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In Vivo Glycemic Response Assessment of Tender Jackfruit Flour Incorporated *Chapathi* among Prediabetic Subjects

Divya C[1], Kalpana B[2]

[1]AICRP on Women in Agriculture, University of Agricultural Sciences, Bangalore 560065, India

[2]AICRP on Women in Agriculture, University of Agricultural Sciences, Bangalore 560065, India
Corresponding Author Email: *divyacdivya6[at]gmail.com*

Abstract: ***The present study evaluated the effect of pretreatments on the browning index of tender jackfruit flour and assessed the in vivo glycemic response of tender jackfruit flour incorporated chapathi among prediabetic subjects. Two tender jackfruit varieties, Horticulture Vegetable-2 (HV2) and Tissue Culture Variety (TCV), were subjected to water blanching, citric acid blanching, and potassium metabisulphite (KMS) blanching followed by tray drying at 50, 55, and 60 °C. Among the treatments, 0.5 % KMS blanching showed the lowest browning index in both varieties. Based on nutritional superiority, HV2 flour was selected for product development. Chapathi incorporated with 15 % tender jackfruit flour showed good sensory acceptability and was selected for glycemic evaluation. The incorporated chapathi exhibited lower postprandial blood glucose levels and a 28 % lower area under the curve compared to the control, indicating improved glycemic response among prediabetic subjects.***

Keywords: Diabetes Mellitus, Tender Jackfruit Flour, Glycemic Response, Functional Food and *Chapathi*

1. Introduction

Diabetes Mellitus is one of the most prevalent metabolic disorders worldwide and has emerged as a leading cause of mortality and morbidity, resulting in a substantial increase in healthcare expenditure. In 2021, diabetes was responsible for more than 6.7 million deaths globally (Wong *et al*., 2013; Mutyambizi *et al*., 2018 and Canto *et al*., 2019). India has the second-largest diabetic population in the world, with approximately 74.9 million people aged 20–79 years affected in 2021, and this number is projected to increase to 124.9 million by 2045 (Wong *et al*., 2013). According to the International Diabetes Federation (IDF), one in every seven adults with diabetes globally resides in India, and one in every three households in the country has at least one diabetic patient. Along with diabetes, the prevalence of prediabetes is also rapidly increasing, making early dietary intervention essential to delay or prevent the progression to type 2 diabetes mellitus.

The increasing incidence of diabetes and prediabetes has been strongly associated with changing dietary patterns and sedentary lifestyles. Traditional plant-based diets rich in legumes, whole grains, fruits, and vegetables are gradually being replaced by westernized diets high in refined carbohydrates, fats, and animal-derived foods (Martiz *et al*., 2022). Elevated postprandial blood glucose levels are considered an important risk factor for cardiovascular diseases and other chronic metabolic complications. Studies have shown that higher postprandial glucose concentrations are associated with arterial stiffness and increased cardiovascular risk even among non-diabetic individuals (O'Keefe and Bell, 2007; Rustveld *et al*., 2009). One-hour postprandial glucose levels were found to increase cardio-ankle vascular index (CAVI) values and arterial stiffness among non-diabetic Japanese individuals (Tsuboi *et al*., 2015). Further, a meta-analysis of 38 prospective studies reported a strong association between two-hour post challenge blood glucose levels and both fatal and nonfatal cardiovascular events among healthy individuals without diabetes (Levitan *et al*., 2004). Therefore, controlling postprandial glycemic response plays a significant role in overall glycemic management and prevention of long-term complications.

Controlling postprandial glucose levels is a vital part of glycemic management, as this period significantly influences blood glucose stability (ElSayed *et al*., 2023). Replacing high glycemic carbohydrates with healthier alternatives during the postprandial phase is considered an effective strategy for improving glycemic control. Moreover, incorporation of culturally acceptable therapeutic diets can reduce postprandial glycemic variability, support vascular health, and improve dietary adherence among individuals with impaired glucose metabolism.

Medical Nutrition Therapy (MNT) has recently gained considerable attention as a primary strategy for diabetes prevention and management. Positive outcomes have been observed when MNT is used alongside anti-diabetic medications (Bashetti, 2022). The American Diabetes Association also recommends increased intake of fiber-rich foods and reduced consumption of carbohydrates and calories to improve glycemic control. Herbal medicines and natural plant-based remedies have also gained popularity due to their lower toxicity and fewer side effects compared to synthetic drugs (Datusalia *et al*., 2012; Shafi and Tabassum, 2013).

India possesses a wide diversity of underutilized fruits with significant nutritional and therapeutic potential. However, many of these fruits remain underexploited due to poor awareness, seasonal availability, inadequate processing technologies, and limited storage facilities (Peter *et al*., 2006). These fruits can serve as affordable nutrient sources and complement major crops because of their low production cost (Nair *et al*., 2018). Jackfruit is one such highly nutritious yet underutilized fruit native to India and other South and Southeast Asian countries (Srivastava *et al*., 2017). It belongs to the Moraceae family and is widely grown in India, Bangladesh, and several parts of South and Southeast Asia (Devalaraja *et al*., 2011).

Jackfruit is recognized as a rich source of carbohydrates, dietary fiber, vitamins, minerals, and antioxidant compounds (Baliga *et al*., 2011). It contains appreciable amounts of vitamin C, thiamine, niacin, riboflavin, folic acid, and vitamin B-6 (pyridoxine). Several parts of the jackfruit plant, including the bark, roots, leaves, and fruits, possess medicinal properties (Hakim *et al*., 2006; Arung *et al*., 2006). Additionally, jackfruit is rich in phytochemicals such as phenolics, flavonoids, sterols, and prenylflavones, which contribute to the prevention and delay of non-communicable diseases (Baliga *et al*., 2011). It also exhibits excellent antioxidant properties (Jagtap *et al*., 2010).

Despite its nutritional and medicinal benefits, approximately 50–70 per cent of jackfruit goes to waste due to inadequate processing and storage facilities (Mittal *et al*., 2018). Processing of jackfruit has received limited attention because of difficulties associated with harvesting, separation of edible bulbs, variability in quality and yield, and its short shelf life. Therefore, value addition through flour production could improve utilization and reduce post-harvest losses.

Tender jackfruit is considered a functional food because of its nutritional and medicinal properties (Kumari and Divakar, 2016). In its mature unripe stage, jackfruit is a good source of potassium, magnesium, manganese, and iron (Kaushal and Sharma, 2016). Nutritionally, 100 g of tender jackfruit provides approximately 26 kcal of energy, 3.48 g of carbohydrates, 7.69 g of dietary fiber, 1.98 g of protein, and appreciable amounts of potassium and vitamin C (Longvah *et al*., 2017). According to the United States Department of Agriculture, one cup of raw sliced jackfruit contains 157 kcal energy, 2.84 g protein, 1.06 g fat, 38.36 g carbohydrates, and 2.5 g dietary fiber.

Compared to mature fruits and seeds, tender jackfruit contains higher amounts of vitamin C, which functions as a potent antioxidant and supports immunity (Jagtap *et al*., 2010). Its potassium-rich and low-sugar composition does not cause rapid elevation of blood glucose levels. Research findings suggest that jackfruit contains high levels of proanthocyanidins and flavonoids, which inhibit lipid peroxide formation and exhibit anti-diabetic properties (Biworo *et al*., 2015). Further, jackfruit extract has shown potential in inhibiting hemoglobin glycation due to the presence of phytochemicals such as carotene, lycopene, and ascorbic acid, thereby reducing glycated hemoglobin levels (Shrestha Banerjee *et al*., 2022). Green jackfruit has also been reported to possess medium glycemic load and is a good source of dietary fiber and resistant starch, making it suitable for dietary management of diabetes and related complications (Hettiaratchi *et al*., 2010).

The processing of tender jackfruit is still under investigation to improve its quality, shelf life, and flour production techniques (Pawar and Giri, 2024). Studies regarding the beneficial effects of tender jackfruit flour on glycemic response among prediabetic subjects remain limited and require further scientific validation. Therefore, *in vivo* trials using products incorporated with tender jackfruit flour are necessary to evaluate their effectiveness in glycemic control. Considering these aspects, the present investigation was undertaken to assess the *in vivo* glycemic response of tender jackfruit flour incorporated products among prediabetic subjects.

2. Problem Definition

The increasing prevalence of prediabetes and type 2 diabetes has created an urgent need for safe, affordable, and food-based strategies that can effectively improve postprandial glycemic control. Although tender jackfruit is recognized as a rich source of dietary fiber, resistant starch, and bioactive phytochemicals with potential antihyperglycemic properties, its utilization remains limited because of inadequate processing technologies, enzymatic browning during flour production, short shelf life, and insufficient product standardization. Existing research has primarily focused on the nutritional composition and phytochemical characteristics of jackfruit, while limited scientific evidence is available on the optimization of processing methods, development of acceptable food products, and evaluation of their in vivo glycemic response among prediabetic individuals. Consequently, the therapeutic potential of tender jackfruit flour has not been adequately validated under clinical conditions. Addressing these research gaps is essential for developing scientifically validated functional foods that can improve glycemic regulation, promote the utilization of underutilized crops, and provide sustainable dietary strategies for diabetes prevention and management.

3. Materials and Methods

Selection and Procurement of Tender Jackfruit

Tender Jackfruit varieties namely Horticulture Vegetable-2 (HV2) and Tissue Culture Variety (TCV) at 6–8 weeks maturity stage were procured from the Department of Horticulture, College of Agriculture, GKVK, Bengaluru. The varieties were selected considering availability, proximity to the laboratory, and convenience of procurement. Young fruitlets were tagged and horticulturists were consulted to determine the maturity stages of the fruits. Other ingredients such as whole wheat flour, corn flour, and food-grade preservatives were purchased from supermarkets in Bengaluru city.

Details of Selected Jackfruit Trees

S. No.	Sample Code	Location
1	HV2	Department of Horticulture, Floriculture Unit Ornamental Section, College of Agriculture, GKVK, Bengaluru
2	TCV	Department of Horticulture, Plant Tissue Culture Laboratory, College of Agriculture, GKVK, Bengaluru

Processing of Tender Jackfruit

Tender jackfruits of uniform size and free from spoilage were selected, sorted, and washed thoroughly under running tap water to remove dirt and adhering soil particles. The fruits were manually sliced into uniform pieces of approximately 1.5–2 cm thickness for further processing.

Pretreatments and Dehydration of Jackfruit Slices

The sliced tender jackfruit samples were subjected to different pretreatments and later tray dried at three different temperatures namely 50°C, 55°C, and 60°C until constant moisture content was achieved.

Pre- treatment details

Treatment	Description
T1	Untreated (Control)
T2	Water blanching at 80°C for 1 minute
T3	Water blanching at 80°C for 2 minutes
T4	Water blanching at 80°C for 3 minutes
T5	Blanching at 80°C with 0.1% citric acid for 1 minute
T6	Blanching at 80°C with 0.25% citric acid for 1 minute
T7	Blanching at 80°C with 0.5% citric acid for 1 minute
T8	Blanching at 80°C with 0.1% potassium metabisulphite for 1 minute
T9	Blanching at 80°C with 0.25% potassium metabisulphite for 1 minute
T10	Blanching at 80°C with 0.5% potassium metabisulphite for 1 minute

The dehydrated samples were powdered using a grinder, sieved uniformly, and stored in airtight containers until further use.

Determination of colour

Colour measurements (L*a*b* values) of the tender jackfruit flour was measured. A spectrophotometer (CM-5, Konica Minolta) was used for the assessment of color parameters values, which directly provide the parameters L* (Darkens and lightness) ranging from 0 (black) to 100 (white), a* (green and red component) ranging from -60 (green) to +60 (red) and b* (blue and yellow component) ranging from -60 (blue) to +60 (yellow). Samples were placed in petri dishes (the dishes were filled up to the full volume). A measuring head was applied to the surface of powder. Measurements were taken at three different points and results were expressed as an average. Before the test, the camera was calibrated with a white pattern (Bashir *et al.,* 2017).

Determination Browing (Palou et al., 1999)

The browning assessment was carried out by calculating formula as follow:

Browning Index (BI) = [100 (x - 0.31)] / 0.17

where x = (a* + 1.75L*) / (5.645L* + a* – 0.3012b*

Formulation of Tender Jackfruit Flour Incorporated Food Products

Based on survey findings among diabetic respondents, commonly consumed food products such as *chapathi* was selected for incorporation of tender jackfruit flour. The formulations were standardized by varying the levels of tender jackfruit flour incorporation. The developed pr oduct was subjected to sensory evaluation.

Formulation of Tender Jackfruit Flour Incorporated Chapathi

Four variations of *chapathi* were prepared using different proportions of whole wheat flour and tender jackfruit flour. *Chapathi* without tender jackfruit flour served as the control.

Ingredients	Control	TJFC1	TJFC2	TJFC3	TJFC4
Whole wheat flour (g)	100	85	80	75	70
Tender jackfruit flour (g)	-	10	15	20	25
Salt (g)	2	2	2	2	2
Oil (g)	5	5	5	5	5
Water (ml)	200	220	230	240	250

Where,
TJFC1 – Tender jackfruit flour incorporated *chapathi* (10%)
TJFC2 – Tender jackfruit flour incorporated *chapathi* (15%)
TJFC3 – Tender jackfruit flour incorporated *chapathi* (20%)
TJFC4 – Tender jackfruit flour incorporated *chapathi* (25%)

Estimation of In Vivo Glycaemic Response

Ethical clearance

The study was approved by the Institutional Ethics Committee under approval number No. DR/STA/Ethical Committee/04/2024-25 dated 28/02/2025. Informed consent was obtained from all participants prior to their inclusion in the study.

Selection of Subjects

Ten prediabetic subjects aged between 35 and 50 years were selected for the study. Informed consent was obtained from all participants after explaining the objectives and procedures of the experiment. Subjects were instructed to undergo overnight fasting for at least 10 hours and avoid vigorous physical activity before the study.

Inclusion Criteria

- Age group between 35–50 years
- HbA1c level between 5.4–6.4%
- Ability to fast for 10 hours before the study
- Free from associated diseases

Exclusion Criteria

- Type 1 and Type 2 diabetes mellitus
- Gestational diabetes
- Subjects allergic to study ingredients
- Subjects below 35 years and above 50 years

Anthropometric Measurements

All the anthropometric measurements were taken following the standard protocols (WHO, 2004). Height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively, using an anthropometric rod, and standard weighing scale, respectively. Minimum waist (WC) and maximum hip (HC) circumferences were measured to the nearest 0.1 cm using a tape measure.

Body Mass Index (BMI)

BMI was calculated by using the following formula to classify the individual as normal, obese and underweight.

$$BMI = \frac{Weight\ (kg)}{Height\ (m^2)}$$

After the cessation of linear growth around the age of 21 years, weight for height indicates muscle and fat mass in the selected subjects. Therefore, BMI provided a reasonable indication of the nutritional status and may also be used as an indicator of health risk. The following had been suggested for Asian criteria by WHO (2017).

Presumptive diagnosis	BMI Class
Under weight	<18.5
Normal range	18.5 – 22.9
Over weight	23.0 – 24.9
Obese I	25.0 – 29.9
Obese II	> 30

Waist Hip Ratio

The ratio of waist to hip is an indicator of central obesity. The abdominal obesity was assessed by waist to hip ratio (Lean *et al.,* 1995).

Gender	WHR class	Presumptive diagnosis
Male	> 0.95	Obese
	< 0.95	Normal
Female	> 0.80	Obese
	< 0.80	Normal

Control and Test Foods

The foods which was commonly consumed by the diabetic respondents were standardized within the laboratory and employed as control test foods in the study. Additionally, variations of chapati were developed by incorporating tender jackfruit flour at different ratios. The variations that exhibited the highest sensory acceptability during the initial evaluations were considered for inclusion in the study. The portion of each test food provided to the subjects was determined by calculating 50 grams of available carbohydrates based on the findings of proximate analysis.

A total of two foods, including one control and test food, were assessed using a standardized portion containing 50 grams of available carbohydrates. The study participants were instructed to with held oral hypoglycaemic agents for a period of 24 h before the tests. then they were administered control food as a baseline, followed by the test foods, which included control *chapatti* and tender jackfruit flour incorporated *chapati*, in order to evaluate their respective glycemic responses. To maintain the integrity of the glycemic assessment, a one-week washout period was implemented between the consumption of each food sample.

Analysis of blood glucose response in the subjects

All study participants observed an overnight fast, lasting between 10 to 12 hours. They were instructed to not to consume any medication while attending the trial. Capillary blood glucose levels were measured at the start of the fasting period. Following this, participants were promptly provided with either the control food or the test foods and instructed to consume them within a 10-minute time frame. Blood samples were obtained through finger pricks using hypodermic needles or lancets. Each blood sample was introduced into a calibrated glucometer (ACCU CHEK-Active/one touch) that generated an immediate reading, utilizing the glucose oxidase assay method, approximately 30 seconds post-collection. Blood glucose levels were monitored at various intervals: 0 (fasting), 30, 60, 90 and 120 minutes, all within the 2-hour study visit after the subjects had consumed the control food and test foods. To ensure the accurate assessment of glucose response for all the samples, a one-week washout period was implemented between each sample evaluation.

Statistical Analysis

The experiments were conducted in triplicate. The obtained data were analyzed using OPSTAT software and Microsoft Excel. Statistical tools such as Analysis of Variance (ANOVA), Duncan's Multiple Range Test (DMRT), and Student's t-test were used to determine the significance of variations among treatments.

4. Results and Discussion

Table 1 presents the impact of various pre-treatments on the browning index of tender jackfruit flour at different drying temperatures (50°C, 55°C, and 60°C) for both HV2 and TCV varieties. For HV2**,** at 50°C**,** the highest browning was observed in T4 (9.68), and the lowest in T10 (1.26). At 55°C**,** T4 recorded the highest browning (9.54), while T10 recorded the lowest (1.19). At 60°C**,** T4 recorded the highest browning (9.22), and T10 had the lowest (0.81). Extending the blanching time resulted in increased browning, as prolonged water blanching may exacerbate browning due to prolonged exposure to heat and oxygen. Similarly for TCV**,** at 50°C**,** the highest browning was found in T4 (9.52), and the lowest in T9 (1.16). At 55°C**,** T4 exhibited the highest browning (10.30), with the lowest in T10 (1.07). At 60°C**,** the highest browning occurred in T4 (9.21), while T10 recorded the lowest (0.40). This highlights the strong inhibitory effect of KMS on browning enzymes. Specifically, at 0.5% concentration of KMS was the most effective pre-treatment for controlling browning in tender jackfruit flour.

Rana *et al.* (2018) reported browning index ranged from 0.035 to 0.057. However, the lower values observed in their study contrasts with present findings are likely a result of variability in concentrations and combinations of treatments used. The study by Babu and Sudheer (2020) found that the browning index of sterilized tender jackfruit samples was 43.81 and 22.42 for pasteurized samples. This discrepancy suggests that the higher temperatures used during sterilization may promote increased enzymatic activity or browning, which negatively impacts the color quality of the product.

Table 1: Effect of pretreatments on browning index of tender jackfruit flour

Treatments	HV2			TCV		
	50°C	55°C	60°C	50°C	55°C	60°C
T1	7.13^{b}	6.93^{b}	6.92^{b}	7.12^{b}	6.84^{b}	6.83^{b}
T2	7.14^{b}	6.64^{b}	6.49^{b}	6.51^{b}	6.57^{bc}	5.88^{c}
T3	6.48^{b}	5.97^{c}	5.39^{c}	6.42^{b}	5.90^{c}	5.70^{c}
T4	9.68^{a}	9.54^{a}	9.22^{a}	9.52^{a}	10.30^{a}	9.21^{a}
T5	3.89^{c}	3.83^{d}	3.80^{d}	4.00^{c}	4.38^{d}	3.87^{d}
T6	3.64^{c}	3.69^{d}	3.43^{d}	3.74^{d}	3.79^{de}	3.39^{cd}
T7	3.60^{c}	3.39^{d}	3.30^{d}	3.17^{d}	3.31^{e}	2.73^{de}
T8	1.45^{d}	1.37^{e}	1.39^{e}	2.24^{ef}	1.71^{f}	1.31^{e}
T9	1.44^{d}	1.50^{e}	1.00^{e}	1.16^{g}	1.10^{f}	0.98^{ef}
T10	1.26^{d}	1.19^{e}	0.81^{e}	1.72^{fg}	1.07^{f}	0.40^{f}
F-value	*	*	*	*	*	*
CD @ 5%	0.596	0.282	0.586	0.316	0.631	0.474
SEm±	0.201	0.095	0.197	0.106	0.212	0.159

Values are means of triplicates, * Significant @5% **T1:**Untreated, **T2**:Water blanching (1 min), **T3:** Water blanching (2 min), **T4**: Water blanching (3 min), **T5**: Citric acid blanching (0.1 %, 1 min) **T6:** Citric acid blanching (0.25%,1 min) , **T7**: Citric acid blanching (0.5%,1 min) , **T8**: KMS blanching (0.1%,1 min), **T9:** KMS blanching **(**0.25%,1 min), **T10:** KMS blanching (0.5%,1 min)

Considering the commonly consumed foods of diabetic patients and the nutritional superiority of the HV2 variety, HV2 tender Jackfruit flour was selected for the development of *chapathi*. *Chapathi's* are unleavened flatbreads made from whole wheat flour (atta), have been a staple in the Indian subcontinent and parts of the Middle East for centuries. Recently, the substitution of wheat flour with healthier plant-based flours in *Chapathi* preparation has gained popularity as a nutritious alternative in modern diets.In this study, four different flour blends were prepared by mixing whole wheat flour with tender jackfruit flour at varying ratios: 10% (TJFC1), 15% (TJFC2), and 20% (TJFC3). *Chapathi*s made entirely from 100% whole wheat flour were used as the control.The sensory evaluation scores of *Chapathi* are presented in Table 2. Appearance scores ranged from 8.90 to 6.61, color from 8.33 to 6.04, texture from 8.57 to 6.07, flavor from 8.16 to 5.78, taste from 8.38 to 5.78, and overall acceptability (OAA) from 8.19 to 5.46. In terms of overall acceptability control was rated the most favorable (8.19), followed by TJFC1 and TJFC2 with scores of 7.56 and 7.52 respectively. TJFC3 and TJFC4 were rated significantly lower, with OAA scores of 6.52 and 5.46 respectively. A statistically significant difference ($p < 0.05$) was observed across all sensory attributes, demonstrating that the panelists could clearly perceive the variations among the treatments. The marked decline in sensory attributes suggests that the higher levels of tender jackfruit flour negatively impacted overall consumer preference. This could be attributed to the bitterness caused by the presence of polyphenols and flavonoids in the tender jackfruit flour. While the differences are noteworthy, they still fall within an acceptable range for sensory acceptability. Considering the non significant difference in sensory attributes of TJCF1 (10%) and TJCF2 (15%) , along with the health benefits and nutritional value of tender jackfruit flour, it was decided to proceed with a 15 per cent incorporation for further research. Sultana *et al.,* (2014) reported that the formulation, with 80 per cent whole meal wheat flour, 5 per cent white jackfruit seed flour, 10 per cent brown jackfruit seed flour, and 5 per cent Bengal gram flour, was considered the most acceptable according to sensory evaluation.

The present findings contrast with study by Paul and Isaac (2017), they reported *Chapathi* made with 100% tender jackfruit flour received the highest acceptance, achieving a mean score of 4.9. This discrepancy may be attributed to differences in the stage of harvesting and the variety of jackfruit used.

Table 2: Sensory evaluation of tender jackfruit flour incorporated *Chapathi*

Sample	Appearance	Texture	Colour	Flavour	Taste	OAA
C	8.90±0.30^{a}	8.57±0.48^{a}	8.33±0.77^{a}	8.16±0.49^{a}	8.38±0.57^{a}	8.19±0.85^{a}
TJFC1	7.85±0.59^{b}	7.92±0.71^{b}	7.26±0.80^{b}	7.36±0.89^{b}	7.09±1.17^{b}	7.56±0.53^{b}
TJFC2	7.72±0.53^{b}	7.89±0.90^{b}	7.20±0.91^{b}	7.18±0.86^{b}	7.04±0.78^{b}	7.52±0.47^{b}
TJFC3	7.19±0.53^{d}	6.71±1.34^{d}	6.61±0.94^{c}	6.23±1.47^{c}	5.80±1.67^{c}	6.52±0.87^{c}
TJFC4	6.61±1.02^{e}	6.07±0.84^{e}	6.04±0.87^{d}	5.78±1.16^{d}	5.78±1.15^{c}	5.46±0.85^{d}
F-value	*	*	*	*	*	*
CD at 5%	0.394	0.554	0.531	0.649	0.714	0.465
SEm±	0.140	0.197	0.189	0.231	0.254	0.165

*Significant @5%, Means in the same column followed by different superscripts are significantly different from each other ($P \leq 0.05$)

C: Control, TJFC1: Tender jackfruit flour *Chapathi* (10%), TJCF2: Tender jackfruit flour *Chapathi* (15%), TJCF3: Tender jackfruit flour *Chapathi* (20%), TJCF4: Tender jackfruit flour *Chapathi* (25%)

In vivo postprandial glycemic response study among diabetic subjects

Postprandial hyperglycemia, a typical response following the consumption of carbohydrate-rich meals, is of particular concern for individuals with diabetes or those seeking to maintain stable blood glucose levels throughout the day. Managing postprandial glucose levels is essential for reducing cardiovascular risks and improving overall glycemic control (Elsayed *et al*., 2023). This study specifically evaluates the post prandial glycemic response of *Chapathi* incorporated with tender jackfruit flour. By investigating the potential of these food products to positively influence postprandial glycemic responses, this research contributes to the broader scope of dietary strategies for glycemic control. The study involved ten pre-diabetic subjects aged 35 to 45 years, with HbA1C range of 5.4 to 6.4, with an equal distribution of five males and five females, ensuring gender balance in the research cohort. Anthropometric data is essential in nutritional research, aiding in the characterization of the study population and contributing to a deeper understanding of their physical profiles. Mean anthropometric measurements of the 10 diabetic subjects enrolled under study are presented in Table 3. The average weight of male participants was 74.2 ± 6.97 kg, while that of female participants was 62.73 kg. Similarly, the mean height recorded was 168.00 cm for males and 156.50 cm for females. As expected, males were generally taller and heavier than females, reflecting typical gender-based physiological differences. The mean Body Mass Index (BMI) was 26.3 kg/m² in males and 25.8 kg/m² in females. Both values fall under obese I category according BMI classification.

The mean waist circumference was 88.51 cm in males and 77.16 cm in females. The average hip circumference was 101.21 cm for males and 99.00 cm for females. The waist-to-hip ratio (WHR) was found to be 0.9 for males and 0.8 for females.

Table 3: Anthropometric measurements of the subjects (n=10)

Parameters	Male	Female
	Mean ± SD	Mean ± SD
Weight (kg)	74.2±6.977	62.73±7.35.35
Height (cm)	168.00 ± 6.90	156.50 ±4.71
BMI (kg/m^2)	26.3±2.64	25.8±1.88
Waist circumference (cm)	88.51 ± 8.54	77.16 ±4.21
Hip circumference (cm)	101.21± 5.89	99.00 ± 6.28
Waist-to-hip ratio	0.9±0.08	0.8±0.02

Results expressed as Mean ± SD

In vivo postprandial glycemic response of tender jackfruit flour incorporated product among diabetic subjects

A key aspect of the glycemic response study was the calculation of portion sizes, ensuring a standardized carbohydrate intake of approximately 50 grams per portion. This precise control of portion sizes ensures consistency in carbohydrate consumption across test foods, allowing for accurate comparison of their glycemic responses. Among the best accepted value- added products, *Chapathi* incorporated with 15% tender jackfruit flour was selected for glycemic response testing. The control *Chapathi* without incorporation of tender jackfruit flour required a portion size of 94 g, while the tender jackfruit flour-incorporated *Chapathi* required a slightly larger portion of 108 to achieve the same target carbohydrate content. These adjustments highlight the efforts to maintain consistent carbohydrate intake while accommodating ingredient modifications. The participant provided informed consent and was briefed on the study's purpose before the experiment. Participants were instructed to refrain from medication and physical exertion during the study period. Each subject completed two test periods in the initial period, they consumed a 94 g control product within 15 minutes under observation. In the second test period, they consumed 108 g chapatis (incorporating tender jackfruit flour) providing approximately 25 g of available carbohydrates, also within 15 minutes under observation. The glucose response to the consumption of control *Chapathi* and tender jackfruit flour incorporated *Chapathi* among pre-diabetic subjects (n = 10) was estimated and The findings are detailed in Table 4.

The Mean blood glucose (mg/dL) response after ingestion of control *Chapathi* and tender jackfruit flour incorporated *Chapathi* among ten pre diabetic subjects was detailed in Table 4. Fasting Blood Glucose (FBG) levels were measured for all participants prior to the consumption of either the control *Chapathi* or the *Chapathi* incorporated with tender jackfruit flour on each study day to establish baseline values. The mean FBG were similar between the groups, with 118.3 mg/dL recorded for the control *Chapathi* and 119.49 mg/dL for the jackfruit flour *Chapathi* group, indicating baseline uniformity across participants.

Following consumption of the control *Chapathi*, blood glucose levels rose to 165.03±4.82 mg/dL at 30 minutes, then gradually declined to 149.17±9.99 mg/dL at 60 minutes, 130.26±7.08 mg/dL at 90 minutes, and 127.48±19.22 mg/dL at 120 minutes. In contrast, consumption of the tender jackfruit flour incorporated The tender jackfruit flour incorporated *Chapathi* consistently resulted in lower Postprandial Blood Glucose (PBG) levels at each measured time point, with values of 155.03 ± 14.14 mg/dL at 30 minutes, 140.18 ± 13.34 mg/dL at 60 minutes, 126.18 ± 6.54 mg/dL at 90 minutes, and 121.41 ± 7.03 mg/dL at 120 minutes. This signifies a sustained decrease in postprandial glycemic response relative to the control *Chapathi*.

The Area Under Curve (AUC) for the jackfruit flour *Chapathi* was approximately 28% lower than that of the control *Chapathi*, highlighting its potential in moderating postprandial glycemic excursions. This notable reduction in cumulative glycemic exposure suggests meaningful implications for the dietary management of prediabetes and diabetes. The observed decrease in blood glucose levels at multiple time points, coupled with a reduced AUC, suggests that jackfruit flour may effectively mitigate postprandial blood glucose spikes.

This beneficial effect could be attributed to dietary fiber content, phytochemicals, lower glycemic index of tender jackfruit flour and ability to inhibit carbohydrate-digesting enzymes such as α-amylase and α-glucosidase as identified in study. Further, polyphenol rich foods are well-documented for their beneficial effects on postprandial glycemia (Haldar *et al*., 2018; Haldar *et al*., 2019). These findings support the rationale for incorporating tender jackfruit flour into commonly consumed foods like *Chapathi* to could offer a practical and a promising dietary approach for individuals with prediabetes or impaired glucose tolerance. The current results are consistent with previous studies by Almaski *et al*., 2023; Kim *et al*., 2015 and Kokubo *et al*., 2022 reported improvements in glycemic control following the consumption of functional or plant-based foods. The findings are further supported by earlier studies highlighting the glucose-lowering effects of jackfruit-based and other cereal- and millet-based foods. Substituting wheat flour with tender jackfruit flour in *Chapathi* led to a significant attenuation of early postprandial blood glucose spikes and a considerable reduction in overall glycemic load. This suggests that jackfruit flour-enriched *Chapathi* could be a promising dietary strategy to improve glycemic regulation in individuals at risk of type 2 diabetes.

Comparable findings were reported by Urooj *et al*. (2000) and Narayanan *et al*. (2016), who observed that cereal- and millet-based foods significantly attenuated postprandial blood glucose responses. Urooj *et al*. (2000) demonstrated that the intake of cereal-based foods Led to a significant reduction in blood glucose levels at 30, 60, and 120 minutes in both individuals with non-insulin-dependent diabetes mellitus

(NIDDM) and healthy subjects. Similarly, Narayanan *et al.* (2016) reported a highly significant reduction ($P < 0.001$) in postprandial glucose levels among type 2 diabetes patients who consumed millet-based (foxtail) dosa compared to those who consumed rice-based dosa.

Additional support comes from the findings of De Carvalho *et al*. (2017) and Thomas *et al*., (2024). De Carvalho *et al*., 2017 observed that high-fiber meals, whether from foods or supplements, led to lower PBG responses, although slightly higher AUC values were reported due to differences in study design and participant profiles. Thomas *et al*. found that a high-protein, low-fat nutritional shake significantly lowered the glucose-positive AUC in individuals with type 2 diabetes compared to an instant oatmeal breakfast.

Further, Kokubo *et al*., (2022) demonstrated that the incremental area under the curve (iAUC) for blood glucose over 120 minutes was significantly reduced following the intake of a low-carbohydrate oral nutritional supplement (LC-ONS) compared to a standard supplement (ST-ONS), with respective values of 2207 ± 391 and 3735 ± 391 mg/dL·min ($p < 0.001$). Similarly, Almaski *et al*. (2023) reported that finger millet muffins significantly decreased peak postprandial blood glucose levels and insulin incremental area under the curve (iAUC) at 180 minutes in prediabetic individuals compared to wheat muffins. Similarly, Kim *et al*. (2015) found that Morus alba leaf extract (MLAE) significantly reduced postprandial blood glucose levels at 30 and 60 minutes ($P = 0.003$ and $P = 0.0325$, respectively) in subjects with impaired fasting glucose.

The non-significant t-values observed at various time points may be attributed to relatively less proportion of tender jackfruit flour incorporated into the *Chapathi*, inter-individual variability or greater heterogeneity in insulin secretion among individuals and the small sample size. Additionally, HbA1c was used as the primary diagnostic criterion for study inclusion, the individuals with Impaired Fasting Glucose (IFG) and impaired Glucose Tolerance (IGT) cannot be distinguished (Shukla *et al*., 2019).

Table 4: Mean blood glucose (mg/dL) levels after ingestion of control and test foods (*chapati*) among pre diabetic subjects (n=10)

Time period	FBG	30 min	60 min	90 min	120 min	AUC
C	118.3±7.24	165.03±4.82	149.17±9.99	130.26±7.08	127.48±19.22	2510
TJFC2	119.49±7.08	155.03±14.14	140.18±13.34	126.18±6.54	121.41±7.03	1811
t-value	0.66^{NS}	2.26^{NS}	1.8^{NS}	0.21^{NS}	0.81^{NS}	

FBG: Fasting Blood Glucose; AUC: Area under the curve C: Control *Chapathi*, TJFC2: Tender jackfruit flour incorporated *Chapathi*(15%)

5. Conclusion

The present investigation revealed that different pretreatment methods significantly influenced the browning index of tender Jackfruit flour in both HV2 and TCV varieties. Among the treatments studied, potassium metabisulphite (KMS) blanching at 0.5 per cent concentration was found to be the most effective in reducing browning during drying.Tender jackfruit flour was successfully incorporated into *chapathi* at different incorporation levels. Sensory evaluation indicated that *chapathi* incorporated with 15 per cent tender jackfruit flour showed good acceptability with desirable sensory attributes and was selected for further glycemic response assessment.The *in vivo* postprandial glycemic response study among prediabetic subjects demonstrated that tender jackfruit flour incorporated *chapathi* produced lower postprandial blood glucose levels compared to the control *chapathi* at all measured intervals. In addition, the incorporated *chapathi* exhibited a lower Area Under Curve (AUC), indicating reduced glycemic response and better blood glucose regulation. The beneficial effect of tender jackfruit flour may be attributed to its high dietary fiber, resistant starch, and phytochemical components such as polyphenols and flavonoids, which help in slowing carbohydrate digestion and absorption. Therefore, incorporation of tender jackfruit flour into commonly consumed foods like *chapathi* may serve as a simple, economical, and culturally acceptable dietary strategy for improving glycemic control among prediabetic individuals and reducing the risk of progression to type 2 diabetes mellitus.

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Conflict of interest
The authors declare no conflict of interest.

6. Future Scope

Future research should focus on the isolation and characterization of bioactive compounds, particularly polyphenols and flavonoids, from tender jackfruit flour to better understand their contribution to its functional and health-promoting properties. The influence of different maturity stages on the nutritional composition, physicochemical characteristics, and processing suitability of tender jackfruit flour should also be investigated. Further studies are warranted to develop and optimize a wider range of value-added food products, while evaluating their sensory quality, storage stability, and shelf life under different packaging conditions. Comprehensive consumer acceptability studies among diabetic and health-conscious populations are recommended to assess market potential. In addition, long-term clinical intervention studies are needed to validate the efficacy of tender jackfruit flour-based products in glycemic management and to support their application as functional foods in diabetes prevention and management.

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