06± 1.66	3.18± 1.84

to the control sample. Among all other variations, the palm tuber powder incorporated *kolukkattai* mix with 30 % incorporation level obtained the highest overall organoleptic score of 24.8 out of 25. The organoleptic evaluation of the *kolukkattai* mix was high and significantly comparable with the control sample in all incorporation levels, including appearance, colour, flavour, taste, and consistency. However, as compared to other recipes, palm tuber powder incorporated soup mix variations had the lowest sensory rating for all sensory attributes. The highest sensory rating of 4.98 out of 5 was recorded in many of the sensory characteristics in 30 % palm tuber powder incorporated *kolukkattai* mix and the lowest sensory score of 2.6 out of 5 was noted in the 40 % palm tuber powder incorporated soup mix. In addition to the *kollukkattai* mix, the health mix with palm tuber powder received good sensory ratings at all incorporation levels. In comparison to the 20 % level of incorporation in the *kolukkattai* mix, the 20% level of palm tuber powder incorporation in the health mix achieved a significant level of equal overall mean score of 24.3. The total rating range for the *kolukkattai* mix variations was 19.6 to 24.3 out of 25. Out of all the sensory qualities, soup variants with palm tuber powder received the lowest overall score.

The mean overall acceptability sensory rating score of the palm tuber powder incorporated recipes is shown in Figure 1.

3.2. Nutrient Content of Highly Accepted Palm Tuber Incorporated *Kolukkattai* Mix

The nutrient content of palm tuber incorporated *kolukkattai* mix at 30 % level has gained the higher concentration of essential nutrients like protein (11.83 g), fat (1.89 g), calcium (63.5 mg), iron (6.4 mg), fibre (1.31 g), and folic acid (2.9 mg) when compared to the nutrient content of standard *kolukkattai* mix recipes. Moreover, the *kolukkattai* mix with palm tuber added had less calories and carbohydrates than the standard variation, which helps diabetic people to control their blood sugar levels. The palm tuber can successfully be incorporated into the food products for the upliftment of nutritional and sensory attributes (Table 3, Figure 2).

3.3 Effect of Supplementation of Palm Tuber Incorporated *Kolukkattai* Mix on Blood Glucose Level

3.3.1 Demographic Profile of the Selected Diabetic Subjects

The selected patients with diabetes were primarily in the age range of 30 to 60. Most of the subjects (48%) were between the ages of 40,50and 30. And 11% were between the ages of 30 and 40. Among the individuals, 70% were female and 30% were male. 5% of the individuals were single, and 95% of them were married. Most 72% of the subjects were literate, while 28% were

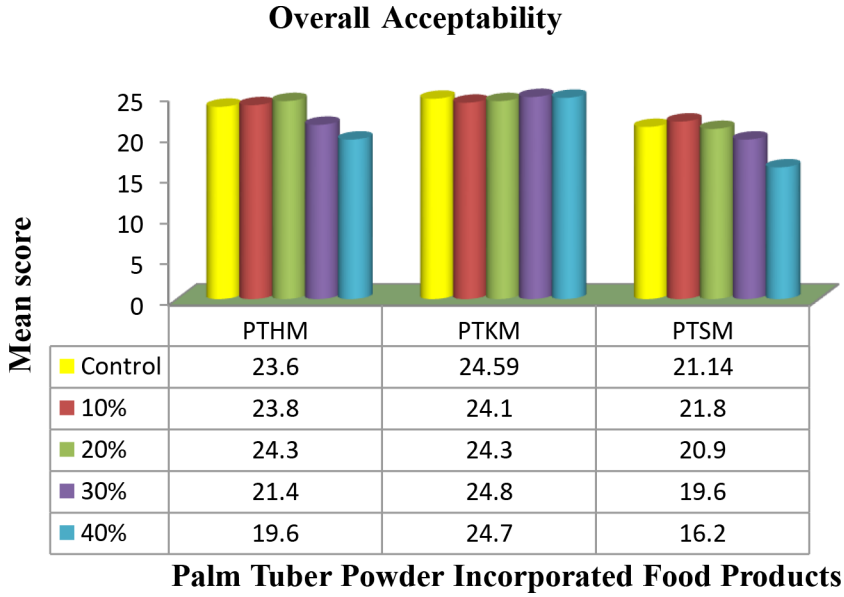


Figure 1. Mean overall acceptability score of the palm tuber powder incorporated food products.

Table 3. Nutritional Qualities of Palm Tuber (30 %) incorporated *Kolukkattai* Mix (PTKM)

Nutrient Content	Standard *Kolukkattai* Mix	Palmyra Tuber Powder (30 %) Incorporated *Kolukattai* Mix (100gm)
Energy(kcal)	424.14	396.17
Carbohydrate(g)	89.78	82.96
Protein(g)	9.56	11.83
Fat(g)	1.78	1.89
Calcium(mg)	55.9	63.5
Iron(mg)	5.32	6.4
Fiber(g)	0.23	1.31
Folic acid (mg)	1.6	2.9

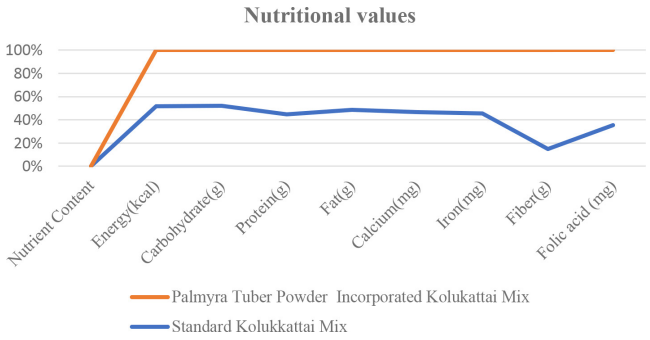


Figure 2. Nutritional qualities of palm tuber incorporated *kolukkattai* mix and standard *kolukkattai* mix.

Table 4. Demographic profile of the selected diabetic subjects

Demographic profile of the diabetic people	Number	Percentage
Age Category		
30 – 40 Years	15	30.0
40 – 50 Years	24	48.0
50 – 60 Years	11	22.0
Gender		
Male	15	30.0
Female	35	70.0
Marital Status		
Married	47	95.0
Unmarried	3	5.0
Educational Status		
Illiterate	14	28
Literate	36	72

illiterate. The participants are cooperative and highly attentive (Table 4, Figure 3).

3.3.2 *Effect of Supplementation of Palmyra Tuber Powder Incorporated Kolukkattai Mix on Anthropometric Parameter and Blood Glucose Level of the Diabetic Patient*

Table 5 compares the mean anthropometric and biochemical profiles of diabetic patients before and after palmyra tuber powder incorporated *kolukkattai* mix supplementation. The mean body height of thediabetic patients increased on an average of 0.04 cm after *kolukkattai*mixes supplementation. The mean weight, body mass index, hip circumference, waist circumference, and waist-hip ratio of the patients decreased at rates of 1.32 kg, 0.5, 0.28 cm, 1.28 cm, and 0.02 respectively, as a result of the palmyra tuber incorporation supplementation, which highlighted the advantages of supplementation.

As a result, the diabetic patient's weight, Body Mass Index (BMI), waist circumference, and hip circumference levels differed significantly between before and after supplementation at a level of less than 1 %. The anthropometric measurements of height and waist-hip ratio did not differ significantly. The diabetic patients' mean blood glucose level dropped from 182.92 mg/dl to 177.28 mg/dl, demonstrating the excellent hypoglycemic effect of supplementing with palmyra tuber powder incorporated *kolukkattai* mix. A statistically significant difference at the rate of less than 1 percent was noted in the blood glucose level of the patients with the effect of supplementation.

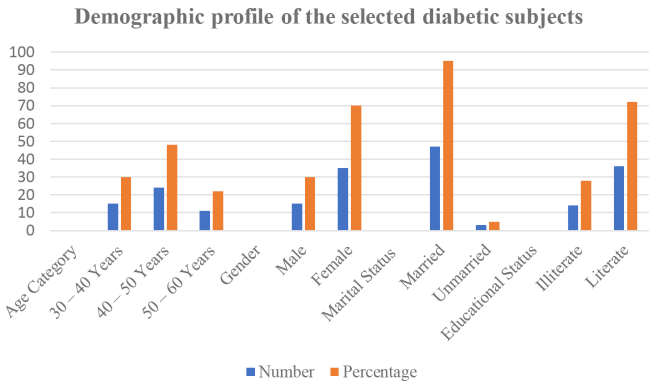


Figure 3. Demographic profile of the selected diabetic subjects.

Table 5. Anthropometric indices and blood glucose level of the diabetic patient with before and after supplementation

Parameters	Before Supplementation	After Supplementation	Mean Difference	't' Value
Height (cm)	161.44 ± 13.35	161.48 ± 12.92	0.04	0.5^{NS}
Weight (kg)	65.68 ± 9.07	64.36 ± 7.99	1.32	10.07***
Body Mass Index (BMI)	25.39 ± 4.16	24.89 ±3.81	0.5	11.1***
Waist Circumference (cm)	59.0 ± 15.53	58.72 ± 15.46	0.28	13.4***
Hip Circumference (cm)	71.72 ± 14.80	70.44 ± 14.69	1.28	9.78***
Waist Hip Ratio	0.818 ± 0.11	0.82 ± 0.11	0.02	0.98^{NS}
Blood Glucose mg/dl	182.92 ± 47.19	177.28 ± 19.36	5.64	4.5***

NS- Not Significant***P= <0.01

4. Conclusion

In this research, formulate the palmyra tuber powder incorporated health mix, *kollukkattai* mix and soup mix. The result of the sensory analysis shows *kolukkattai* mix has strong acceptability. The nutritional analysis indicates that *kolukkattai* mix has strong nutritional value to enhance the body's function. Finally, all the result explains that palmyra tuber powder incorporated into *kolukkattai* mix, generally enhances the nutritional value and sensory scores of the prepared products. Additionally, the supplement has several kinds of effects on the patients' anthropometry and biochemical profiles.

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6. Author Contribution

Vidhya and G. K. Gomathi: Conceived the study, collected data, analyzed results and wrote the draft. Both the authors have read and agreed to the published version of the manuscript.

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