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Consumer Acceptability of Therapeutic Finger Millet-Based Food Formulation Among Type 2 Diabetes Patients in Migori County, Kenya

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ABSTRACT

Background: Finger millet (*Eleusine coracana*), recognized for its low glycemic index and high fibre content, offers potential therapeutic benefits for glycemic management. The purpose of this study was to assess consumer acceptability of a therapeutic finger millet-based formulation among patients with type 2 diabetes mellitus.
Methods: A cross-sectional analytical design was used with 90 randomly selected participants. An interviewer-administered questionnaire was used to collect data on sociodemographic characteristics, sensory attributes, modifications, enhancers, and barriers to sensory acceptability, employing the Trials of Improved Practices (TIPs) technique. Data were analyzed using Statistical Package for the Social Sciences (version 29) and described using means, proportions, frequencies, and standard deviations. t-tests, ANOVA, and multiple linear regression were used to assess associations.
Results: The formulation, comprising roasted finger millet flour biofortified with chromium and oyster mushrooms biofortified with potassium, received high overall sensory acceptability (mean score of 4.406 ± 0.585) based on a five-point Likert scale. No significant differences in acceptability were observed across gender ($t = 1.180$; $p = 0.241$), education level ($F = 0.676$; $p = 0.569$), or product modifications ($F = 1.717$; $p = 0.154$). The majority of respondents (86.7%) rated the formulation's sensory attributes as comparable to traditional finger millet. Key enhancers of intake included knowledge of health benefits, weight control, convenience, and natural content. The barriers to acceptability comprised misconceptions about finger millet as a rural food associated with scarcity and limited market availability.
Conclusion: Findings support the potential of this therapeutic formulation as an acceptable dietary intervention for managing type 2 diabetes mellitus and provide insights to facilitate its integration into diabetic meal planning.

Keywords: Consumer acceptability, Therapeutic Finger Millet, Type 2 Diabetes, Formulation

INTRODUCTION

Globally, the prevalence of Type 2 Diabetes Mellitus (T2DM) continues to rise, with over 589 million adults currently affected, underscoring the urgent need for effective dietary interventions (IDF, 2025). In Kenya, 3.1% adults have diabetes, a metabolic disorder associated with dietary transition, urbanization, and lack of exercise (IDF, 2025). Cardiovascular diseases increase the risk of morbidity and mortality among individuals with T2DM (1). Effective management of T2DM is therefore essential to prevent complications and improve quality of life. While pharmacological treatment remains important in T2DM management, dietary modification plays a critical role in glycemic control. Functional foods are increasingly being explored as complementary strategies for managing hyperglycemia.

Finger millet, a cereal that is low in glycemic index and high in fibre, has been shown to improve glucose regulation and reduce insulin resistance (2). However, poor dietary adherence and more reliance on medication among T2DM patients may limit treatment effectiveness and increase the risk of complications (3). Additionally, biofortification of the formulation with chromium and potassium improves insulin sensitivity and glucose metabolism, regulates blood pressure, and reduces oxidative stress (4 -5). Despite the potential health benefits of the finger millet formulation, consumer acceptability among individuals with T2DM remains inadequately explored. A comprehensive understanding of patient perceptions and preferences is therefore essential for the successful integration of these dietary interventions as sustainable and effective complements to conventional pharmacological treatments.

Finger millet (*Eleusine coracana*) is a highly nutritious cereal rich in carbohydrates, dietary fibre, minerals, and unsaturated fats, providing about 336 kcal per 100 g (2). It contains notably high levels of calcium and potassium and is naturally gluten-free, making it suitable for individuals with gluten intolerance (6). Due to its low glycemic index and high fibre content, finger millet plays an important role in regulating blood glucose, with regular consumption associated with reduced fasting glucose and improved insulin sensitivity (7). Additionally, its high calcium content may help lower the risk of type 2 diabetes mellitus (8)

Mushrooms, particularly oyster mushrooms (*Pleurotus ostreatus*), contain bioactive compounds such as polysaccharides, β-glucans, and phenolic compounds that enhance insulin sensitivity and glucose uptake (9 -10). Their antioxidant properties also help reduce oxidative stress associated with diabetes (11). Combining finger millet with oyster mushrooms, along with processing techniques such as fermentation and germination, may therefore improve nutritional quality and glycemic control potency, while micronutrients such as chromium and potassium further support insulin function and glucose metabolism (12 -13).

Despite numerous studies on finger millet in Kenya, much of the available information is often combined with that of other cereals, resulting in limited evidence specifically addressing its consumer acceptability. In particular, studies evaluating the acceptability of finger millet-based therapeutic foods among individuals with type 2 diabetes mellitus (T2DM) remain scarce. Therefore, this study aimed to assess the consumer acceptability of a therapeutic finger millet-based food formulation among individuals with T2DM. By establishing consumer acceptability of the therapeutic finger millet formulation, this study's findings provide health professionals with a basis for promoting this formulation as part of nutrition-based interventions for diabetes care. Also, the study provides evidence to guide the Ministry of Health and food industries in developing nutrition-sensitive policies and value-added finger millet products. Promoting such indigenous functional foods may contribute to improved dietary management of non-communicable

diseases while enhancing market opportunities for finger millet.

The objectives of the study were:

1. To determine consumer acceptability of therapeutic finger millet-based food formulation.
2. To establish enhancers and barriers of consumer acceptance of therapeutic finger millet-based food formulation.
3. To determine consumer modifications on therapeutic finger millet-based food formulation.

MATERIALS & METHODS

Method

A cross-sectional analytical study design was used. The target population for this study was patients with type 2 diabetes mellitus. The study was conducted in Migori County, Kenya, because finger millet was a staple crop and the population was familiar with it. Effective consumer test recommendations were used to determine the sample size **(14)**. The respondents in this study were selected using simple random sampling; individuals attending the diabetes clinic at Migori Hospital formed the sampling frame, and a random number generator was used to select participants. A sample of 90 participants with type 2 diabetes mellitus aged 45-64 years who had lived in Migori County for at least 6 months before the study and provided informed consent was included. An interviewer-administered questionnaire was used to collect data on consumer acceptability of therapeutic finger millet. The questionnaire included questions on social, demographic, and economic characteristics, as well as enhancers, barriers, and modifications to the therapeutic finger millet food formulation. An in-depth interview (IDI) tool was used to collect data on perceptions and cultural beliefs towards the consumption of therapeutic finger millet among individuals with type 2 diabetes. Sensory test data were gathered using a sensory evaluation form with a 5-point hedonic scale. The Trials of Improved Practices (TIPs) technique was used in data collection, which allowed for two follow-ups every seven days with the study participants during the study.

Materials

Finger Millet and Oyster Mushroom Production

Finger millet grains biofortified with chromium were obtained from KALRO, Kisii, while oyster mushrooms were grown on substrates biofortified with potassium sulfate, pasteurised at 121°C for 30 min, and incubated in the dark until the reproductive phase.

Therapeutic finger millet-based food formulation

The therapeutic finger millet flour, made from roasted finger millet and sun-dried oyster mushrooms, was developed, and a sensory evaluation was conducted with eight untrained panellists. Five formulations were prepared and labelled as P1 (germinated finger millet, roasted finger millet, and oyster mushroom in the ratio 30:50:20), P2 (roasted finger millet and oyster mushroom in the ratio 90:10), P3 (germinated finger millet and oyster mushroom in the ratio 70:30), P4 (germinated finger millet), and P5 (roasted finger millet). The sensory acceptability of the formulations was assessed using a 5-point hedonic scale. Among these, P2 achieved the highest acceptability scores and was subsequently selected for the consumer acceptability study. This finding aligns with a previous study (15), which reported that including 10% mushrooms increased micronutrient content without negatively affecting sensory attributes.

Processing of the Finger Millet Flour

The finger millet grains were cleaned, roasted at 180 °C for 1 min on a conveyor oven, then ground into whole flour using a hammer mill and sieved (0.5 um). Fresh oyster mushrooms were steam-blanched for 3 min, sun-dried to a moisture content < 10%, and then milled into flour (mesh size ~32 mm). Both the roasted finger millet and oyster mushrooms were blended at a 90:10 ratio shown in Figure 1.

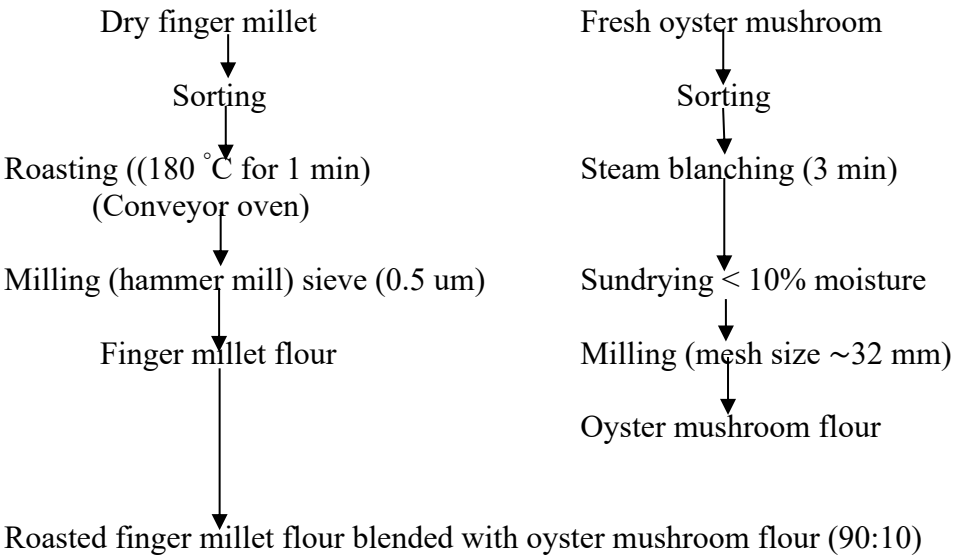

Figure 1: **Flow chart on the processing of flour**

Porridge preparation

In a bowl, 60 grams of the flour were mixed into a paste with 100ml of cold water. The paste was added to a pot containing 600 mL that had been brought to a boil. The mixture was stirred until it thickened. The porridge was simmered for 10 minutes. Participants were allowed to add optional flavours. The porridge was served at room temperature.

Sensory Evaluation

The acceptability test was conducted at home on three different days to reflect real-life consumption patterns and to assess product performance over time. Ninety untrained participants with type 2 diabetes, aged 45-64 years, who were familiar with finger millet and oyster mushrooms, participated in the sensory evaluation. After obtaining informed consent and providing information, respondents were served with the porridge. The taste, aroma, texture, colour, and overall acceptability were evaluated using a 5-point hedonic scale (1 = Dislike extremely, 2 = Slightly dislike, 3 = Neither like nor dislike, 4 = Slightly like, and 5 = Extremely like).

Statistical Analysis

Data were collected using Open Data Kit (ODK), downloaded into MS Excel, coded, and analysed using the Statistical Package for the Social Sciences (SPSS) version 29.0. Data were described using means, proportions, and standard deviations. Associations between acceptability and gender were assessed using t-tests. ANOVA was used to assess the association between acceptability and categorical variables such as education level and consumer modifications. Multiple linear regression was used to examine relationships among variables, and a p-value < 0.05 was considered statistically significant.

Ethical Consideration

The approval to conduct the study was sought from the Kenyatta University Ethical Review Committee, approval number PKU/2703/11827. Permission to conduct the study was obtained from the National Council of Science, Technology, and Innovation (NACOSTI) (Reference number NACOSTI/P/23/27361). Migori County approved the study (REF: MCG/MOH/CRLC/VOL 1/18/2023). Written informed consent was obtained from the participants, and they were allowed to withdraw from the study at any time.

RESULTS

Socio-Demographic and Economic Characteristics

The study included 90 participants who were mainly female (65.6%). Most (56.7%) of them were aged between 45 and 54 years (Table 1). Further, it was noted that most

respondents (83.3%) were married, with a smaller portion (14.4%) widowed. Secondary education was the most common level attained, at 45.6%, followed by primary education, reported by 33.3% of respondents. Nearly half (48.9%) of the participants were self-employed, while 20.0% were unemployed. The majority did not follow a special diet, 56 (62.2%).

Table 1: Socio-demographic and economic characteristics of respondents

Characteristic	Category	Frequency (n)	Percent (%)
Gender	Male	31	34.4
	Female	59	65.6
Age	45-54	51	56.7
	55-65	39	43.3
Marital status	Single	1	1.1
	Married	75	83.3
	Divorced	1	1.1
	Widow	13	14.4
Education Level	Informal	5	5.6
	Primary	30	33.3
	Secondary	41	45.6
	Tertiary	14	15.6
Occupation	Casual	12	13.3
	Employed	16	17.8
	Unemployed	18	20.0
	Self-employed	44	48.9
Special Diet	Yes	34	37.8
	No	56	62.2

Sensory attributes of therapeutic finger millet formulation

Consumer acceptability of the therapeutic finger millet formulation was evaluated using a 5-point hedonic scale sensory test, as shown in Table 2. The mean sensory scores for the finger millet formulation across all three evaluation days remained above 4.0 (Slightly like) for all assessed attributes, indicating that the product was generally well-liked throughout the testing period. The overall acceptability of therapeutic finger millet was 4.406 ± 0.585 on a 5-point hedonic scale, indicating high consumer acceptance. 1= extremely dislike, 2= slightly dislike, 3 = neither like nor dislike, 4 = slightly like and 5 = extremely like.

No significant difference in acceptability was observed between male and female participants ($t = 1.180$; $p = 0.241$), with comparable mean scores recorded for males (4.49 ± 0.459) and females (4.36 ± 0.427). Similarly, consumers with primary education showed a high acceptability (4.487 ± 0.562); however, acceptability did not differ significantly across education levels (ANOVA; $F = 0.676$, $df = 3$, $p = 0.569$). Participants who consumed the product without modification reported the highest acceptability score (4.488 ± 0.518). There was no statistically significant difference in acceptability among respondents who practiced different modifications of the porridge (ANOVA; $F = 1.717$, $df = 4$, $p = 0.154$).

Table 2: Consumer acceptability scores of the formulation

Sensory Attributes	Day 1 Mean	Day 3 Mean	Day 7 Mean	Average Mean
Colour/ Appearance	421±.906	4.28±.862	4.43±.780	4.307±.687
Aroma	4.17±.997	4.49±.723	4.44±.736	4.367±.636
Taste	4.26±.906	4.52±.796	4.57±.688	4.48±.596
Texture/ Smoothness	4.34±.796	4.39±.831	4.41±.634	4.382±.530
Overall tolerance level	4.32±.805	4.60±.667	4.66±.603	4.526±.474
Overall Mean Score	**4.26±.882**	**4.46±.776**	**4.502±.688**	**4.406±.585**

Consumption and hygiene practices by the respondents

Consumption and hygiene practices were observed over seven days. The results showed a generally high product acceptance and positive feeding practices among participants (Table 3). Nearly half (48.9%) of the participants consumed the porridge once a day, with the majority (94.4%), consuming a whole cup. The behavioral responses during feeding were positive, with 81 (90%) of participants appearing cheerful or eager. Hygiene practices were generally good. A large majority reported washing hands before food preparation, 76 (84.4%), and before eating, 72 (80%), indicating strong adherence to recommended hygiene practices.

Table 3: Consumption of the therapeutic porridge and hygiene practices of the respondents

Variable	Category	Frequency (n)	Percentage (%)
Frequency of consumption (Per day)	Once	44	48.9
	Twice	33	36.7
	Thrice	8	8.9
	None	5	5.6
Amount consumed	Whole cup	85	94.4
	>= ¾ cup	4	4.4
	>= ¼ cup	1	1.1
Behaviour/ Expression during feeding	Positive (Cheerful/Eager)	81	90.0
	Negative (Reluctant/ Indifferent)	9	10.0
Washing hands before food preparation	Yes	76	84.4
	No	14	15.6
Washing hands before eating food	Yes	72	80.0
	No	18	20.0

Enhancers and barriers to consumer acceptability of the porridge formulation by respondents

A 4-point Likert scale was used with 1 = not important at all, 2 = slightly important, 3 = important, 4 = very important. All evaluated enhancing factors received mean scores above 3.3, indicating that consumers generally considered each factor moderately important in influencing their choices (Table 4). The overall average was 3.552 ± 0.531, indicating that all these factors significantly increase the acceptability of therapeutic finger millet. Health (3.667±0.408) had the highest mean rating, followed by weight control (3.659±0.421), convenience (3.652±0.455), and natural content (3.648±0.442). Sensory appeal (3.528±0.598) and mood (3.463±0.578) showed a moderate influence secondary to health and functional considerations. Ethical concern (3.406±0.695) and familiarity (3.389±0.652) had low mean scores.

Table 4: Factors enhancing consumer acceptability of the formulation

Factor	Mean
Convenience	3.652± .455
Sensory Appeal	3.528± .598
Familiarity	3.389±.652
Natural content	3.648±.442
Weight Control	3.659±.421
Health	3.667±.408
Mood	3.463±.578
Ethical concern	3.406±.695
Overall	**3.552±.531**

Most factors were not major barriers to consumer acceptance, as reflected in the high proportion of participants who responded 'No' to most items (Figure 2). However, the perception of the product as a rural food (37.8%) was reported to negatively influence acceptance. This suggests that social and cultural perceptions may meaningfully affect consumer attitudes.

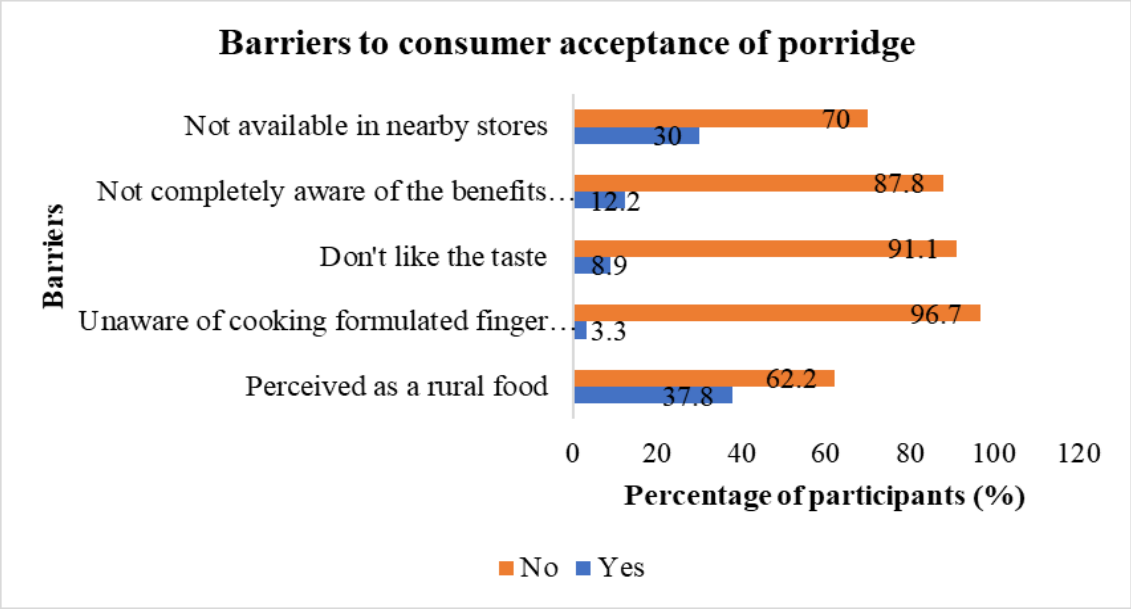

Figure 2: Barriers to Consumer Acceptance of the formulation

Participants' response to modifications of the therapeutic porridge

Most participants preferred the product without any modifications (Figure 3). A large majority (72.2%) reported making no changes, indicating strong acceptance of the formulation as originally formulated. Among those who made modifications, only small proportions added other ingredients. The most common additions were milk and other flavors, each by 8.9% of participants. Fruit juices were added by 5.6%, while honey was the least-used modification at 4.4%.

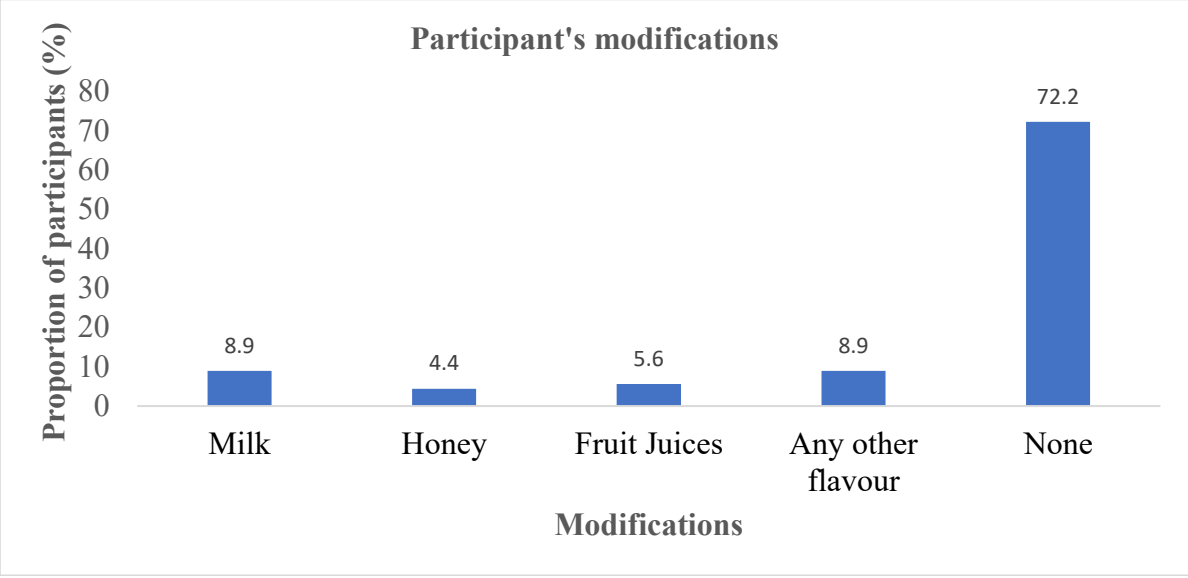

Figure 3: Participants' modifications of the therapeutic porridge

Frequency of eating out

Determining the eating-out pattern is important because it reveals how and where target consumers interact with the therapeutic finger millet formulation, which influences product adoption. Eating patterns helped identify factors such as convenience, cultural context, and familiarity. Patterns of eating out varied by meal type (Figure 4). Daily eating out was most common at breakfast (50.0%), followed by lunch (35.6%) and dinner (34.4%). Moderate-

frequency eating out (4-5 times per week) was reported more for lunch (21.1%) and dinner (18.9%) than breakfast (6.7%). The proportion of respondents who practiced eating out 2-3 times per week was relatively low, with no respondent reporting having eaten dinner outside the home 2 to 3 times a week. Very few participants reported eating out once a week. A considerable proportion reported rarely eating out, particularly for dinner (46.7%), followed by breakfast (37.8%) and lunch (34.4%).

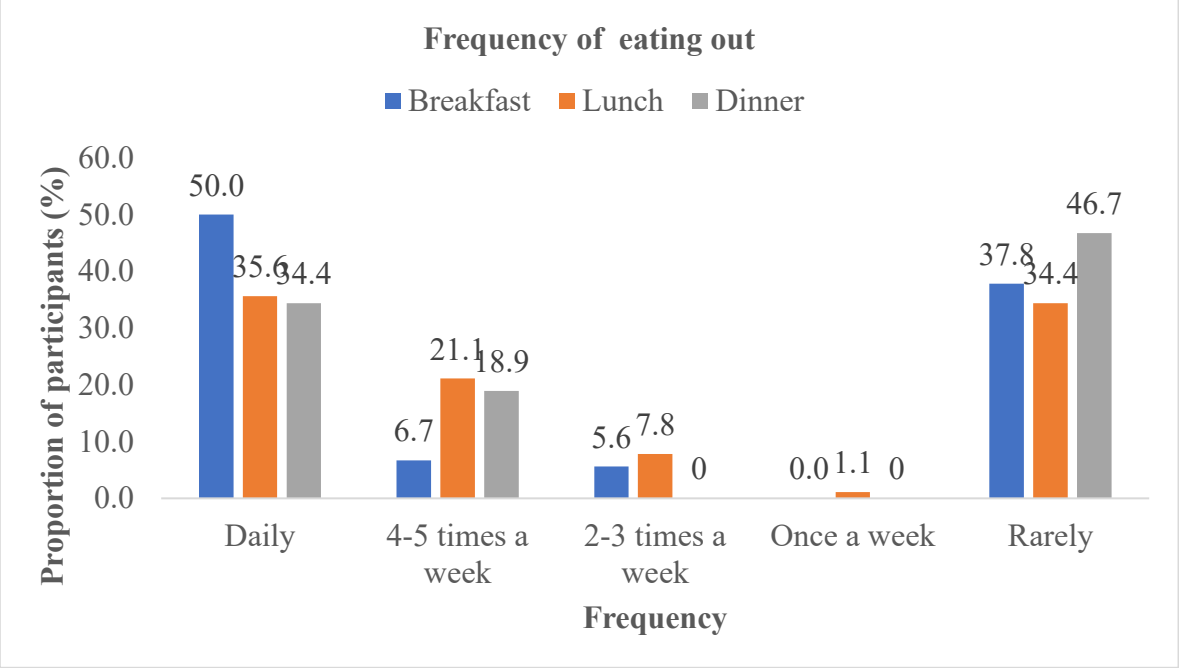

Figure 4: Frequency of eating out per week

DISCUSSION

Social demographic and economic characteristics

Several factors influence consumer acceptability of functional foods. The extent to which various factors influence consumer acceptance was affected by their interactions (16). Social demographic characteristics play a critical role in shaping consumer acceptance of formulated products (17). This study assessed the acceptability of a therapeutic finger millet formulation among 90 respondents, who were mainly female (65.6%), a finding that aligns with a previous study (18) and reflects women's increased health awareness and influence over family healthcare decisions (19). The majority (56.7%) of the respondents were aged 45-54, indicating a health-conscious population willing to try novel food choices. Most respondents were married (83.3%), a demographic characteristic associated with a greater willingness to invest in value-added products (21). Regarding occupation, the largest group was self-employed (48.6%), a segment often facing income limitations that restrict access to nutritious foods (22). However, with 45.6% having completed secondary education, participants possessed sufficient knowledge to make informed choices regarding the therapeutic formulation (23).

Sensory Evaluation of the millet- based therapeutic food formulation

Results from scoring the sensory attributes of the therapeutic finger millet formulation indicated high consumer acceptability, with all attributes receiving mean scores above 4.3. Taste (4.448), texture (4.382), and aroma (4.367) emerged as the primary drivers of acceptability, consistent with a previous study (24), which reported that mean scores above 4.0 indicated strong product acceptance. The inclusion of 10% mushrooms in the therapeutic food

formulation proved optimal, maintaining palatability while offering nutritional benefits, unlike higher mushroom proportions, which have been associated with reduced sensory acceptability (15). This finding aligns with a previous study (15), which reported that finger millet porridge made from a 90:10 finger millet-oyster mushroom blend yielded the highest sensory ratings compared with porridges containing higher proportions of oyster mushrooms. Notably, the high acceptability of aroma contrasts with findings by another author (25), who reported that fortified millet-based foods typically suffer from reduced sensory quality, suggesting that the specific formulation and processing methods employed successfully preserved these critical attributes. Statistical analysis revealed no significant differences in sensory ratings between genders ($t = 1.180$; $p = 0.241$) or across education levels ($F = 0.676$; $p = 0.569$), indicating that the product appeals equally across diverse consumer segments.

Consumption and hygiene practices

In the current study, no adverse effects were reported, indicating that the formulation was well-tolerated and safe for home consumption. Nearly half (48.9%) of participants consumed the therapeutic finger millet-based porridge once daily, 36.7% twice daily, and 8.9% thrice daily, with only 5.6% reporting no consumption, indicating a high overall intake (26). This finding contrasts with Jayawardana (27), who reported that 37.2% of participants rarely consumed finger millet. The high daily intake observed suggests familiarity with the grain and confirms its palatability. Furthermore, 94.4% of participants consumed the full cup of the therapeutic porridge, and the majority (90%) of individuals with type 2 diabetes had cheerful expressions during feeding, indicating enjoyment and acceptance of the product. These findings support the potential of this therapeutic finger millet formulation as an acceptable nutritional intervention for individuals with type 2 diabetes.

Enhancers and barriers to acceptance of the therapeutic finger millet-based food formulation

In the current study, health benefits (3.667), weight control (3.659), convenience (3.652), and natural content (3.648) were the primary contributors to the therapeutic formulation's acceptability. This was consistent with other previous studies that pointed at health and weight management being the major motivators for finger millet consumption (28 -29). However, key barriers to consumption were also identified, with the perception of finger millet as a rural food (37.8%) being the most prominent, followed by limited availability in nearby markets (30%), lack of awareness of its benefits (12.2%), dislike for the taste (8.9%), and unfamiliarity with preparation methods (3.3%). These findings contrast with those of Jayawardana (26), who reported that unique taste was the primary barrier, along with coarse texture, unavailability, unwillingness to try new foods, dislike of color, and allergic reactions. The present study suggests that while sensory attributes were generally well rated, sociocultural perceptions and accessibility remain significant hurdles to the broader adoption of therapeutic finger millet formulations.

Consumer modifications

Most participants preferred the therapeutic finger millet formulation in its original form, with the majority (72.2%) reporting no modifications to the product. This strong acceptance of the unaltered formulation suggests that the sensory profile was well-matched to consumer expectations and required no further enhancement to achieve palatability. Among those who made modifications, a small proportion added ingredients: milk and other flavors were the most common additions (8.9% each), followed by fruit juices (5.6%), while honey was the least-used modification (4.4%). These findings align with previous research

indicating that minimal modification of functional food products often signals high initial acceptability (30) and that consumers who readily accept novel formulations tend to prefer them in their intended form without additional flavourings or sweeteners (31). The low rate of modification further supports the conclusion that the therapeutic finger millet formulation was well formulated to meet consumer preferences while delivering its intended nutritional benefits.

Frequency of eating out per week

Patterns of eating out varied considerably by meal type among respondents. Eating out was most common for breakfast (50.0%), followed by lunch (35.6%) and dinner (34.4%), highlighting a strong reliance on convenience options for morning meals. Conversely, a considerable proportion of respondents reported rarely eating out, particularly for dinner (46.7%), followed by breakfast (37.8%) and lunch (34.4%). These findings align with Maredia (32), who observed that urban consumers in Kenya frequently rely on out-of-home breakfast options due to time constraints, while evening meals present greater opportunities for home-prepared foods. Similarly, Annunziata and Vecchio (33) emphasised that the successful integration of functional foods into consumer diets depends on aligning product formats with established eating patterns and convenience needs. The prevalence of home-based evening meals suggests that dinner may be the most viable opportunity to introduce therapeutic finger millet formulations that require preparation, while breakfast and lunch occasions call for more convenient, ready-to-use product innovations.

CONCLUSION

The therapeutic finger-millet-based food formulation was acceptable to patients with T2DM. Sensory attributes, particularly taste, aroma, and texture, were key determinants of consumer acceptability, while social demographics and consumer modification showed no significant influence. However, mood significantly affected acceptability, indicating that psychological factors may influence dietary preferences. Given its high dietary fibre content, low glycemic index, and cultural relevance, finger millet offers a promising food-based approach to improving glycemic control and supporting the dietary management of T2DM.

Declaration by Authors

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Conflict of Interest: The authors declare no conflict of interest.

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