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## Results and Discussion

The results and discussion of the study entitled “**Starch Characterization, Functional Properties, Prebiotic Potential of Unripe Banana Flours and Development of Ready-to-Eat and Ready-to-Cook Products**” are presented in the following sections.

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#### 4.1. Phase 1: Consumers' Knowledge, Attitude, and Practice of RTE and RTC Foods

Consumer perceptions and inclinations toward RTE and RTC foods with functional ingredients strongly influence product design and acceptance. Comprehension of this provides vital information about the factors influencing decision-making, facilitating customized product creation with improved health benefits. The results and discussion of the Phase I research- Consumers' Knowledge, Attitude, and Practice of RTE and RTC Foods are presented in the following session.

##### 4.1.1. Background Information of the Study Participants

###### 4.1.1.1. Age and Gender

The age and gender distribution of the respondents are depicted in Table XVIII.

**Table XVIII**  
**Age and Gender Profile**

Age/ Gender	20-30 Years		31-40 Years		41-50 Years	
	No	Frequency	No	Frequency	No	Frequency
<b>Male</b>	53	13.25	28	7	18	4.5
<b>Female</b>	198	49.5	80	20	23	5.75
<b>Total</b>	251	62.75	108	27	41	10.25

The demographic analysis indicates that most participants were from the 20-30 years age group, representing 62.75% of the total sample, with a significant proportion being female (49.5%) compared to males (13.25%). The 31-40 years age group accounted for 27% of respondents, with 20% females and 7% males. The smallest representation was seen in the 41-50 years group, comprising only 10.25% of the sample (5.75% females and 4.5% males).

Overall, 75 % of the participants were female and 25% were male, and the results highlight a stronger engagement from younger consumers, especially women in the 20-30 age group, which may shape the overall Knowledge, Attitude, and Practice observed.

Recognizing these demographic patterns is essential for developing targeted strategies and interventions. Research studies agree that gender influences the adoption of functional foods. Verneau et al. (2019) stated that women tend to prefer functional foods, possibly due to their key responsibility in food procurement and meal preparation.

A study found that young adults (18 to 44 years) who prioritize nutritional quality when choosing foods tend to have a more favorable perception of functional foods, while middle-aged adults (45 to 65 years) often view them as medications (Safraid et al., 2024).

#### 4.1.1.2. Educational Status

Table XIX displays the educational status of the respondents.

**Table XIX**

#### Gender and Educational Qualification of the Respondents

Educational qualification / Gender	Higher Secondary		Graduation		Post Graduation	
	n	%	n	%	n	%
Male	3	0.8	67	16.8	29	7.3
Female	61	15.3	99	24.8	141	35.3
Total	64	16	166	41.5	170	42.5

16 % of the respondents had completed higher secondary education, 41.5 % were graduates, and 42.5% were postgraduates. Studies have also shown that educational level significantly impacts consumer acceptance (Baker et al., 2022). Çakiroğlu and Uçar (2018) found that university graduates were more likely to consume functional foods.

#### 4.1.1.3. Income and Family Type

Table XX indicates the household income level of the respondents, and Figure 14 depicts the family type of the respondents.

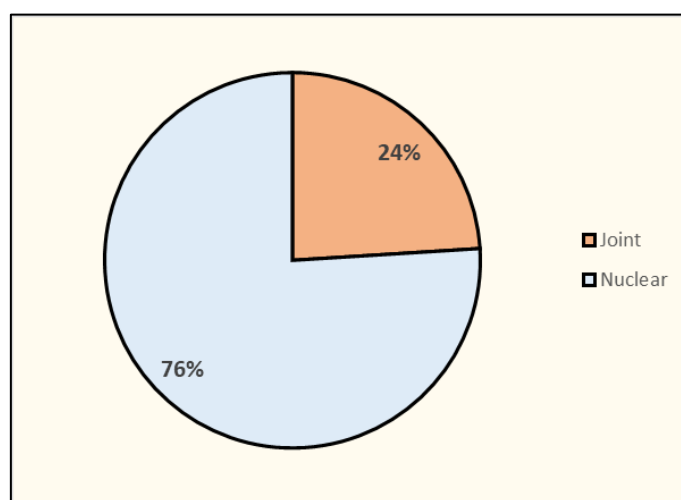
**Table XX**

#### Household Income of the Respondents

Income per month/ Gender	Below Rs.30000		Rs 30000- Rs 50000		Rs 50000- Rs 100000		Above Rs 100000	
	n	%	n	%	N	%	n	%
Male	11	3	47	12	31	8	10	3
Female	105	26	57	14	73	18	66	17
Total	116	29	104	26	104	26	76	19

The analysis revealed noticeable differences in income distribution by gender. While 12 % of men and 14 % of women were in the income bracket of Rs.30,000 – Rs.50,000, 18 % of women had a household income of Rs.50,000 – Rs.100,000. 26% of women predominantly occupied the below Rs.30,000 category.

According to Szakály et al. (2019) a high emolument was frequently linked to greater purchase intentions. This relationship can be ascribed to the fact that consumers with greater financial resources have a greater capacity to spend on functional foods.



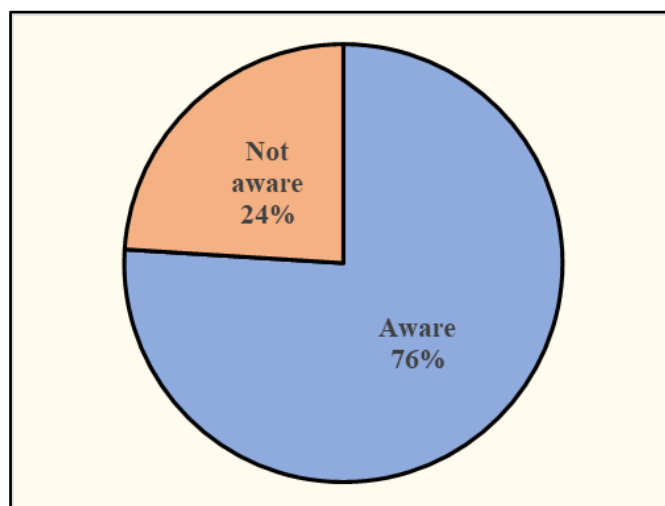
**Figure 14: Family Type of the Respondents**

76% of the respondents belong to the nuclear family type, and 24% live in a joint family system. Markovina et al. (2011) found that households with fewer members were more likely to buy functional foods than those with larger family sizes.

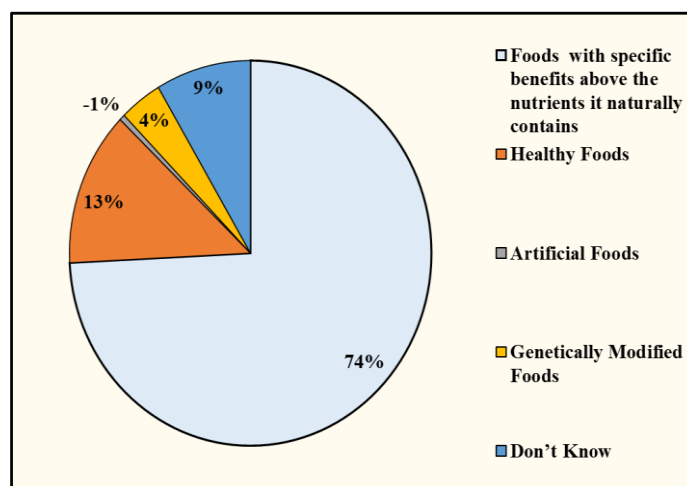
#### **4.1.2. Awareness and Knowledge of Functional Foods**

##### **4.1.2.1. Knowledge of Functional Foods**

Figure 15 depicts the respondents' awareness of functional foods, and Figure 16 displays the perceived explanation of functional foods by the respondents.



**Figure 15: Awareness of Functional Foods**



**Figure 16: Perceived Explanation of Functional Foods**

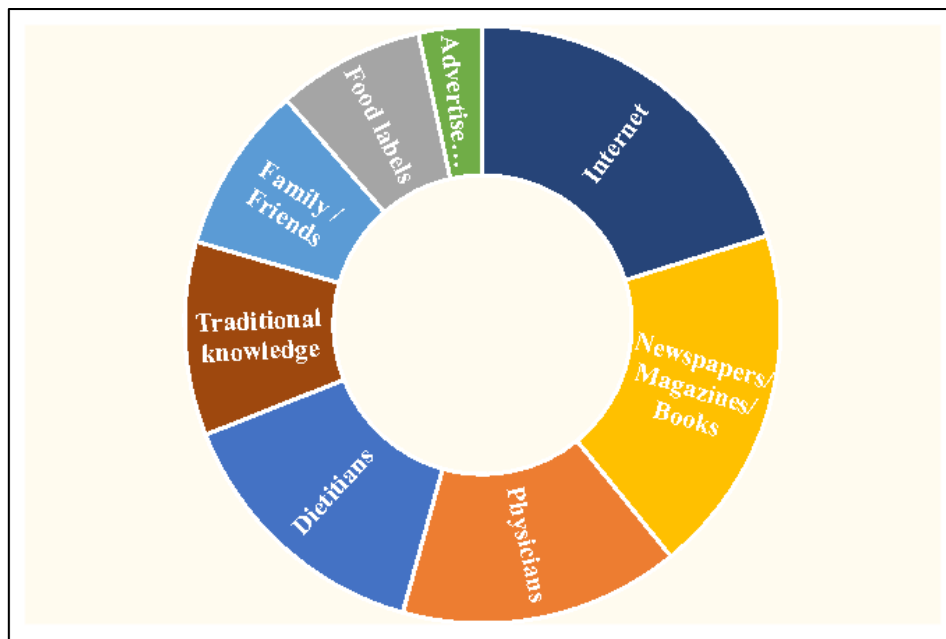
The study assessed participants' understanding of functional foods, including their definitions and key characteristics. It was found that 76% of the participants demonstrated familiarity with functional foods/nutraceuticals, while 24% indicated they lacked awareness of them.

Among the 400 respondents, 74 % described functional foods as those with specific benefits beyond their inherent nutrients. 13% of respondents characterized functional foods simply as healthy foods. 9 % admitted uncertainty about the best definition for functional foods. Additionally, 4% mistakenly identified functional foods as genetically modified, while 0.5% referred to them as artificial foods. The respondents' average knowledge score was  $2.22 \pm 1.10$  out of a maximum score of 3.

Consumers' knowledge significantly influences their food choices (Wardle et al., 2000) and acceptance of functional foods (Topolska et al., 2021). Safraid et al., (2024) found that in terms of consumption and awareness of functional foods, 61% of participants recognized the term "functional food," while 37% reported having moderate knowledge of their benefits in their research in Brazilian cities.

#### 4.1.2.2. Key Information Channels for Functional Foods

Figure 17 indicates how consumers access information on functional food.



**Figure 17: Information Channels about Functional Foods**

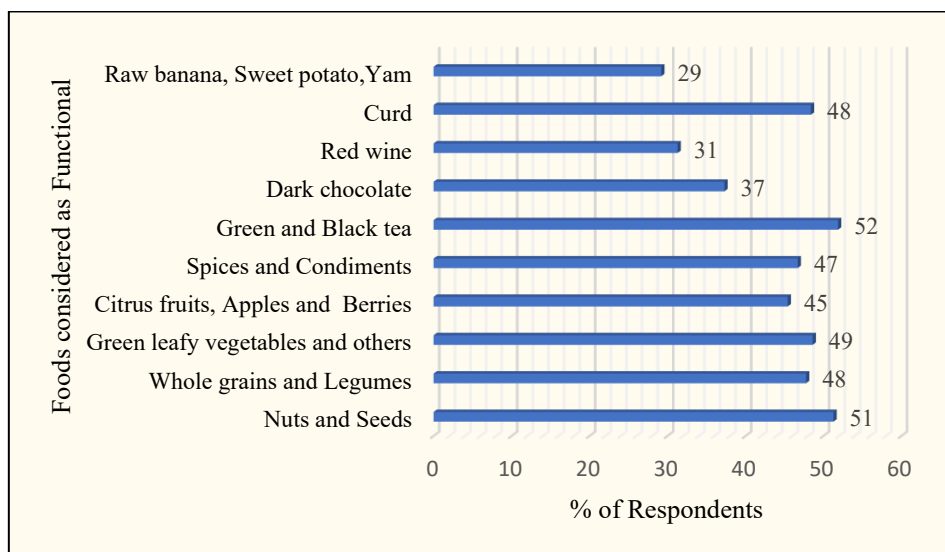
\*Respondents could choose multiple options

The Internet remains the main source of information for 42% of the respondents, followed by Newspapers, magazines, and books, chosen by 39.8 % of the respondents. 30.9 % of respondents got information on functional foods from dietitians.

According to a pioneer researcher of functional foods, Urala et al. (2003), nutrition and health information, as well as their origin, possess the capacity to shape the acceptance of functional foods by effectively conveying the wellness advantages.

#### 4.1.2.3. Ability to Recognize Functional Foods and Ingredients

Figure 18 represents the consumers' choices of functional food ingredients.



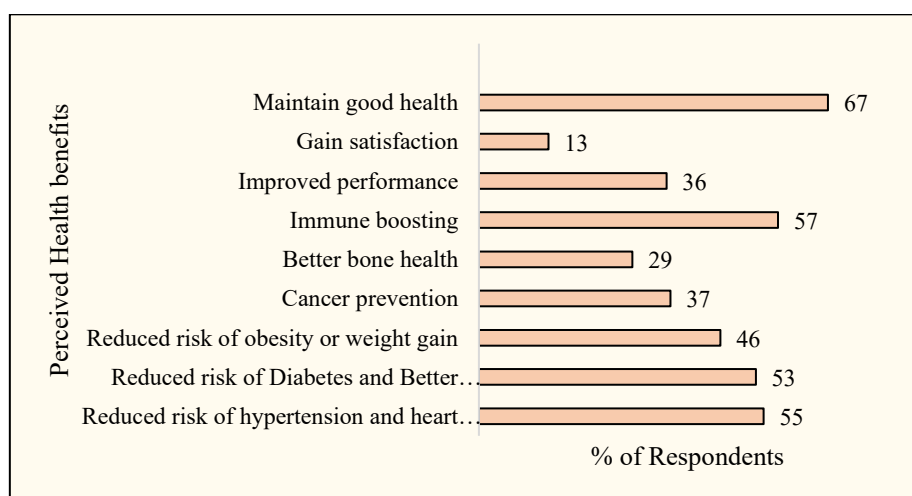
**Figure 18: Foods considered as Functional**

\*Respondents could choose multiple foods.

Although 74.4% of respondents successfully defined and explained functional foods, the overall recognition rate for foods classified as functional was 46.5%. Green tea and black tea were considered functional by 52% of the respondents. Spices, condiments, nuts, oil seeds, green leafy vegetables, and whole grains were recognized as functional on an average by 47% of the respondents. Only 29.2 % of the respondents considered raw banana and sweet potato as functional foods.

#### 4.1.2.4. Perceived Wellness Advantages of Functional Foods

Figure 19 represents the perceived wellness advantages of functional foods



**Figure 19: Perceived Benefits of Functional Foods.**

\* Multiple selections allowed

Participants were prompted to link functional foods with their associated health benefits. Among the respondents, 54.5% believed that functional foods could decrease the risk of hypertension and cardiovascular disease. A total of 212 respondents (53.1%) perceived functional foods as reducing the risk of diabetes. 66.9% of participants endorsed functional foods for maintaining good health, while 184 respondents favored their potential to reduce the risk of obesity or weight gain. Concerning cancer prevention, 36.8% of respondents attributed health benefits to functional foods, while 57.4% regarded them as immune-boosting. Finally, 16.5% of respondents expressed uncertainty regarding the benefits of functional foods.

According to Rezai et al. (2014), consumers who perceived benefits from functional foods exhibited higher acceptance of these functional food products.

#### **4.1.3. Respondents' Attitude towards Functional Foods Ingredients and RTE and RTC Foods**

A Mean Attitudinal Score of  $2.36 \pm 0.30$  was recorded on a three-point Likert scale. The attitude scores concerning functional foods are outlined in Table XXI

**Table XXI**

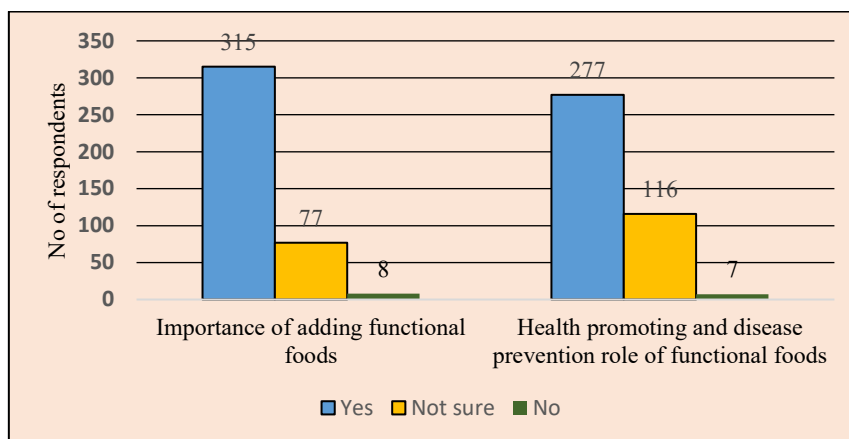
#### **Participants' Attitude towards Functional Ingredients in RTE and RTC Foods**

<b>Attitudinal Framework- 3-point Likert Scale</b>	<b>Positive Responses %</b>	<b>Mean Likert Score <math>\pm</math> SD</b>
Importance of functional foods in the daily diet	78.7	2.77 $\pm$ 0.47
Health-promoting and disease-prevention	68.9	2.68 $\pm$ 0.48
Preference for Functional ingredients in commonly consumed ready to eat foods	51.5	2.41 $\pm$ 0.65
Willingness to afford a higher cost	31.2	2.05 $\pm$ 0.76
Readiness to compromise on the taste	67.1	2.35 $\pm$ 0.94
Safety of functional foods and nutraceuticals	45.1	2.45 $\pm$ 0.50
Functional foods, if consumed in excess, can be harmful. #	14.2	1.83 $\pm$ 0.65

# Reverse coding

#### 4.1.3.1. Importance of Functional Foods in Diet

Figure 20 represents respondents' opinions on the daily inclusion of functional ingredients and foods in their diet and their role in health promotion and preventing disease.

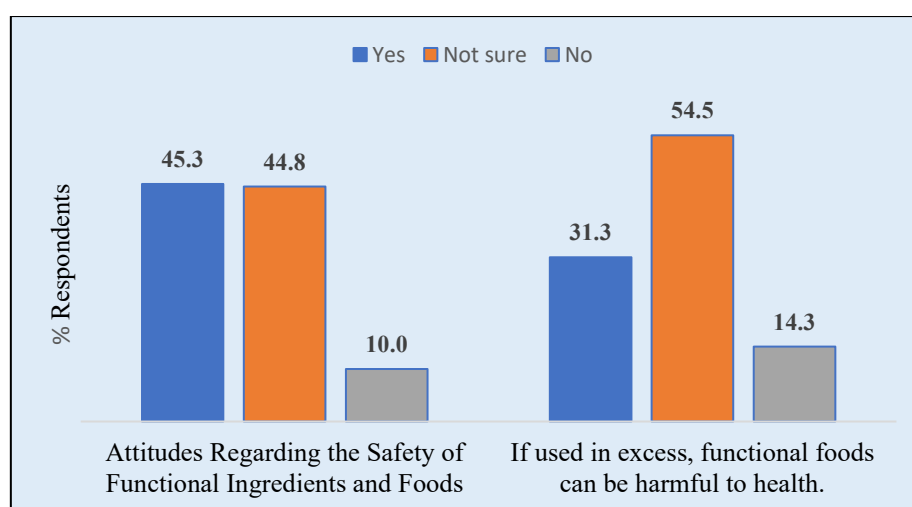


**Figure 20: Importance of Functional Foods in Diet**

Among the study population, 78.75% (315 respondents) expressed their positive affirmation of the significance of incorporating functional ingredients and foods into their diet, with a mean Likert score of  $2.77 \pm 0.47$ . Respondents showed a mean Likert score of  $2.68 \pm 0.48$  regarding their belief in functional foods promoting health and preventing disease. Specifically, 69% of participants held positive views, while 29% expressed uncertainty, and 1.75% rejected. According to Landström et al. (2009), individuals displaying heightened levels of health awareness tend to exhibit more favorable attitudes toward functional foods.

#### 4.1.3.2 Attitudes on the Safety of Functional Ingredients and Foods

Figure 21 represents attitudes on the reliability of functional ingredients and foods.

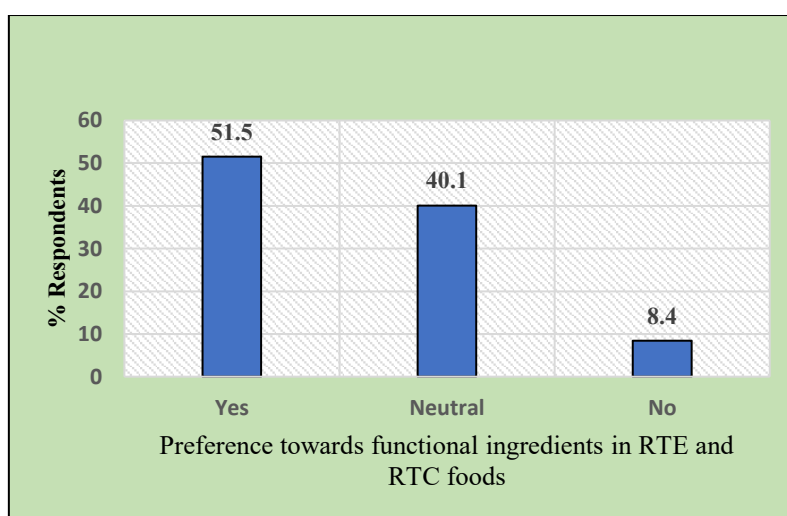


**Figure 21: Attitude on Safety of Functional Ingredients**

It can be difficult for consumers to confirm the precise and noticeable health benefits of functional meals during consumption. As a result, the level of consumer trust significantly impacts the adoption of functional foods (Miroso & Mangan-Walker, 2017). Regarding the critical aspect of safety concerning functional foods and nutraceuticals, 45.3% of the participants expressed confidence in their safety, while 44.86% remained neutral, and 10% conveyed a lack of confidence. Most participants (54.5%) indicated uncertainty regarding the potential deleterious effects of excessive consumption of functional foods or nutraceuticals. Specifically, 31.3 % believed excessive usage was harmful, while 14.3 % reported it as not harmful. The uncertainty and mixed perceptions likely stem from inadequate knowledge, poor labelling, creditability of information and inconsistent regulatory communication. Addressing these through education, transparent labelling, and regulatory oversight can help consumers make informed decisions.

#### 4.1.3.3. Inclination for the Inclusion of Functional Ingredients in RTE/ RTC Foods

Figure 22 represents the respondents' preference for incorporating functional ingredients in RTE/ RTC foods.

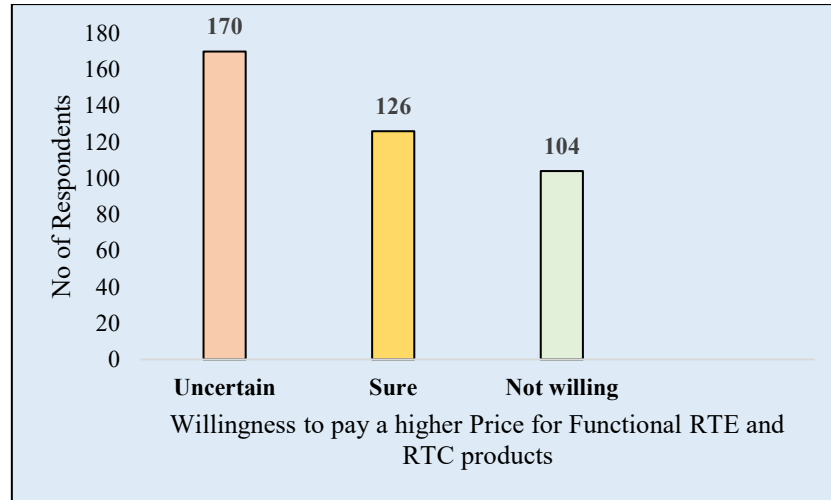


**Figure 22: Preference towards Functional Ingredients**

Developing new functional foods involves incorporating functional ingredients into a suitable food carrier (Granato et al., 2020). The choice of carriers and ingredients is a key element influencing consumers' attitudes and adoption of these products. (Huang et al., 2019). 51.5% of the respondents preferred functional ingredient incorporation in ready-to-eat and ready-to-cook foods. 40 % were neutral in their opinion. A Likert score of  $2.41 \pm 0.65$  was obtained.

#### 4.1.3.4. Attitudes Toward Paying a Premium Price

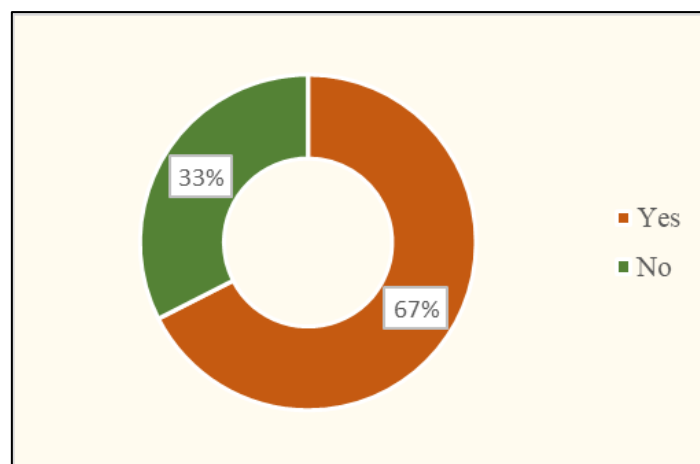
Figure 23 indicates the participants' readiness to pay a premium price for functional RTC and RTE foods



**Figure 23: Attitude to Pay a Premium Price**

Out of the total, 126 respondents (31.5%) expressed readiness to afford a higher cost, 170 respondents (42.5%) remained uncertain about their stance, and 104 respondents (26 %) asserted that they were unwilling to accept a higher price. The Likert score obtained was  $2.05 \pm 0.76$ . According to Pappalardo & Lusk (2016), consumers who prioritized their well-being were inclined to spend more for the health advantages linked to functional food consumption, but few studies have reported that consumers were receptive to only a marginally higher price. Ares et al. (2009) reported that higher prices reduced consumers' choice for functional yogurts. Karelakis et al. (2019) found that consumers were ready to pay 20% more for functional foods when they trusted their health enhancements.

#### 4.1.3.5. Attitude toward Taste Compromise

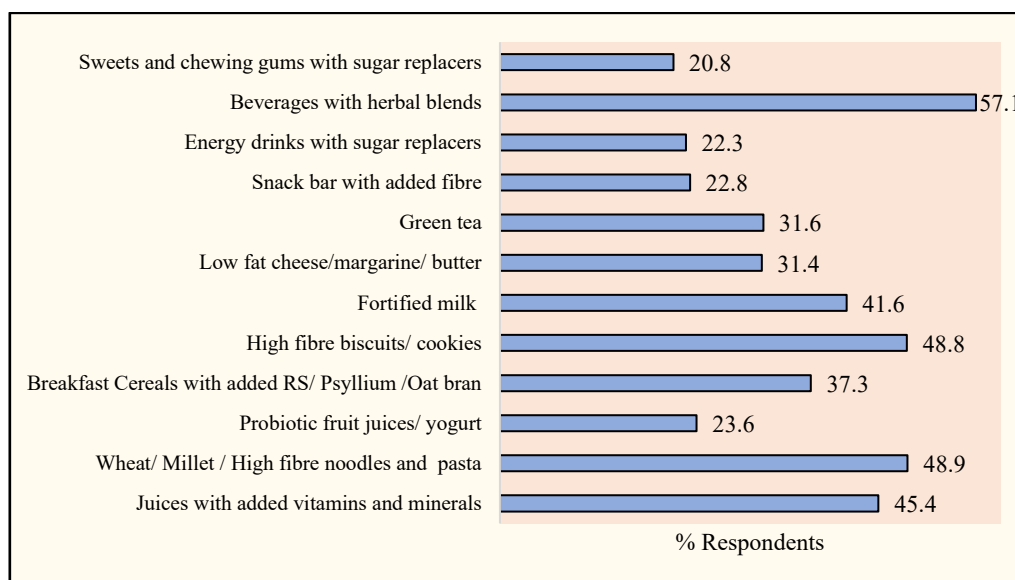


**Figure 24: Willingness to Compromise on Taste**

Figure 24 indicates the participants' readiness to sacrifice taste in functional RTC and RTE foods. Taste or anticipated taste significantly impacts consumers' choices regarding functional foods. Most respondents, accounting for 67%, indicated a willingness to accommodate the taste of functional foods, while 33% declined any compromise. The Likert score recorded was  $2.35 \pm 0.94$ . The impact of taste may outweigh the health benefits, as research has shown that individuals are often unwilling to sacrifice taste for wellness advantages (Temesi et al., 2019).

#### 4.14. Consumption Practice of Commercially Available Functional Foods and Nutraceuticals

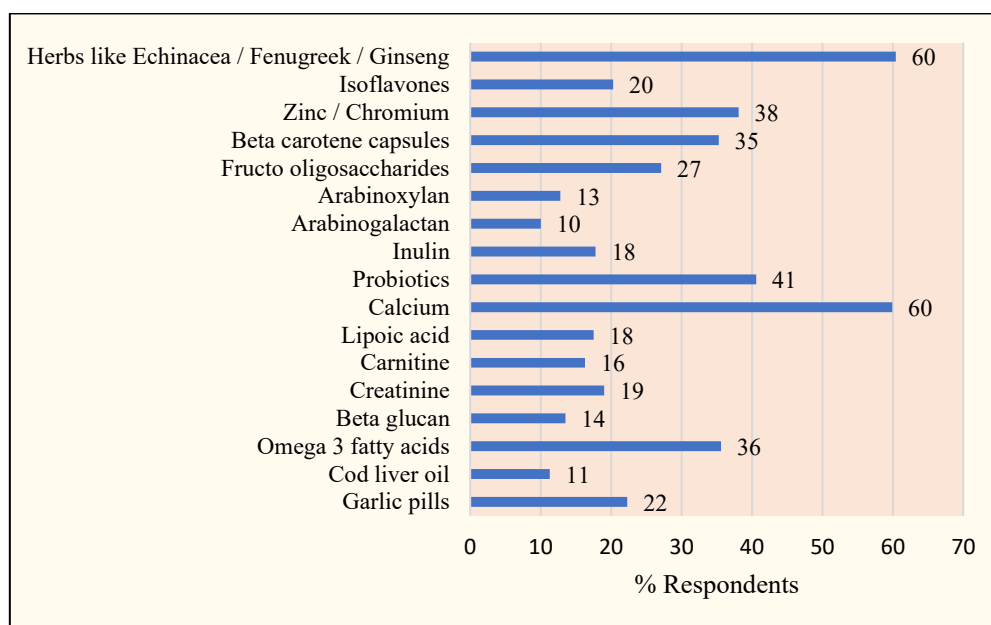
The consumption trend of commercial functional foods is given in Figure 25.



**Figure 25: Consumption of Functional Foods**

The increasing trend in the consumption of beverages with herbal blends was a very popular household practice during the prevailing COVID-19 period, and this is reflected in the study. High fiber noodles and pasta made with wheat and millets, high fiber cookies and biscuits, juices with added vitamins and minerals were consumed by the majority of the respondents.

Consumption patterns of nutraceuticals among participants over the seven days preceding their participation are given in Figure 26.



**Figure 26: Consumption of Nutraceuticals**

60% of respondents took calcium supplementation and herbs like Echinacea, Fenugreek and Ginseng. 41% consume probiotic supplements, while prebiotic products like inulin, fructo-oligosaccharides, and arabinoxylans have a lesser reach. This result signifies that consumers prefer functional foods rather than nutraceuticals. A mean score of  $0.94 \pm 0.65$  out of a maximum of 3 was obtained for the consumption practices of commercial functional foods and nutraceuticals in the market.

#### 4.1.5. Correlation of Knowledge, Attitude, and Practice

Any correlation in KAP is depicted in Table XXII.

**Table XXII**

#### Association of Knowledge, Attitude, and Consumption Practice

Spearman's Rank Correlation	p-value	r value	Strength of association
Knowledge vs Attitude	0.038	0.104	$r < 0.3$ None or very weak
Attitude vs Consumption/Practice	0.128	0.076	$r < 0.3$ None or very weak
Knowledge vs Consumption/Practice	0.225	0.061	$r < 0.3$ None or very weak

The Spearman's Rank Correlation R value indicates a very weak relationship between respondents' knowledge, attitude, and consumption trends.

Baker et al. (2022) examined eighteen studies investigating the link between consumers' knowledge levels and the willingness to adopt functional foods. 13 of these studies found strong associations between respondents' knowledge (covering areas like functional foods, nutrition, and familiarity) and their willingness to accept of such products. However, two studies identified significant negative association between nutritional knowledge and their frequency of purchasing functional foods. Meanwhile, three studies found no significant association between participants' subjective nutritional knowledge and the endorsement of health foods.

Sparke and Menrad (2009) emphasized that while a direct correlation between consumers' understanding of functional foods and their preference for it may not always exist, knowledge remains a critical factor influencing consumer acceptance.

Table XXIII depicts the association between KAP scores and education and age, and Table XXIV represents the association between consumption score and income and health factors.

**Table XXIII**  
**Association between KAP and Education/ Age**

<b>Variables</b>	<b><math>\chi^2</math> Chi-Square value</b>	<b>Df</b>	<b>p-value</b>
Knowledge vs Education	23.095	6	0.001*
Knowledge vs Age	9.486	9	0.394
Attitude vs Education	49.591	22	0.001*
Attitude vs Age	42.632	33	0.122
Consumption vs Education	58.766	54	0.305
Consumption vs Age	71.190	81	0.774

\*p<0.05 Significant

The Chi-Square test revealed a noteworthy correlation linking respondents' academic qualifications and KAP scores, but no significant association was observed concerning age.

In their research, Corso et al. (2018) reported that participants with higher levels of education demonstrated greater knowledge of the health benefits associated with consuming antioxidant-enriched coffee compared to younger participants with lower education levels. In a research study, educational attainment tended to influence participants' perceptions of

functional foods, with 53% of those having over 12 years of education expressing a favorable view (Safraid et al., 2024).

**Table XXIV**

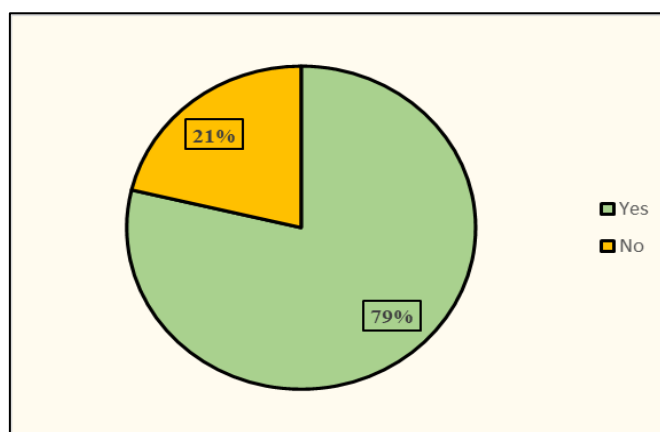
**Association between Consumption and Monthly Household Income/ Health Concerns**

Variables	$\chi^2$ Chi-Square value	Df	p-value
Consumption vs Income	85.250	81	0.352
Consumption vs reported health concerns-(diabetes, hypertension, cardiovascular problems, obesity, kidney disease, hypothyroidism)	1500.564	1701	1.000

The Pearson Chi-Square test revealed no significant correlation between participants' consumption scores and their income, nor between respondents or their family members experiencing common health issues. The non-significant association between consumption and income or health issues indicates that the use of functional foods and nutraceuticals is influenced more by awareness, perceived benefits, and attitudes than by economic status or immediate health needs

#### 4.1.6. Consumers' Choice of Functional Ingredient

The number of respondents reading health claims and nutrient labels is presented in Figure 27, and Figure 28 depicts Consumer preference for functional ingredients.

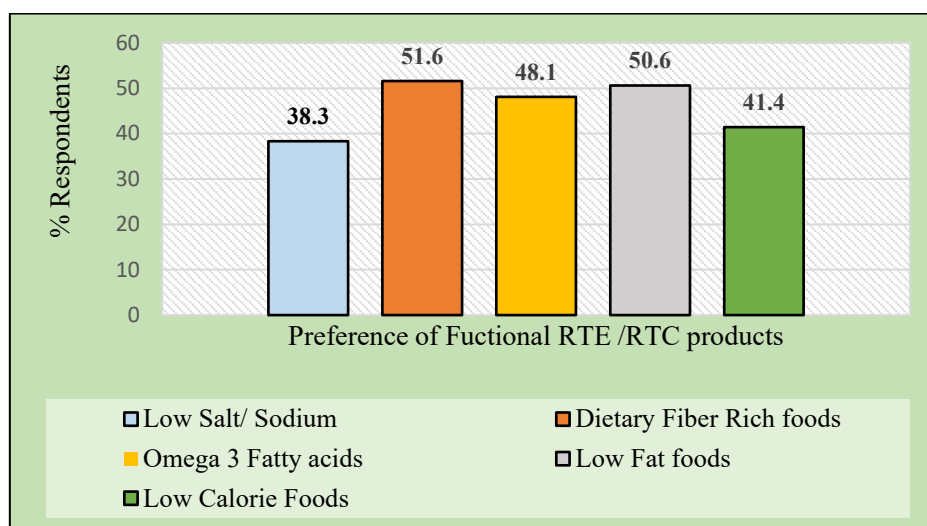


**Figure 27: Reading Health Claims and Nutrient Labels**

Numerous food products boast assertions regarding their health and nutritional benefits, a common practice within the food industry. Consequently, various nations have

implemented legal frameworks to govern health and nutrition claims associated with food, aiming to uphold their integrity and safety within the market (Steinhauser & Hamm, 2018).

79% of the respondents read health claims and nutritional labels, and 21% of the respondents answered negatively. A study found that providing health and wellness benefits can increase purchase intentions (González-Díaz et al.,2020).



**Figure 28: Respondents' Choices of Functional Ingredients**

Among the choices, 52 % opted for dietary fiber-rich foods, while 48% selected omega-3 fatty acids. Additionally, 42 % opted for low-calorie foods and 38% expressed a preference for low-salt or low-sodium foods. Krutulyte et al. (2010) stated that consumers tend to show greater acceptance of functional foods when they contain recognizable, well-known ingredients.

The current progress in the functional food sector emphasizes the optimization and enhancement of nutrients and bioactive compounds to maximize their health benefits. However, the successful application of functional food design necessitates the utilization of food by-products to adopt a sustainable and health-focused approach to developing new ingredients and formulations (Cena & Calder, 2020).

As most respondents expressed a preference for dietary fiber-rich and low-calorie foods and preferred functional ingredient incorporation in ready-to-eat and ready-to-cook foods, further investigation was directed towards developing bioactive-rich, high-fiber, and high-resistant starch RTE and RTC foods. Unripe banana flour was chosen as the functional ingredient by virtue of its resistant starch and rich bioactives presented in the literature.

## Phase 2: Physical Characteristics, Ripening Stage, and Unripe Banana Flours Preparation and Yield -*Musa paradisiaca*, Peyan and Monthan

### 4.2.1 Description of the Selected Cultivars

#### 4.2.1.1. *Musa paradisiaca*, Peyan (ABB)

The description of the fruit *Musa paradisiaca*, Peyan (ABB) is presented in Table XXV, and Plates 4-6 show the Peyan banana fruit.

**Table XXV**

**Description of *Musa paradisiaca*, Peyan (ABB)**

<b>Fruits</b>	<ul style="list-style-type: none"> <li>• Short with flat sides, distinct angled ridges</li> <li>• Broad base with a slightly tapered apex ending in a blunt beak</li> <li>• Pedicel is short</li> </ul>
<b>Skin</b>	<ul style="list-style-type: none"> <li>• Green in appearance with a subtle bloom</li> <li>• Transitions to a dull yellow hue when fully ripe</li> </ul>
<b>Peel</b>	<ul style="list-style-type: none"> <li>• Thick, leathery peel with a spongy, fibrous inner surface</li> </ul>
<b>Pulp</b>	<ul style="list-style-type: none"> <li>• Predominantly white</li> <li>• Distinctly visible core</li> </ul>
<b>Taste</b>	<ul style="list-style-type: none"> <li>• Distinct blend of mild sweetness and tanginess</li> <li>• Similar to the flavour of sapota fruits</li> </ul>
<b>Synonyms</b>	<ul style="list-style-type: none"> <li>• <i>Mada Vazhai, Pey Monthan, Pey Valai, and Peyan Mayil Vazhai</i></li> </ul>

(Venkataramani, 1946).



**Plate 4: *Musa paradisiaca*, Peyan (ABB)**



**Plate 5: *Musa paradisiaca*, Peyan (ABB)**



**Plate 6: *Musa paradisiaca*, Peyan (ABB)**

#### **4.2.1.2. *Musa paradisiaca*, Monthan (ABB)**

Monthan (ABB), a widely cultivated banana variety, is mainly valued as a cooking vegetable. The description of the fruit is presented in Table XXVI and depicted in plates 7-9.

**Table XXVI**  
**Description of *Musa paradisiaca*, Monthan (ABB)**

<b>Fruits</b>	<ul style="list-style-type: none"> <li>• Fruits are about 10 inches long and 6 inches in girth</li> <li>• Display a slight curvature, plump form, and an irregular five-sided shape with distinct angled ridges, and flat or slightly inflated sides</li> <li>• Feature a broad base that gradually narrows into a long, angled pedicel</li> <li>• Apex is broad with a noticeable knob-shaped beak</li> </ul>
<b>Skin</b>	<ul style="list-style-type: none"> <li>• Green, thick, and tough</li> <li>• Upon ripening, the skin turns a straw-yellow hue</li> </ul>
<b>Peel</b>	<ul style="list-style-type: none"> <li>• Thick, leathery peel with a spongy, fibrous inner surface</li> </ul>
<b>Pulp</b>	<ul style="list-style-type: none"> <li>• Firm and cream-colored, with a distinct core</li> </ul>
<b>Taste</b>	<ul style="list-style-type: none"> <li>• Mildly sweet with a pasty taste when fully ripe</li> </ul>
<b>Synonyms</b>	<ul style="list-style-type: none"> <li>• <i>Bontha, Kanch Kela, Bankel, Bantheesa, and Kalyanakai</i></li> </ul>

(Venkataramani, 1946).



**Plate 7: *Musa paradisiaca*, Monthan (ABB)**



**Plate 8: *Musa paradisiaca*, Monthan (ABB)**



**Plate 9: *Musa paradisiaca*, Monthan (ABB)**

#### 4.2.2. Physical Characteristics of the Fruit and Ripening Stage

Table XXVII presents the physical characteristics of the fruit, and Table XXVIII and Figure 29 depict the moisture content, total solids, and total soluble solids of the unripe fruits.

**Table XXVII**

##### Physical Characteristics of the Unripe Banana Fruit

Fruit Characteristics	Peyan	Monthan	p-value
Fruit length (cm)	12.16 ±1.01	18.75 ±0.45*	.00001
Fruit Circumference (cm)	12.68± 0.62	15.98 ±0.73*	.00001
Fruit wt. (g)	74.42 ±4.15	192.71±4.81*	.00001
Pulp wt. (g)	46.75±3.21	130.39±6.53*	.00001
Peel wt. (g)	27.68 ±2.57	62.31±3.35*	.00001
Pulp/ Peel ratio	1.70±0.24	2.10±0.19*	.00018

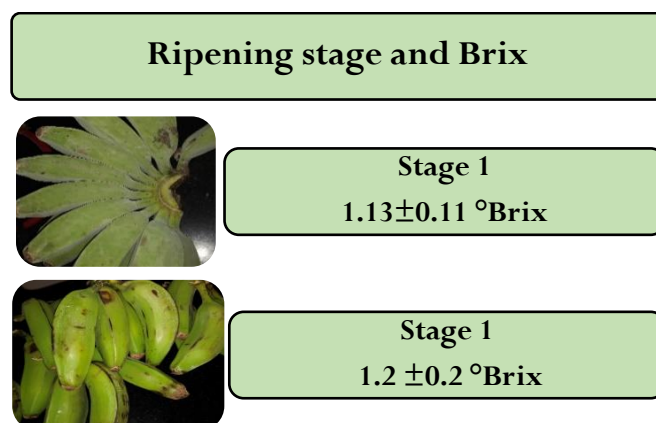
Data presented are the mean value of 12 measurements ± standard deviation (n = 12)  
\*t-test (Independent samples, two-tailed) p-value <0.05 significant

**Table XXVIII**

##### Moisture, Total Solids, and TSS in Unripe Banana Fruits

Parameters	Peyan	Monthan	p-value
Moisture Content (%)	69.56 ±1.48	76.80 ± 2.49*	.00001
Total Solids (%)	30.44 ±1.47	23.20±2.49*	.0023
Brix(°Brix)	1.13±0.11	1.2 ±0.2 <sup>NS</sup>	.6433

Data presented are mean value of triplicates ± standard deviation (n = 3)  
\*t-test (Independent samples, two-tailed) p-value <0.05 significant



**Figure 29: Ripening Stage of the Cultivars**

Fruit length and circumference varied across the cultivars. A significantly higher fruit length and circumference of  $18.75 \pm 0.45$  cm and  $15.98 \pm 0.73$  cm were recorded for Monthan, whereas Peyan fruit recorded  $12.16 \pm 1.01$  cm in length and  $12.68 \pm 0.62$  cm in circumference. A similar trend was observed in fruit, pulp, and peel weights. The average fruit weight was  $74.42 \pm 4.15$  g for Peyan and  $192.71 \pm 4.81$  g for Monthan. Peyan exhibited a thicker peel and comparatively a lower pulp-to-peel ratio of  $1.70 \pm 0.24$ . The pulp/ peel ratio of Monthan was  $2.10 \pm 0.19$ .

Aquino et al. (2017) reported that the flesh-to-peel ratio of unripe fruits varied between 1.18 and 2.26 across 15 different cultivars. In a research study, the fruit weight of  $145.1 \pm 15.4$  was recorded for Grand Naine and  $186.3 \pm 10.6$  for Monthan, and the pulp/ peel ratio of  $1.47 \pm 0.11$  and  $1.93 \pm 0.34$  was recorded for Grand Naine and Monthan, respectively (Kumar et al., 2019).

Understanding the moisture content of the raw material is crucial for estimating flour yield. The yield can be determined based on the initial moisture content of the raw material in its natural state and the target moisture content of the flour, as water removal during drying is the primary factor affecting yield (Acosta-Coello et al., 2021). Fresh unripe bananas (*Musa paradisiaca* cv Peyan and Monthan) had moisture contents of  $69.56 \pm 1.48$  and  $76.80 \pm 2.49$ , respectively.

The ripening stages of the fresh mature unripe bananas *Musa paradisiaca* cultivars Peyan and Monthan, expounded according to the scale of Von Loesecke (1950) were determined to be in stage 1, defined as totally green. The total soluble solids (TSS) of the unripe pulp were found to be 1.13 - 1.2 °Brix, reflecting low values typical of stage 1 ripening.

According to Campuzano et al. (2018), a TSS content of 1.2 - 2.1 °Brix validates the ripening stage 1 -completely green bananas. Alkarkhi et al. (2011) reported 1.03° Brix for green banana pulp.

#### **4.2.3. Flour Yield**

Table XXIX depicts the unripe banana flour yield from Peyan and Monthan cultivars.

**Table XXIX**  
**UBF Flour Yield**

Specifications	Peyan	Monthan
Number of Fruits(no.)	52	20
As Purchased Weight(g)	4224	4020
Peel weight(g)	1370	1125
Fresh Weight of pulp (g)	2552	3074
Weight of Dry flour(g)	763	716
Yield %	30.45	23.25



**Peyan Fruit Slices– Distinct ridges**



**Monthan Fruit – Irregular 5-sided**

**Plate 10: *Musa paradisiaca* Peyan and Monthan Fruit Slices**



**PUBF**

**MUBF**

**Plate 11: *Musa paradisiaca* Peyan and Monthan Flour**

According to Borges et al. (2019), pulp yield is an essential criterion for processing and fresh consumption. In flour production, maturation primarily influences starch breakdown into sugars and the overall flour yield. The yield is largely determined by factors such as the pulp/peel ratio, accumulation of dry matter, specific cultivar, and the material's moisture content (Cândido et al., 2023)

The banana flours had a creamy, pale-yellow hue. The flour recovery was 30.45 % for Peyan and 23.25 % for Monthan, indicating variation in processing efficiency between the two cultivars. The lower yield of MUBF can be due to greater moisture content in the Monthan fruit. Maximizing flour yield is significant for obtaining market value.

Flour recovery of 25-31% was documented for banana cultivars by Suntharalingam and Ravindran (1993). The flour recovery of UBF is comparable to sweet potato flour (26-28%) (Santi et al., 2022) and yam flour yield ( 20-30%) Setyawan et al., 2021), which are comparable sources of resistant starch.

### Phase 3: Starch Morphology, Characteristics, and Functional Properties of Unripe Banana Flours – PUBF and MUBF

#### 4.3.1 Starch Morphology and Characteristics- SEM Images, XRD pattern, and FTIR Spectra

Microstructural images of the unripe banana flours are shown in Figures 30-33.

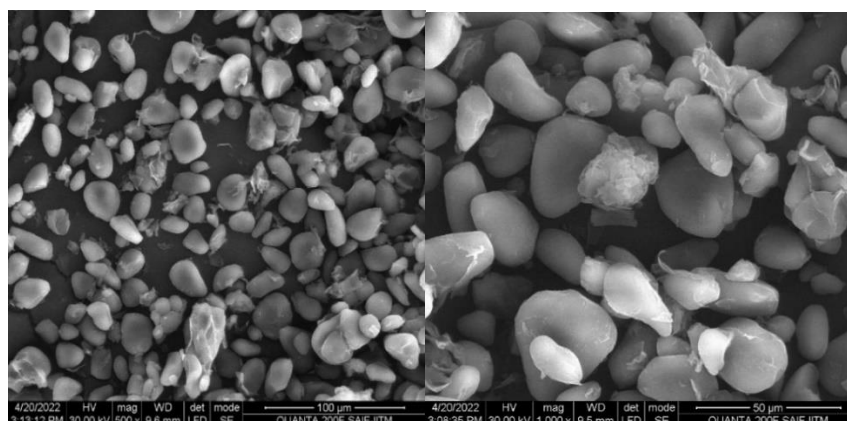


Figure 30: SEM images of PUBF (100 μm and 50 μm)

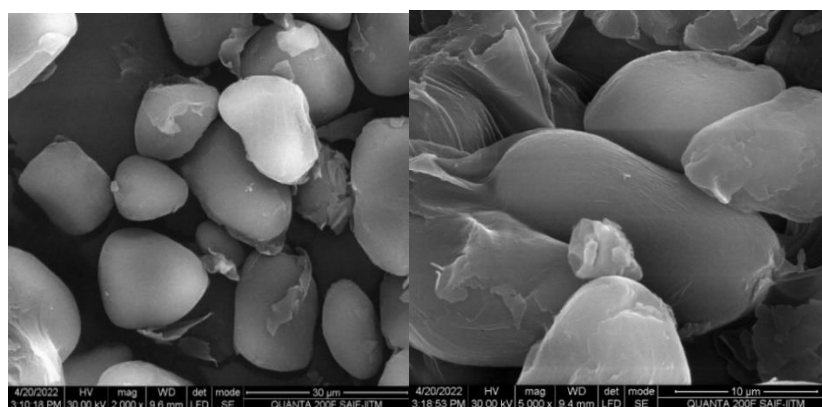


Figure 31: SEM images of PUBF (30 μm and 10 μm)

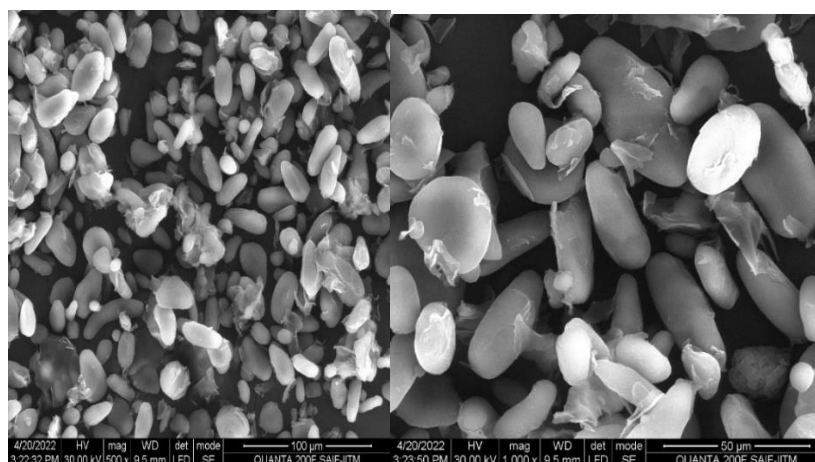
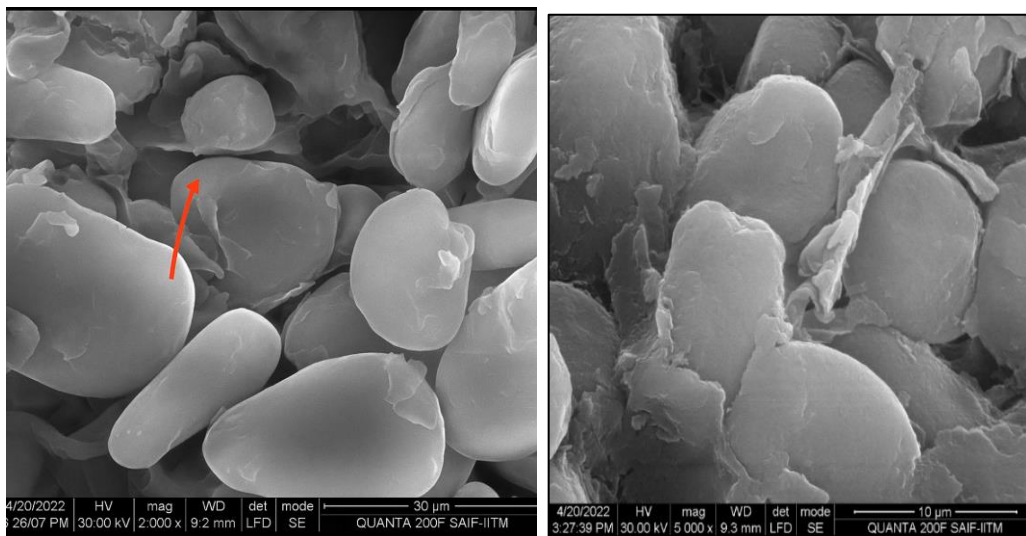


Figure 32: SEM images of MUBF (100 μm and 50 μm )



**Figure 33: SEM images of MUBF at 30  $\mu\text{m}$  and 10  $\mu\text{m}$  (Red arrow depicting fibers)**

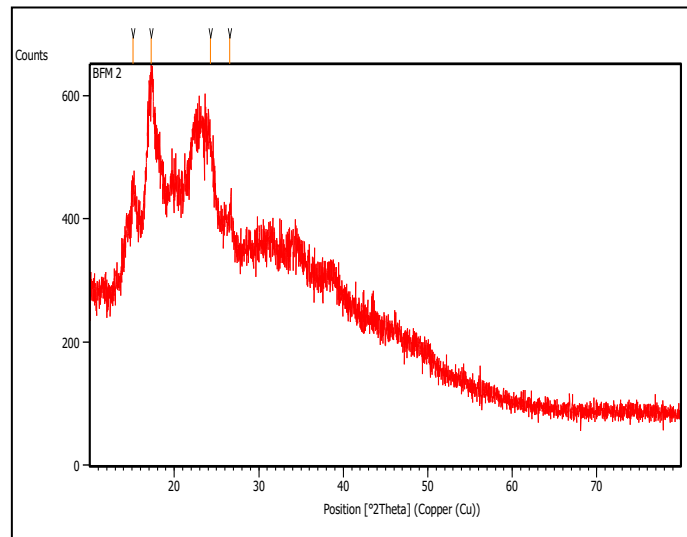
*Musa paradisiaca* Peyan flour exhibited a combination of irregularly shaped round, oval, spherical, and a few flattened or elongated granules. In contrast, the *Musa paradisiaca* Monthan flour predominantly showed elongated, oval-shaped granules with a few spheroid forms. The starch granules appeared intact without any fractures, indicating that the process used to obtain UBF did not cause drastic damage to the granule structure. The microstructure of the flour also exhibited varying degrees of fiber presence, and no parallel grooves were observed in the starch granules, indicating an unripe stage.

Reddy et al. (2015) reported granule shapes as irregularly ovoid with uniform surfaces for Karpuravalli, medium rod-like and irregularly ovoid for Poovan, and elongated cylinder-like with even surfaces for Sevvazhai. According to researchers, the starch biomorphs of unripe bananas exhibit an even surface, whereas those of ripened display parallel grooves (De Barros Mesquita et al., 2016). Starch digestion dynamics are strongly linked to its structural characteristics. Smaller, rough granules digest more quickly than larger, smooth ones, providing a greater surface area for enzyme action. Compared to intact granules, damaged starches exhibit higher enzyme susceptibility due to increased cold-water solubility and an expanded surface area available for hydrolysis (Ouyang et al., 2021).

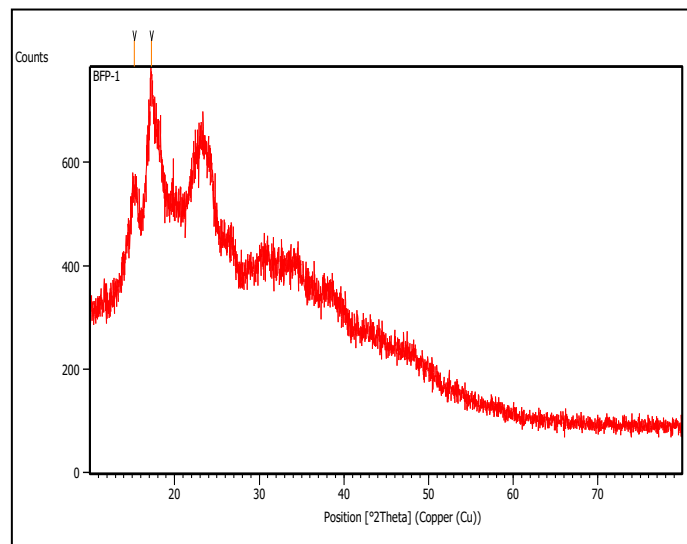
The presence of fibers is indicated by the delicate, sheet-like forms surrounding the starch granules (Padhi and Dwivedi, 2022), and the fibers in the starch matrix exhibit a negative correlation with the digestibility of starch (Ajala et al., 2022). Pandey et al. (2020) suggested that the material observed on the granule surface is likely the amyloplast

membranes that encapsulate the starch granules within banana fruit cells. Haralampu et al. (2000) reported that starch characteristics impact thermal properties, rheological properties, and hydration capacity.

Figures 34 and 35 present the XRD pattern of *Musa paradisiaca* Peyan and Monthan flour.



**Figure 34: X-ray Diffraction Patterns of PUBF**



**Figure 35: X-ray Diffraction Patterns of MUBF**

The presence of crystalline reflections at specific  $2\theta$  angles was observed in the Peyan and Monthan flour X-ray diffraction spectra. For PUBF, the recorded peaks were at  $2\theta$  angles of  $15.22^\circ$  and  $17.24^\circ$ . MUBF exhibited prominent reflections at  $2\theta$  angles of  $15.12^\circ$ ,  $17.25^\circ$ ,

24.28°, and 26.52°. The highest peak for both flours appeared at 17.24° - 17.25°, followed by a peak at 15.22° - 15.12.

As described by Ouyang et al. (2021), the XRD patterns of type A exhibit pronounced crystalline reflections around 15° and 23°, and this pattern displays less well-defined peaks at about 17° and 18°. In contrast, type B XRD features prominent peaks at 17°, accompanied by smaller peaks at around 15°, 20°, 22°, and 24°. Type B patterns also exhibit prominent intensities at 5.6°. Type C patterns demonstrate a combination of characteristics observed in types A and B. Characteristics of the type C XRD pattern showcase prominent intensities at approximately 17° and 23°, along with smaller peaks close to 5.6° and 15°.

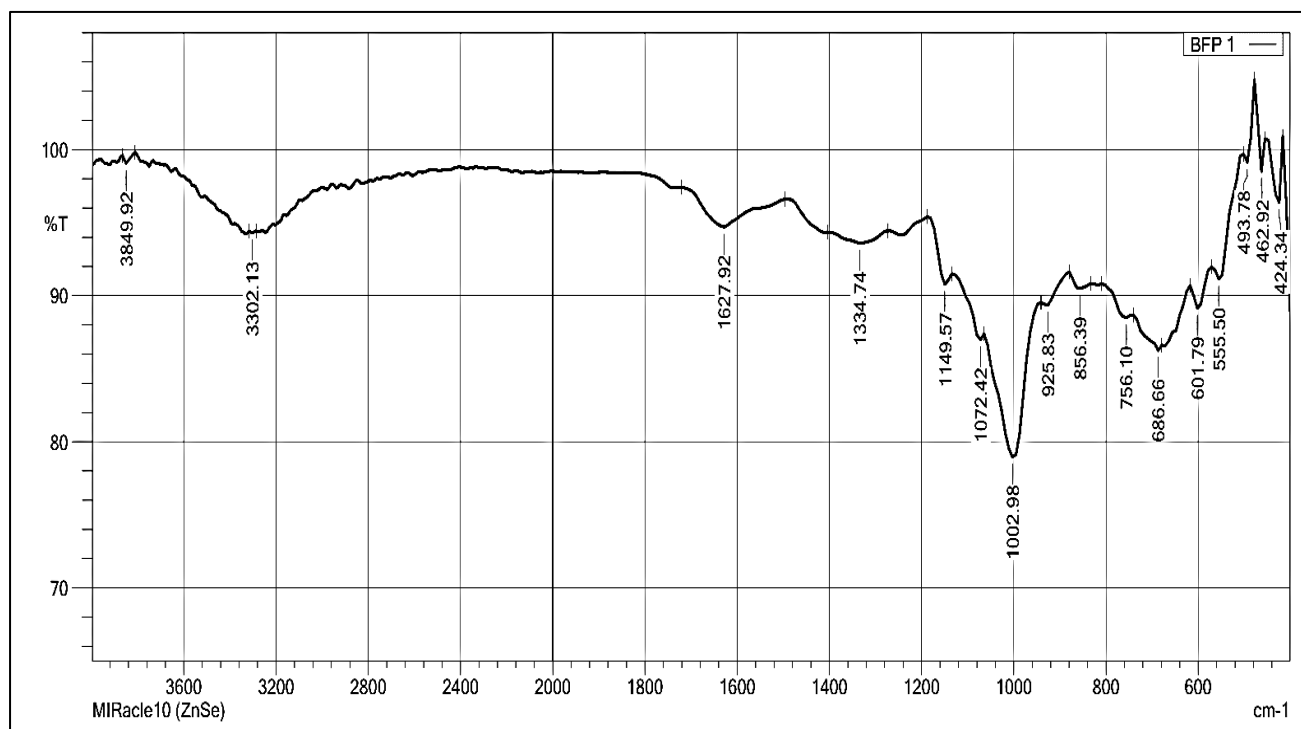
From the diffraction patterns depicted in Figures 34-35, it is evident that both Peyan and Monthan flours possess type B crystallinity. PUBF exhibited a relative crystallinity percentage of 8.91%, while MUBF had a relative crystallinity percentage of 13.06%.

In a study by Thanyapanich et al. (2021), starch from unripe bananas of Hom Khieo (AAA) and Namwa (ABB) showed a B-type crystalline structure, and the researchers report that the crystallinity pattern is influenced by the growing conditions of the plant, as well as the chemical composition of the flour.

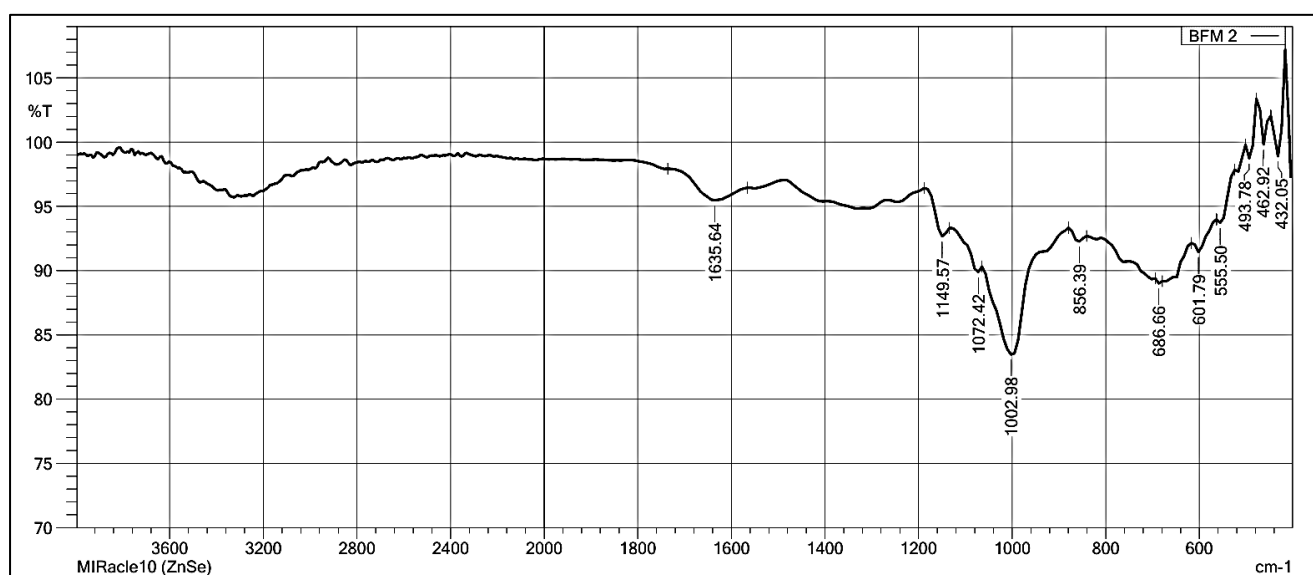
A range of crystallinity percentages between 9.38% and 12.22% was documented for unripe banana flours of different varieties (Kumar et al., 2019). Padhi and Dwivedi (2022) reported a relative crystallinity of 8.73% for UBF. The crystalline regions of starch exhibit greater resistance to enzymatic breakdown compared to amorphous zones, as their supramolecular structure is less susceptible to enzyme action. Differences in enzyme action are observed across starches with varying crystalline structures. A-type starch, which has surface pores (0.1–0.3 µm in diameter), facilitates a faster digestion rate than B-type starch, using a combination of 'inside-out' and 'side-by-side' digestion mechanisms. ( Li et al., 2020).

The current study aligns with the aforementioned results and the research of Liang et al. (2024), documenting that banana starches with a B-type diffraction pattern exhibit lower susceptibility to enzymatic degradation.

Figures 36 and 37 depict the FTIR spectra of the unripe banana flours- PUBF and MUBF.



**Figure 36: FTIR Spectra of PUBF**



**Figure 37: FTIR Spectra of MUBF**

The band observed at 3600- 3200  $\text{cm}^{-1}$  in the infrared spectrum of unripe banana flours indicates the stretching vibrations of O–H bonds, confirming the existence of hydroxyl groups. Nandiyanto et al. (2019) stated that a wide absorption region spanning 3650 and 3250  $\text{cm}^{-1}$  indicates a hydrogen bridging and affirms the occurrence of hydrate, hydroxyl, ammonium, or amino group. For a hydroxyl compound, it should be followed by the presence

of spectra at frequencies of 1600–1300, 1200–1000, and 800–600  $\text{cm}^{-1}$ . According to Wang et al., (2014), the wide band around 3300 and 3400  $\text{cm}^{-1}$ , which corresponds to the stretching of hydrogen-bonded O–H groups, serves as strong evidence for the presence of phenolics.

A broadband was observed around 1334  $\text{cm}^{-1}$ . Padhi and Dwivedi (2022) reported that the band at 1334  $\text{cm}^{-1}$  represents O-H bending and C-N stretching groups, confirming the presence of phenolic compounds in unripe green banana flour. The band detected at 1627  $\text{cm}^{-1}$  for PUBF and 1635  $\text{cm}^{-1}$  for MUBF signifies C=C stretching (Nandiyanto et al., 2019). Both cultivars displayed a peak at 1002  $\text{cm}^{-1}$ , attributed to the vibration of carbonyl bonds, which are responsible for bananas' characteristic flavor and aroma compounds (Khoza et al., 2021).

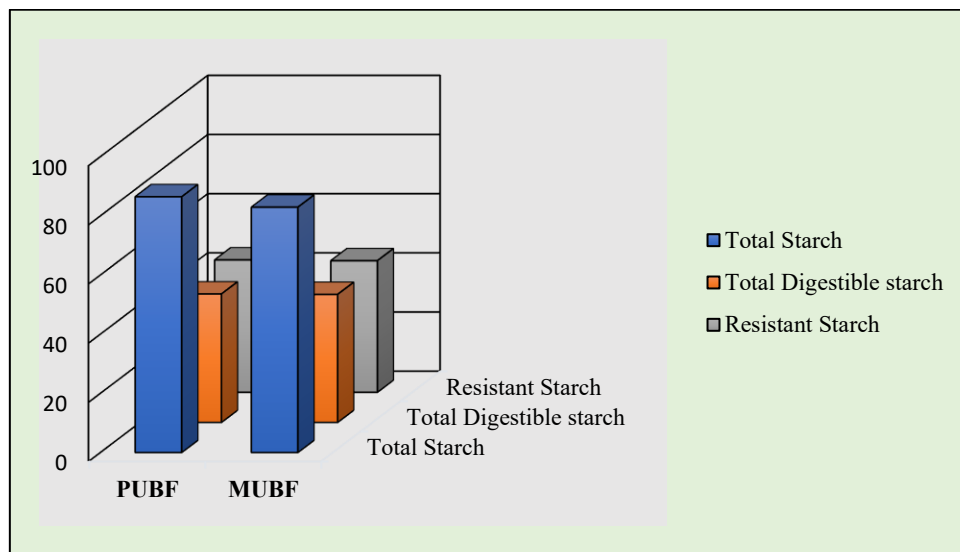
#### 4.3.2. Starch Fractions- Total Starch, Resistant Starch, Amylose, and Amylopectin

The starch composition of UBFs is depicted in Table XXX and Figures 38 and 39.

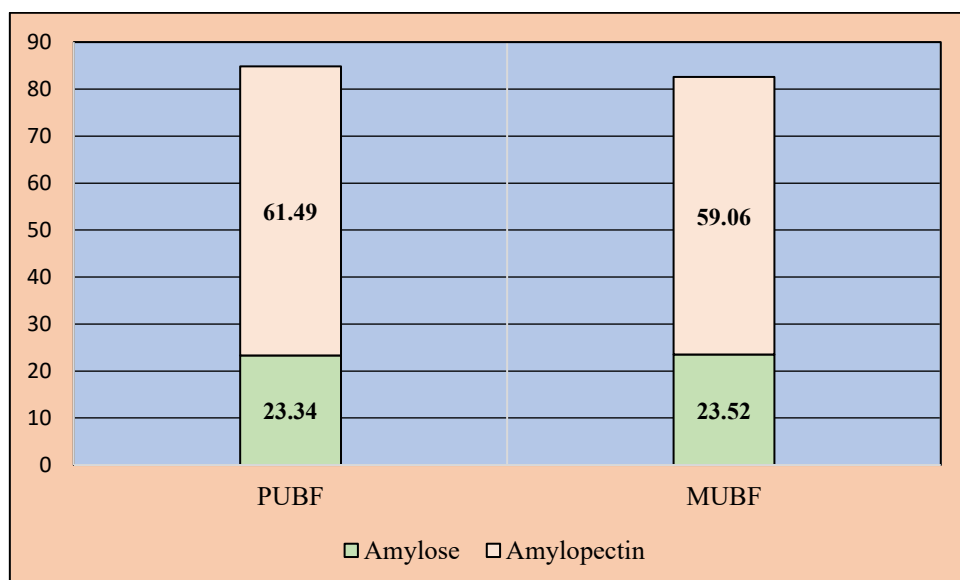
**Table XXX**  
**Starch Composition of PUBF and MUBF**

Starch Fractions (g/ 100g on d.w)	PUBF	MUBF	p-value
<b>Total Starch</b>	86.47±3.05	82.94±3.05 <sup>NS</sup>	.2302
<b>Amylose</b>	23.34±0.77	23.52±0.64 <sup>NS</sup>	.731762
<b>Amylopectin</b>	61.49±2.37	59.06±1.35 <sup>NS</sup>	.134059
<b>Total Digestible Starch</b>	43.42±0.37	43.27±0.18 <sup>NS</sup>	.698489
<b>Resistant Starch</b>	44.75±1.24	44.47±0.87 <sup>NS</sup>	.822862

Data presented are mean value of triplicates ± standard deviation (n = 3), \*t-test (Independent samples, two-tailed) p-value <0.05 significant



**Figure 38: Starch Fractions of PUBF and MUBF**



**Figure 39: Amylose and Amylopectin content of UBF**

The total starch content of *Musa paradisiaca* Peyan and Monthan was found to be  $86.47 \pm 3.05\%$  and  $82.94 \pm 3.05\%$ , respectively. Both varieties exhibited an amylose content of 23%, with Peyan flour having a higher amylopectin content of  $61.49 \pm 2.37\text{g}/100\text{g}$  dry weight.

Starch content ranging from 81% to 93% has been reported for unripe fruits of hybrid plantain cultivars (Khoza et al., 2021). An amylose content of 24% has been reported for the Monthan and Karpuravalli cultivars, while Saba and Nendran cultivars showed significantly higher amylose content of 35-36% (Kumar et al., 2019).

The ratio of amylose and amylopectin in UBF affects gelatinization, gelation, and retrogradation characteristics. Amylose content determines the amorphous regions in starch and is positively associated with resistant starch (RS) content (Cornejo-Ramírez et al., 2018).

Both cultivars exhibited 44% RS content and 43% digestible starch. The similar characteristics observed in both cultivars could be attributed to their belonging to the same genome ABB.

Resistant starch (RS) has been linked to various health advantages, including a reduced glycemic response, increased satiety, and a potential prebiotic effect (Bojarczuk et al., 2022). Li et al. (2020) reported an RS content of 42.33 % for unripe banana Pei Chiao. Pelissari et al. (2012) recorded an RS content of 49.5% and an amylose value of 23% for the Terra Plantain variety. Zheng et al. (2016) found that sweet potato flour has 5 % RS. Fabbri et al. (2016) reported a 2 % resistant starch in lyophilized, cooked legumes. Compared to other sources, UBF had presented a higher RS content. Unripe banana flour, with its high RS content, can be valued for functional food applications.

#### 4.3.3. Thermal Properties

The gelatinization characteristics are summarized in Table XXXI and Figures 40-41.

**Table XXXI**  
**Gelatinization Characteristics of Banana Flours**

Flour/ Parameters	PUBF	MUBF
To °C	30.44	31.37
Tp °C	85.60	88.37
Tc °C	162.44	161.37
ΔT °C	132.0	130.03
ΔH(J/g)	210.8	253.5

To: onset temperature, Tp: peak temperature, Tc: completion temperature

ΔT: gelatinization temperature range ( $T_c - T_o$ ), ΔH: gelatinization enthalpy

The thermal gelatinization range of UBF was 85.6 to 88.37 °C. Monthan flour exhibited a higher gelatinization temperature of 88.37 °C, accompanied by an enthalpy of gelatinization of 253.5 J/g. Peyan flour displayed a lower ΔH value of 210.8 J/g.

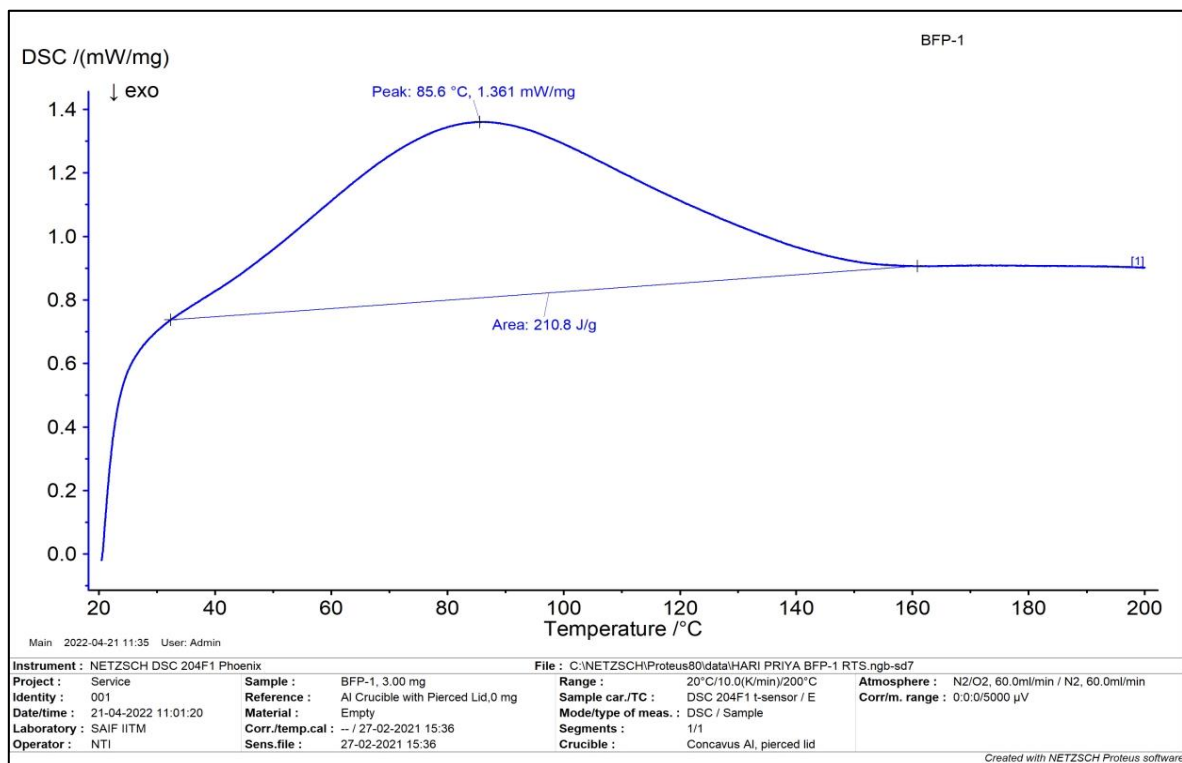


Figure 40: Differential Thermogram of PUBF

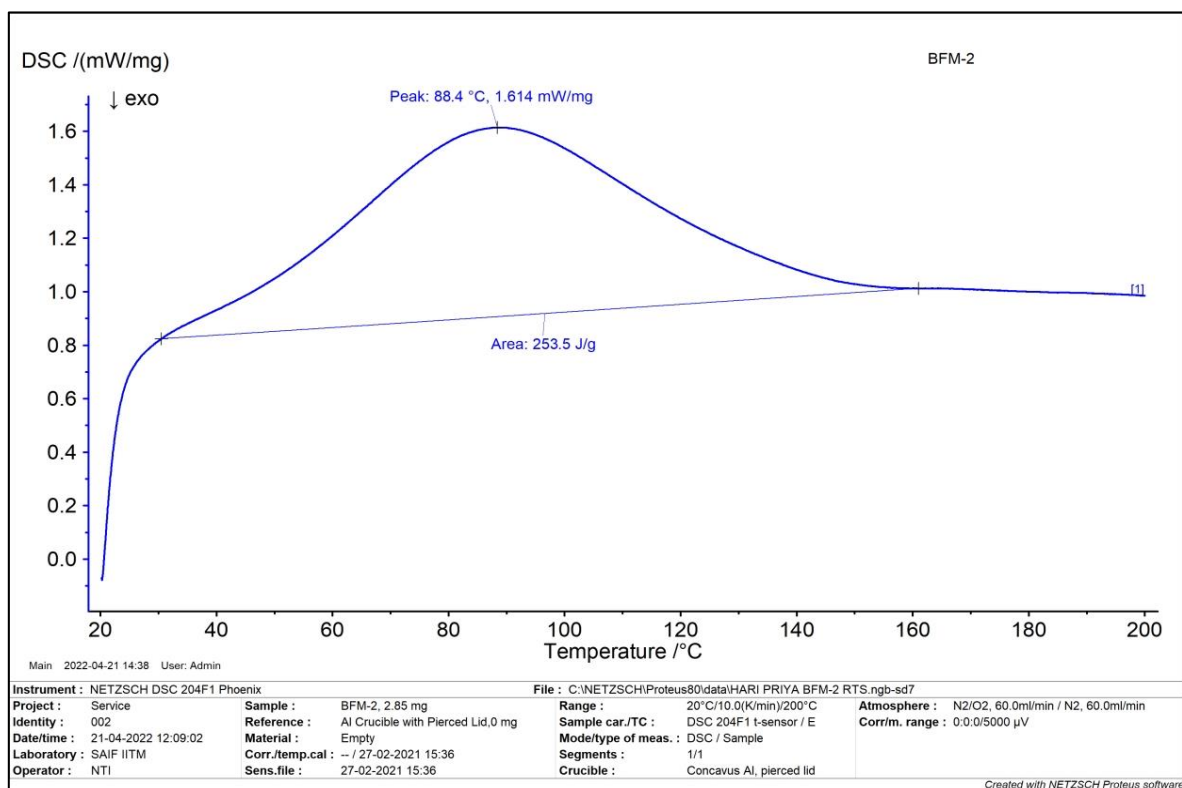


Figure 41: Differential Thermogram of MUBF

The lower  $\Delta H$  value for Peyan can be due to variations in crystal stability linked to starch granule size. The proteins and fibers in the UBF may impede water penetration into the

granules, contributing to the higher gelatinization temperature (Padhi and Dwivedi, 2022). Previous research has also highlighted the influence of starch morphology, starch fractions, crystallinity, and mineral content on the starch gelatinization characteristics. (Cornejo-Ramírez et al., 2018, Das et al., 2022)

Gelatinization temperature in the range of 77.49 to 79.99°C was reported for different varieties of unripe bananas, namely Saba, Mas, and Berangan (Mamat et al., 2021). In a research study, Monthan flour had a higher gelatinization temperature of 111°C, and the researchers appreciate this characteristic that renders unripe banana flour potentially beneficial in products requiring delayed pasting (Kumar et al., 2019).

#### 4.3.4. Physicochemical Properties

Table XXXII depicts the physicochemical properties of Unripe Banana flour.

**Table XXXII**  
**Physicochemical properties of Unripe Banana flour**

Physicochemical properties	PUBF	MUBF	<i>p</i> Value
Bulk Density (g/ cc)	0.69 ±0.01	0.68±0.01 <sup>NS</sup>	.671242
Tapped Density (g/ cc)	0.71±0.01	0.70±0.01 <sup>NS</sup>	.370414
Carr Index %	3.17±0.71	2.74±0.03 <sup>NS</sup>	.355687
Hausner ratio	1.03±0.00	1.02±0.01 <sup>NS</sup>	.355914
Foaming capacity (%)	0.73±0.12	0.67±0.12 <sup>NS</sup>	.518519
Emulsion Activity (%)	6.45±0.97	8.15±1.35 <sup>NS</sup>	.151714
Emulsion Stability (%)	0	0	-
Oil absorption capacity (g/g)	1.71±0.02	1.75±0.02 <sup>NS</sup>	.113523
Swelling volume ml/g	3.49 ±0.21	6.20± 0.87*	.006426

Data presented are the mean ± standard deviation (n = 3) \**p* value<0.05 significant independent t-test (two tailed)

##### 4.3.4.1. Density and Flowability Parameters

The bulk density of unripe banana flours was recorded as 0.68 - 0.69 g/ cc., and the tapped density of the UBFs was 0.70-0.71g/cm<sup>3</sup>.

Anajekwu et al. (2020) reported a bulk density range of 0.72 to 0.77 g/cc for green banana flour samples. The desired bulk density of unripe banana flour can vary depending on the intended application. Higher bulk density offers packaging advantages (Thakur et al., 2016); a lower value is advantageous for formulating weaning and health foods.

The flowability and cohesiveness of the flour can be defined by the Carr Index and Hausner Ratio, respectively. A higher Carr Index indicates poor flowability and high compressibility. A Hausner Ratio between 1.00 and 1.11 denotes excellent flowability, while values from 1.12 to 1.18 indicate good flowability. The Carr Index of PUBF was  $3.17 \pm 0.71\%$ , while MUBF showed  $2.74 \pm 0.03\%$ . The Hausner Ratio for both flours ranged from 1.02 to 1.03. Based on the compressibility index and Hausner Ratio, PUBF and MUBF fall under the "excellent" or "very free-flowing" category.

According to Alam et al. (2023), the tapped density of UBF prepared using various drying methods ranged from  $0.62 \pm 0.04$  to  $0.93 \pm 0.03$  g/mL. The treated flours had a Hausner Ratio range of 1.13 to 1.16, defining good flowability.

#### **4.3.4.2. Foamability and Emulsification Properties**

The foamability of the flours was observed to range from 0.67% to 0.73%. Unripe banana flour recorded a poor foaming capacity. Qadir and Wani (2023) observed no foam formation in Zhag rice flour, attributing it to the elevated levels of amphiphilic lipids, which inhibited protein binding at the interface.

Peyan and Monthan cultivars UBF exhibited emulsion activity of  $6.45 \pm 0.97\%$  and  $8.15 \pm 1.35\%$ , respectively. The emulsion stability test resulted in a negative result. The emulsion activity values of UBFs indicate a limited ability to form emulsions, likely due to native proteins and surface-active polysaccharides. However, the negative stability result shows that these emulsions rapidly separated, making UBFs unsuitable as primary emulsifiers in products such as dressings or beverages. They may still function as supplementary ingredients to enhance volume or contribute fiber and viscosity, with improved applicability achievable through blending with hydrocolloids.

Mamat et al. (2021) recorded emulsion activity of UBFs from three cultivars—Saba (BBB), Mas (AA), and Berangan (AAA)—varying between 2.08% and 17.36%. The Mas cultivar demonstrated the highest emulsion activity, whereas the Berangan cultivar had the lowest. In a research study, an emulsion capacity of 9.52% was observed in brown Zhag rice flour and 2.32 % in polished K-39 rice flour. Additionally, they recorded low emulsion stability of the flour and attributed that to its insufficient protein content, which was inadequate for providing the necessary repulsive forces to maintain emulsion stability (Qadir and Wani, 2023).

The emulsion activity of UBFs was relatively low compared to values reported for other starchy flours (Chandra et al., 2014).

#### 4.3.4.3. Oil Absorption Capacity

OAC in unripe banana flours was 1.71 - 1.75 g/g. An oil absorption capacity of 1.16 to 1.22 g/g was reported for banana starch (Thanyapanich et al., 2021). OAC of flour helps retain flavour and improves mouthfeel when used in food preparation. There was no significant difference in the functional properties among the selected cultivars.

#### 4.3.5. Flour Hydration Properties and Flour Gelling Properties

##### 4.3.5.1. Flour Hydration Properties

Figures 42 and 43 depict the flour hydration properties of UBFs at temperatures 70-90 °C.

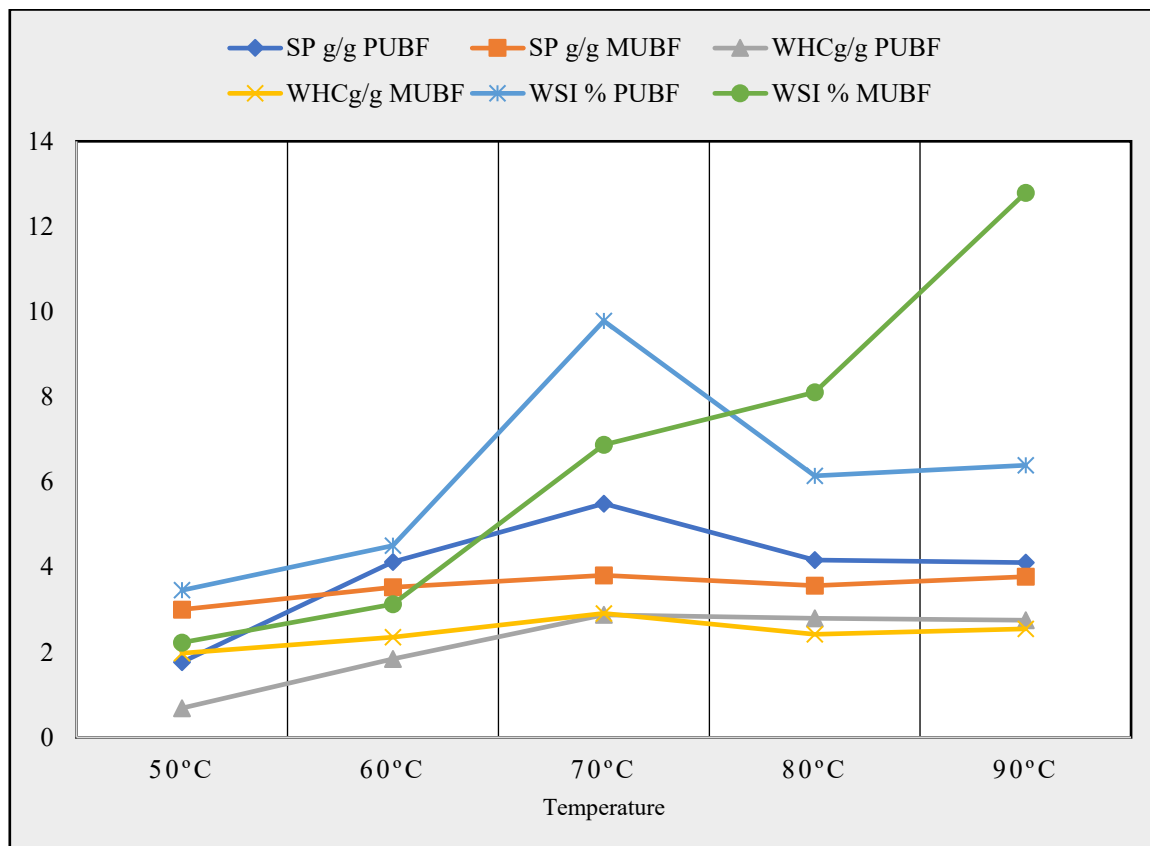
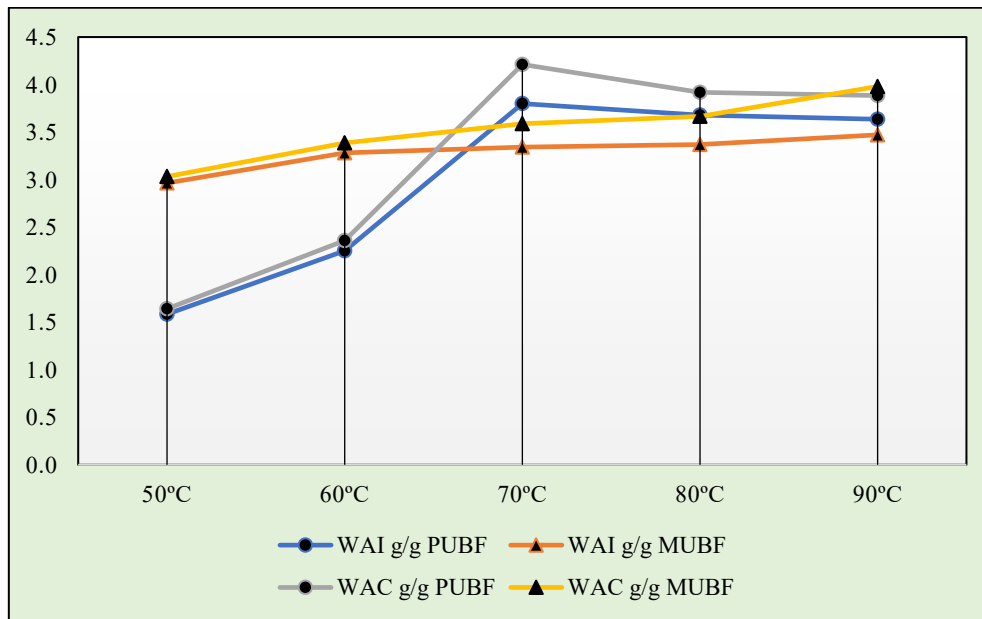


Figure 42: Flour Hydration properties of UBFs



**Figure 43: Water Absorption Index and Water Absorption Capacity of UBFs**

#### 4.3.5.1.1. Water Holding Capacity (WHC)

WHC measures the water retention without external pressure (Cornejo, 2015). WHC of unripe banana flours increased with an increase in temperature from 50 °C to 90 °C and ranged from 4 to 4.31 g/g. WHC of 6.66 g/g was observed for green banana flour (Cavendish, AAA) in stages 1 and 2 of ripening (Campuzano et al., 2018).

#### 4.3.5.1.2. Water Absorption Capacity (WAC) and Water Absorption Index (WAI)

WAC quantifies the volume starch granules occupy upon expansion in surplus water (Khoozani et al., 2019). The WAC of Peyan flour was maximum at 4.21 g/g at 70°C, while MUBF recorded a WAC of 3.98 g/g at 90°C. These values reflect the starch granules' capacity to absorb water and hydrate at different temperatures.

The water absorption index (WAI) is another parameter employed to evaluate the WAC of flour. A linear increasing trend in WAI was observed from 50°C to 90°C for MUBF. At 90°C, PUBF and MUBF had a WAI of 3.63 g/g and 3.47 g/g, respectively. PUBF had the peak hydration of 3.99 g/g at 70°C.

Savlak et al. (2016) reported a WAI range of 2.92-4.60 g/g dw for unripe banana flour of the Dwarf Cavendish' banana (*Musa* spp. AAA). Campuzano et al. (2018) reported a WAI in the range of 3.39-3.52 g/g dw for green banana flour (Cavendish, AAA) in stages 1 and 2 of ripening.

#### **4.3.5.1.3. Water Solubility Index**

A lower water solubility index was observed at low temperatures, and an increasing trend was recorded with increasing temperatures. Peyan flour had a higher WSI of 9.78% at 70°C, while Monthan flour had a WSI of 12.7% at 90°C. WSI in the range of 5.58-6.71% was observed for different varieties of bananas (Anajekwu et al., 2020).

#### **4.3.5.1.4. Swelling Power and Swelling Volume**

The swelling power of PUBF ranged from 1.76 to 4.1 g/g for the temperature range of 50-90°C, while Monthan flour had a swelling power of 3 to 3.7g/g. The swelling power of PUBF and MUBF was maximum at 70°C, while Monthan flour recorded a swelling power of 3.78 g/g at 90°C. These values indicate the hydration capacity of the starch granules in the flour. According to a study by Khoza et al. (2021), the swelling power of all banana cultivars increased with rising temperatures, and the flour from the FHIA-01 cultivar recorded 0.52 g/g at 90°C.

Additionally, the swelling volume of Peyan flour was measured at  $3.49 \pm 0.21$  ml/g, while Monthan flour had a higher value of  $6.20 \pm 0.87$  ml/g. Elevated starch concentration enhances the hydration and expansion ability of flours, especially in starches with a greater proportion of amylopectin. (Awuchi et al., 2019).

Overall, these results suggest that unripe banana flours, including Peyan and Monthan varieties, have low solubility in water and exhibit varying degrees of swelling power, indicating their potential for applications where hydration capacity and solubility are important factors. Unripe banana flour has good water-holding capacity, which is desirable for various food applications as it can help retain moisture and improve the texture of food products.

#### **4.3.5.2. Flour Gelling Properties**

##### **4.3.5.2.1. Least Gelation Concentration (LGC)**

The LGC of UBFs is depicted in Table XXXIII

The gel forming ability of flours depends on the interaction for water between protein and starch. In the case of the selected cultivars of unripe banana flour, partial gelation was observed at a starch concentration of 10%, while complete gelation occurred at a

concentration of 12%. The banana starch achieved complete gelation at 10 to 14% w/v in a research study (Thanyapanich et al., 2021). These results suggest that unripe banana flour exhibits gelation properties at a moderate starch concentration.

**Table XXXIII**  
**Least Gelation Capacity of Unripe Banana Flour**

Concentration of Flour dispersions (%)												
	2	4	6	8	10	12	14	16	18	20	22	30
<b>PUBF</b>	-	-	-	-	±	+	+	+	+	+	+	+
<b>MUBF</b>	-	-	-	-	±	+	+	+	+	+	+	+
Gelation levels: None (-), complete (+), partial (±).												

It's important to note that the gelation properties can have significant implications for the functionality and applications of these flours in food systems, as gelation is often desirable for achieving the desired texture, structure, and stability in various food products.

#### 4.3.5.2.2. Paste Clarity and Syneresis

Tables XXXIV and XXXV and Figure 44 depict Light Transmittance and Syneresis of unripe banana flours.

**Table XXXIV**  
**Light Transmittance of UBFs**

Light Transmittance at 650nm / Storage in hours	PUBF	MUBF	<i>p</i> Value
24	3.25 ± 0.02	1.49 ± 0.05*	.000555
48	3.01 ± 0.33	1.38 ± 0.04*	.0206
72	2.55 ± 0.34	1.27 ± 0.07*	.035842
96	1.83 ± 0.25	1.04 ± 0.08 <sup>NS</sup>	.053128
120	1.61 ± 0.01	0.76 ± 0.22*	.033312

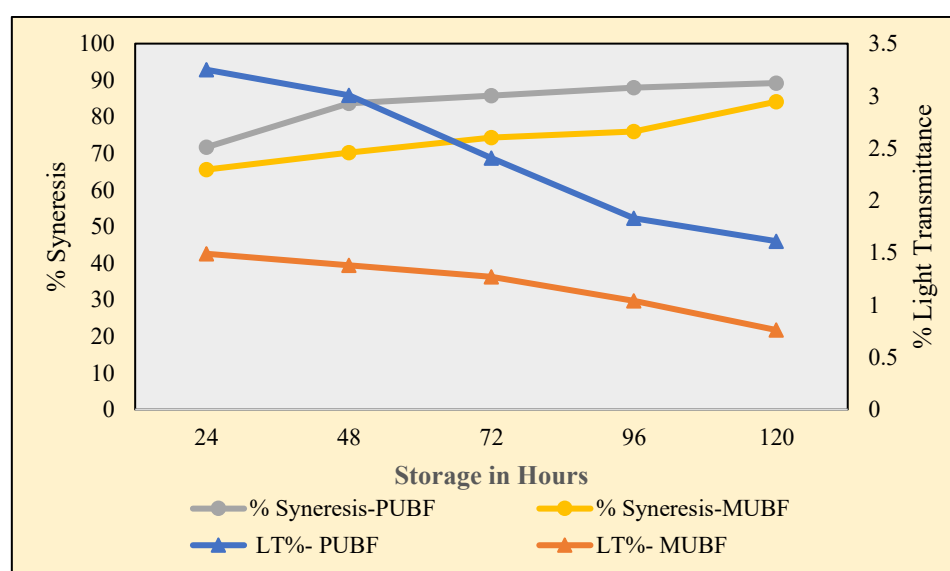
Data presented are the mean ± standard deviation (n = 3),  
p value < 0.05 significant independent t-test (two-tailed)

Storing unripe banana flour samples at 4 °C for up to 120 hours resulted in a decreasing trend in light transmittance and increased syneresis. The paste clarity and syneresis characteristics of PUBF and MUBF differed significantly.

**Table XXXV**  
**Syneresis of UBFs**

Syneresis / Storage in hours	PUBF	MUBF	p Value
24	71.68± 2.23	65.56±2.87 <sup>NS</sup>	.140525
48	83.66± 1.47	70.23±1.78*	.00973
72	85.76 ±0.734	74.36± 2.77*	.030152
96	87.94±2.35	75.99±1.65*	.027714
120	89.23 ±0.69	84.14±2.09 <sup>NS</sup>	.082604

Data presented are the mean ± standard deviation (n = 3), p value<0.05 significant independent t-test (two-tailed)



**Figure 44: Syneresis and Light Transmittance of UBFs**

The decrease in light transmittance is attributed to starch retrogradation and the recrystallization of amylopectin. Initially, the light transmittance (%) was higher, but as amylose leached into the solution, transmittance decreased due to increased light absorbance. In research work, starch from Monthan and Saba (ABB) cultivars exhibited syneresis of 70.26 and 77.05%, respectively, and the syneresis further increased to 80-85 % after storage for 5 days (Paramasivam et al., 2021).

The diverse physicochemical and functional characteristics observed in UBF present an array of opportunities for its utilization in the food processing sector. Substantial amylose levels and elevated gelatinization temperature of these unripe banana flours make them potentially suitable as supplements in extruded products. Furthermore, the high resistant starch in banana flour projects UBF as an ideal ingredient for creating low GI foods.

## Phase 4: Nutrient Composition, Phytonutrients, Antimicrobial Activity, Antioxidant Potential, Prebiotic Potential, and Predicted GI of Unripe Banana Flours- PUBF and MUBF

### 4.4.1. Nutrient Composition of Unripe Banana Flours

Nutritional composition analysis of unripe banana flour is essential due to the limited research on specific cultivars, such as Peyan and Monthan, which remain underexplored. Given the variability in nutrient profiles across different banana varieties, this study seeks to explore the unique nutritional attributes of these cultivars, supporting their potential in developing functional RTE and RTC products.

#### 4.4.1.1. Physicochemical Parameters

Table XXXVI depicts the results of the physicochemical analysis

**Table XXXVI**  
**Physicochemical Analysis of UBFs**

Parameters (dwb)	PUBF	MUBF	<i>p-value</i>
Moisture (%)	3.95 ±0.75	8.67 ±0.67*	.000371
Total Solids (%)	96.05±0.67	91.33 ±0.67*	.000371
pH	4.54 ±0.02	6.4 ±0.11*	.00001
Titrateable acidity (as % citric acid)	0.22 ±0.01	0.43 ± 0.01*	.000015
Brix(°Brix)	2.86 ±0.11	1.97±0.05*	.00027

Data presented are mean value of triplicates ± standard deviation (n = 3)

\*t-test (Independent samples, two-tailed) p-value <0.05 significant

The moisture content of PUBF and MUBF was found to be  $3.95 \pm 0.75\%$  and  $8.67 \pm 0.67\%$ , respectively. A moisture content of approximately 10% is generally regarded as optimal for maintaining shelf stability (Zambrano et al., 2019). Elevated moisture levels can adversely affect the texture, chemical composition, and biochemical characteristics of the food while also fostering the growth of microorganisms (Alp & Bulantekin, 2021). The moisture content of PUBF and MUBF indicates strong storage stability and quality retention. The moisture content in the range of 6.15% to 7.27% was recorded in a study by Anajekwu et al. (2020) for plantain varieties

The pH levels of UBFs varied between  $4.54 \pm 0.02$  for PUBF and  $6.4 \pm 0.11$  for MUBF, with a titratable acidity ranging from 0.22 to 0.43 g of citric acid per 100 g dry weight. The Peyan flour is moderately acidic, and the Monthan flour is slightly acidic, close to neutral. pH of the food is an important intrinsic factor influencing microbial growth viability, and titratable acidity is a more accurate indicator highlighting the flavors influenced by organic acids. (Tyl & Sadler, 2017). The slightly acidic pH of UBF can contribute to its enhanced storage stability. In an investigation, Nendran and Popoulu varieties exhibited pH values of  $5.0 \pm 0.10$  and  $5.78 \pm 0.20$ , respectively (Kumar et al., 2019).

The TSS of PUBF was  $2.86 \pm 0.11$  and for MUBF it was  $1.97 \pm 0.05$  °Brix. A study by Sardá et al. (2016) reported a 1.7–3.2 °Brix soluble sugar content for *Musa acuminata var. Nanicão*. A low TSS value in unripe bananas is attributed to their stage 1 ripening, marked by low soluble solids content and high levels of resistant starch. A statistically notable difference ( $p < 0.05$ ) was recorded for Peyan and Monthan flour in all the physicochemical parameters.

#### 4.4.1.2. Macronutrients in Unripe Banana Flours

Table XXXVII depicts the macronutrients in unripe banana flours of Peyan and Monthan.

**Table XXXVII**  
**Macronutrient Composition of UBFs**

Composition % dry weight basis	PUBF	MUBF	p-value
Ash	$3.89 \pm 0.24$	$4.51 \pm 0.187^*$	.006408
Protein	$4.89 \pm 0.18$	$6.15 \pm 0.52^*$	.007849
Fat	$1.96 \pm 0.07$	$1.36 \pm 0.29^*$	.028044
Total Carbohydrate	$88.03 \pm 1.16$	$86.70 \pm 1.71^{NS}$	.305105
Crude Fiber	$1.17 \pm 0.51$	$1.52 \pm 0.28^{NS}$	.360199
Dietary Fiber	$13.77 \pm 0.53$	$13.41 \pm 0.43^{NS}$	.40901
Total Sugar	$2.87 \pm 0.05$	$2.94 \pm 0.05^{NS}$	.292893
Reducing sugar	$1.16 \pm 0.02$	$1.03 \pm 0.38^{NS}$	.582414
Cellulose	$2.12 \pm 0.05$	$3.11 \pm 0.39^{NS}$	.071022
Pectin as calcium pectate	$0.144 \pm 0.01$	$0.176 \pm 0.05^{NS}$	.448023

Data presented are mean value of triplicates  $\pm$  standard deviation (n = 3)

\*t-test (Independent samples, two-tailed) p-value  $< 0.05$  significant

The amount of ash statistically varied from 3.89% to 4.51%. For unripe banana flour derived from *Musa spp* (AAA). Variations in ash content can be attributed to agricultural practices, climate change, and soil type. Higher ash content in food reflects greater levels of minerals (Khoozani et al., 2020). Cheng et al. (2024) documented a total mineral content of 3.22 % to 3.87 %.

MUBF had a higher protein content of 6.15 % compared to 4.89 % in PUBF. Da Mota et al. (2000) attributed the protein variation to the inherent traits of dessert and plantain bananas. In a research study, UBF had 4.40 % - 7.35 % protein (Cheng et al., 2024). UBF has lower protein compared to wheat flour (10%).

The fat content of PUBF and MUBF was in the range of 1.36- 1.96 %. The low-fat content in UBF reduces the risk of rancidity, enhancing shelf life (Ye et al., 2018)

The UBFs exhibited a total carbohydrate content of 86-88 %, comprising a total starch value of 82- 84%. The recorded values for total sugars were 2.87 - 2.94 %, and 1% reducing sugars were quantified. The sugar content in unripe banana pulp typically ranges from 1% to 2%, rising to 15%–20% as the fruit ripens (da Mota et al., 2000).

The chosen cultivars displayed a noteworthy dietary fiber content of 13%. The crude fiber was found to be 1.17 - 1.52 %. Fiber is a key ingredient in the formulation of functional foods due to its positive health effects, including improved gut regulation, enhanced satiety, better appetite control, glycemic regulation, and potential cancer prevention (Khorasaniha et al., 2023).

PUBF and MUBF contained 2.12 - 3.11 % of cellulose. Pectin quantified as calcium pectate was 0.144% to 0.176%. These indigestible components would further add to the dietary fiber.

Variations in physicochemical characteristics between banana flour and banana starch are influenced by the presence and behaviour of non-starch constituents, and this highlights the unique benefits of banana flour (Yu et al., 2020). Studies have shown that banana flour has lower digestion rates compared to banana starch due to the presence of proteins, cellulose, and pectin, which can inhibit starch digestion (Bi et al., 2017). These attributes suggest a promising avenue for developing innovative food products that leverage the health benefits of unripe banana flour.

#### 4.4.1.3. Micronutrients in Unripe Banana Flours

The micronutrient profile of PUBF and MUBF is presented in Table XXXVIII.

**Table XXXVIII**  
**Micronutrient Composition of UBFs**

Parameters (per 100g on a dry weight basis)	Peyan (PUBF)	Monthan (MUBF)	p-value
Vitamin B6 (mg) <sup>s</sup>	0.172	0.142	-
Vitamin C (mg)	35.55±0.77	37.8± 0.28 <sup>NS</sup>	.061481
Calcium(mg)	30.9 ±0.11	35.0±0.94*	.02602
Phosphorus (mg)	85.44±2.53	92.89±4.06*	.020703
Iron (mg)	2.98 ±0.32	4.81±0.54*	.038307
Potassium (mg)	1390±0.82	1403±0.42*	.014167

Data presented are mean value of triplicates ± standard deviation (n = 3) <sup>s</sup> single determination

\*t-test (Independent samples, two-tailed) p-value <0.05 significant

The vitamin B6 content of the PUBF and MUBF was found to be 0.172mg/100g and 0.142 mg/100g. Bananas are a reliable source of some of the Vitamin B complex. *Musa paradisiaca* Monthan fresh fruit 100 g, provides approximately 0.51mg of pyridoxine as reported in the Indian food composition table (Longvah et al, 2017). The pyridoxine content of 0.06 µg/ ml and 0.078 µg/ ml was reported by Shini et al. (2024) for Monthan and Peyan flour, respectively. The results suggest that there could be some loss in processing bananas into flour.

Vitamin C in PUBF was found to be 35.55±0.77mg/100g and MUBF had 37.8± 0.28 mg/100g. Vitamin C content in the flours of 'Alukehel' and 'Monthan' was reported as 25 mg/100 g of flour (Suntharalingam and Ravindran, 1993). Fresh fruit *Musa paradisiaca* ( 100 g) has 18.4 mg of Vitamin C (USDA database). Significant losses of vitamin C often occur during the processing of most fruits. However, pre-treatment of the banana slices with citric acid during the preparation of flour not only inhibited enzymatic browning but also helped preserve vitamin C due to its sequestering properties to some extent. There is no significant difference between the cultivars in the vitamin C content.

The calcium content of Peyan flour was determined to be  $30.9 \pm 0.11$  mg/100 g, while Monthan flour contained  $35 \pm 0.94$  mg/100 g. Similarly, the phosphorus content was  $85.44 \pm 2.53$  mg/100 g in PUBF and  $92.89 \pm 4.06$  mg/100 g in MUBF. Khoza et al. (2021) reported that Pisang Awak banana flour had  $28.25 \pm 0.34$  mg/100 g calcium, while Grande Naine contained  $18.38 \pm 0.23$  mg/100 g. The same study documented phosphorus levels of 72- 99 mg/100 g in AAA varieties.

PUBF had  $2.98 \pm 0.32$  mg/100g of iron, and the MUBF had  $4.81 \pm 0.54$  mg/100g. Iron content in branded UBF was in the range of 2.57–11.1 mg /100 g (Ferreira & Tarley, 2020).

The potassium content of PUBF was found to be  $1390 \pm 0.82$  mg/100g, and the MUBF had  $1403.8 \pm 0.42$  mg/100g. Anyasi et al. (2018) documented potassium as the predominant mineral in UBF of AAA and ABB cultivars, ranging from 9117 –14,746 mg/kg.

A statistically significant variation was recorded in micronutrients among the cultivars, except for vitamin C. Variations in elemental concentrations may arise from factors such as soil conditions - acidity, organic matter, and mineral composition, and the growing season. Agricultural practices, climate change, and processing methods can impact the mineral content of flour (Herrera-Agudelo et al., 2017).

Peyan and Monthan cultivars prove to be excellent sources of minerals, and this enhances their nutritional value, providing essential nutrients such as calcium, potassium, phosphorus, and iron. These minerals contribute to bone health, electrolyte balance, and metabolic function, making UBF a beneficial addition to a balanced diet. Incorporating unripe banana flour into various food products can help address mineral deficiencies and promote overall health.

#### **4.4.2. Phytonutrient Composition**

##### **4.4.2.1 Qualitative Analysis**

Table XXXIX presents the phytonutrient qualitative screening results.

**Table XXXIX**  
**Qualitative Screening of Phytonutrients**

Metabolites	PUBF	MUBF
Alkaloids	+	+
Flavonoids	+	+
Sterols	-	-
Terpenoids	-	-
Anthraquinone	-	-
Phenolic compounds	+	+
Tannin	+	+
Saponins	-	-
Cardiac glycosides	-	-
Lignin	-	-
Coumarins	-	-
Volatile oils	+	-

Qualitative screening for phytochemicals revealed the presence of alkaloids, flavonoids, phenolic compounds, tannins, and volatile oils. The results of this qualitative analysis direct the study further to quantify the phytonutrients detected.

#### 4.4.2.2. Quantitative Analysis for Phytonutrients

Table XL depicts the phytonutrients in UBFs.

**Table XL**  
**Phytonutrients in UBF**

Secondary Metabolites (per 100g on d.w)	Peyan	Monthan	p-value
Polyphenols (mg GAE)	118.85±4.19	87.15±6.17*	.026628
Tannins (mg TAE)	611.62±5.19	461.32±7.14*	.001719
Phytic acid (g)	0.598±0.04	0.129±0.08*	.004471
Flavonoids (mg QE)	112.78±13.47	178.89±6.73*	.001606

Data presented are mean value of triplicates ± standard deviation (n = 3)

\*t-test (Independent samples, two-tailed) p-value <0.05 significant

PUBF showed a markedly higher TPC (119 mg GAE/100g) than MUBF (87 mg GAE/100g). In recent research, the TPC of Monthan was reported as 96.14±0.64 mg GAE per 100g (Shini et al., 2024).

A higher quantity of tannins and phytic acid was observed for PUBF. Tannins have been shown to inhibit  $\alpha$ -amylase activity contributing to improved postprandial hyperglycemia management, enhanced insulin sensitivity, and lower postprandial blood glucose levels (Golovinskaia & Wang, 2022). A. Kumar et al. (2019), based on their study, commented that the presence of phytic acid in rice could negatively influence starch digestibility, leading to a slower starch breakdown in the human digestive system and subsequently a reduced glycemic response.

The cultivars contained notable flavonoids, with MUBF (179 mg QE/100g) significantly exceeding PUBF (113 mg QE/100g).

The statistical analysis revealed a significant variation in the phytonutrient content of PUBF and MUBF. Peyan flour has a pronounced quantity of polyphenols, tannins, and phytic acid, whereas the Monthan variety showed a significantly higher flavonoid content. Both cultivars prove to be reservoirs of phytonutrients and exhibit great potential to be considered as functional ingredients.

#### **4.4.3. Antimicrobial Activity**

Banana, one of the oldest medicinal plants, has been studied for its natural antimicrobial properties (Al-Mqbali & Hossain, 2019). Studies have shown that bananas possess health-promoting benefits, including the treatment of gastrointestinal ailments, largely due to their bioactives that exhibit antimicrobial activity. The antimicrobial properties of bananas have led to their recommendation for managing bacterial infections, with certain varieties, such as those in Thailand, also noted for gastroprotective effects (Afzal et al., 2022)

Table XLI shows the antimicrobial activity of the unripe banana flour of Peyan and Monthan.

**Table XLI**  
**Anti-microbial Activity of PUBF and MUBF**

<b>Zone of Inhibition / UBFs</b>	<b><i>E.coli</i> MTCC 452 (Gram Negative)</b>	<b><i>S. aureus</i> MTCC 096 (Gram positive)</b>
<b>*PUBF (25mg/ 100µl)</b>	<b>13 mm</b>	-
<b>*MUBF (25mg/ 100µl)</b>	<b>11 mm</b>	-
*Lower concentrations other than tabulated (20,60, 80 µl) showed no zone of inhibition		

Methanolic extracts of PUBF (25mg/ 100µl) exhibited a 13 mm zone of inhibition against *E. coli*, a gram-negative bacterium, while MUBF showed 11 mm inhibition. In a study by Jahan et al. (2019), methanolic extracts (1000 mg/ml) of *Musa* sp. (village variety) pulp were tested against *E. coli*. The methanolic extract produced an inhibition zone of 15 mm, while the ethanolic extract resulted in a larger inhibition zone of 25 mm. Mostafa (2021) reported that polyphenols in UBF extracts exhibit antimicrobial properties.

UBF extracts exhibited no zone of inhibition for *Staphylococcus aureus*, a gram-positive bacterium. As a Gram-positive bacterium, *S. aureus* has a thick peptidoglycan cell wall reinforced with teichoic and lipoteichoic acids, providing structural rigidity and limiting permeability. These features, along with their resistance mechanisms and biofilm formation can reduce the efficacy of plant-derived antimicrobial agents (Nikolic and Mudgil,2023).

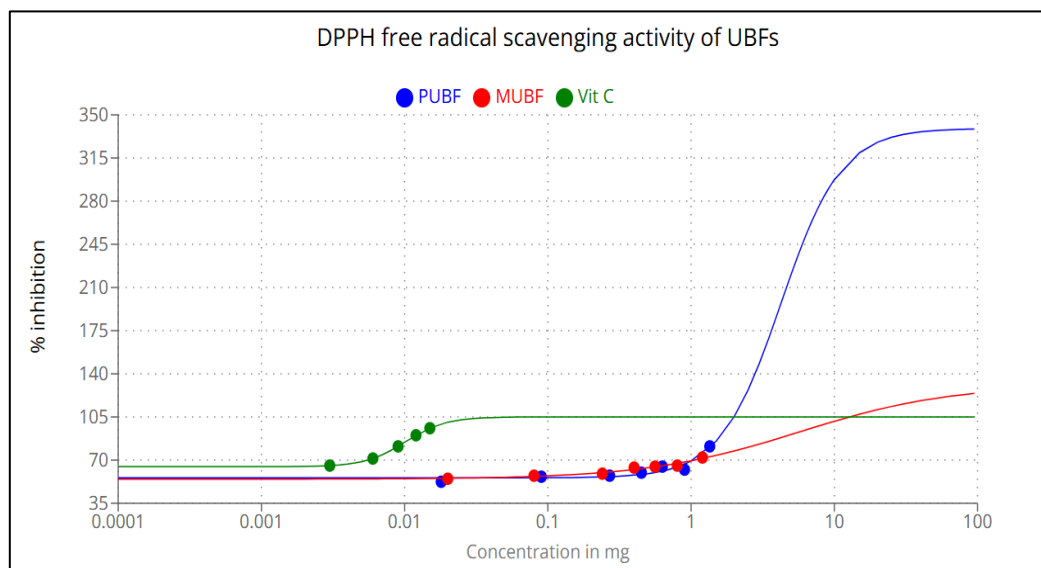
Ajjjolakewu et al. (2021) in their review stated that few studies have reported the anti-microbial activity of banana peel against *Staphylococcus aureus*, which could be due to a greater concentration of phytonutrients in the peel.

The susceptibility of microorganisms to antimicrobial agents can vary significantly. Factors like polarity, solubility, stability of the extracts, and concentration of active compounds affect their diffusion rate in agar, while the microbial species and gram type also influence the antimicrobial effect and inhibition zone size (Bubonja-Šonje et al., 2020)

#### 4.4.4. Antioxidant Potential of UBFs

##### 4.4.4.1. DPPH Free Radical Scavenging Assay

Figure 45 and Table XLII illustrate the DPPH radical scavenging potential of Unripe banana flours.



**Figure 45: DPPH Radical Scavenging Potential of UBFs**

**Table XLII**

**Anti-oxidant Capacity of UBF – DPPH Assay**

Parameter	PUBF	MUBF	Vitamin C
IC <sub>50</sub>	5.006 mg/mL	6.641 mg/mL	10.13 µg/mL

The half-maximal inhibitory concentration (IC<sub>50</sub>) refers to the amount of bioactive compounds needed to inhibit 50% of the oxidation process. The IC<sub>50</sub> values for the UBF extracts were calculated as 5- 6 mg/mL. These values indicate that while the extracts effectively scavenge free radicals, higher concentrations are needed to achieve the inhibition level represented by their IC<sub>50</sub> values compared to vitamin C.

The study results are comparable to Jannoey et al. (2021), who reported the IC<sub>50</sub> values for the methanol fraction of UBF from *Musa ABB* sp. Kluai “Namwa” at 5.46 mg/mL for the DPPH assay. The researcher stated that ethanolic UBF extracts have a lower IC<sub>50</sub> value of 2.54 mg/mL.

#### 4.4.4.2. Ferric Reducing Antioxidant Power (FRAP)

Figure 46 illustrates the FRAP Assay Optical Density values of UBF Extracts at 700 nm and Table XLIII presents the TAC by FRAP assay.

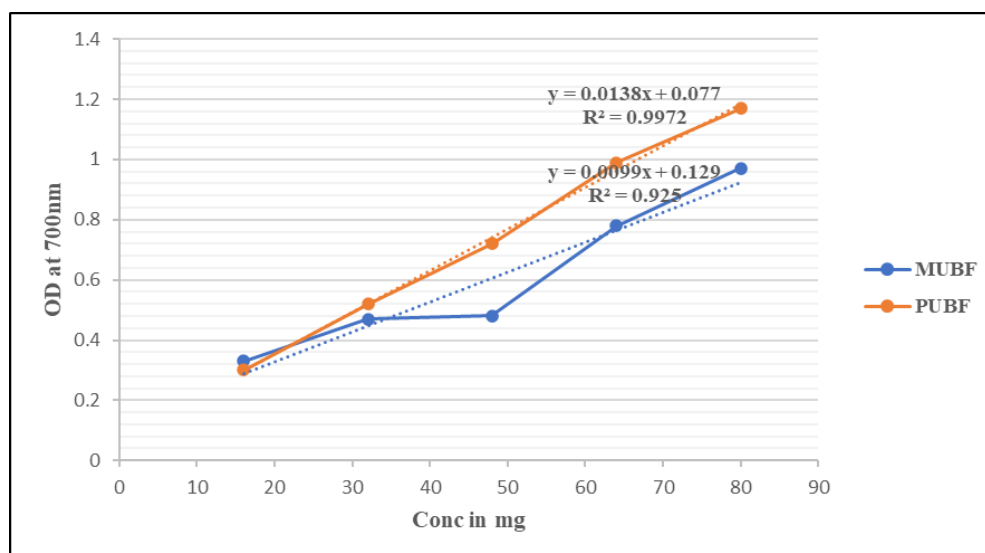


Figure 46: FRAP Assay- Optical Density Values of UBF Extracts

Table XLIII

Antioxidant capacity of PUBF and MUBF -FRAP Assay

Total Antioxidant capacity expressed as Ascorbic acid equivalent	PUBF	MUBF
	16.75 ± 0.48 mg AAE/g	13.64 ± 0.64 mg AAE/g

The antioxidant capacity of unripe banana flours as determined by FRAP assay was 16.75 ± 0.48 mg AAE/g for the Peyan cultivar and 13.64 ± 0.64 mg AAE/g for the Monthan cultivar. These results are consistent with reported FRAP values for plant-based extracts, highlighting the antioxidant capacity of UBF. Amarasinghe et al. (2021) reported FRAP values between 25.35 to 28.75 mg TE/g in banana flours

#### 4.4.4.3. ABTS Free Radical Scavenging Assay

Figure 47 illustrates the ABTS Assay Optical Density Values of UBF Extracts and Table XLIV presents the IC<sub>50</sub> values

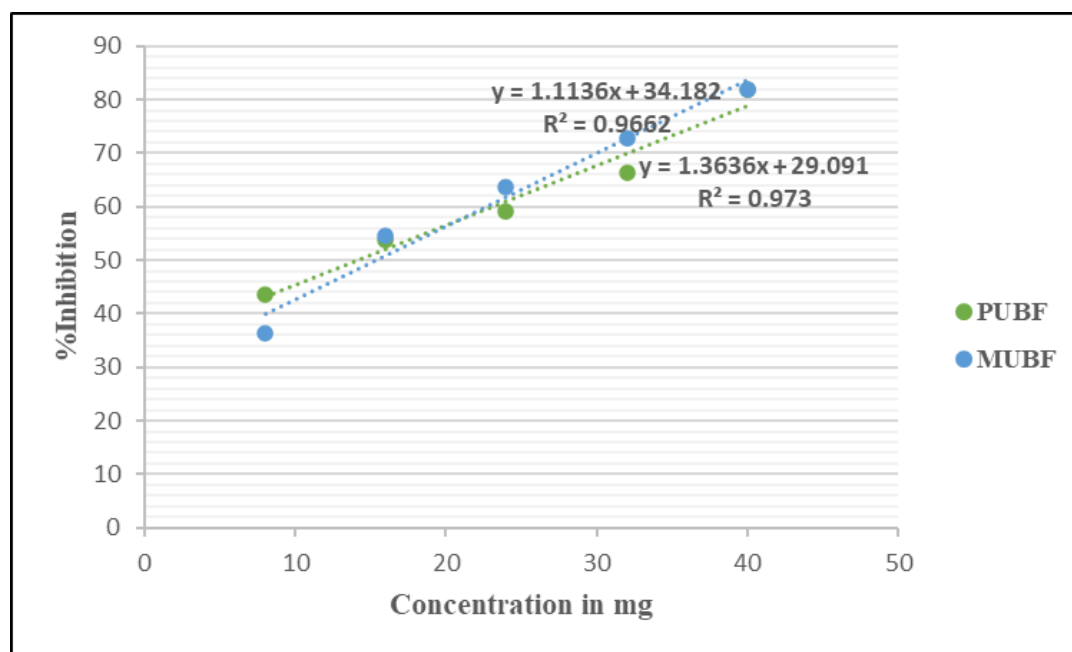


Figure 47: Antioxidant activity of UBF by ABTS Assay

Table XLIV

Antioxidant activity of UBF by ABTS Assay

Parameter	PUBF	MUBF
IC <sub>50</sub>	14.21 mg/mL	15.33 mg/mL

A concentration-dependent increase in inhibition was observed for PUBF ( $R^2 = 0.973$ ) and MUBF ( $R^2 = 0.9662$ ). The IC<sub>50</sub> values of the methanolic extracts of PUBF and MUBF were 14.21 mg/mL and 15.33 mg/mL, respectively, for the ABTS assay. Jannoey et al. (2021) reported the IC<sub>50</sub> values for the methanol fraction of UBF from *Musa ABB* sp. Kluai “Namwa” as 6.42 mg/mL for the ABTS assay. The researcher stated that ethanolic UBF extracts have a lower IC<sub>50</sub> value of 5.97 mg/mL. Variations in the phytochemical composition or extraction solvent could influence the ABTS radical scavenging activity.

Table XLV

## Pearson's Correlation between Antioxidant Activity and Phenolic Compounds

	TPC	TFC	Tannin	DPHH	ABTS	FRAP
TPC	1					
TFC	-0.92017	1				
Tannin	0.98925	-0.96749	1			
DPHH	0.37833	-0.04389	0.25820	1		
ABTS	0.52750	-0.15396	0.39852	0.82140	1	
FRAP	0.87713	-0.62045	0.79776	0.73133	0.86216	1

The Pearson correlation coefficient indicated a strong positive correlation linking the FRAP assay with phytonutrients (total polyphenol and total tannin content) as well as with other antioxidant assays, including DPPH and ABTS. The ABTS assay showed a strong positive correlation with the DPPH assay ( $r = 0.8214$ ) and a moderate positive correlation with total polyphenol content. These results indicate that both PUBF and MUBF exhibit robust antioxidant potential across different mechanisms, suggesting a more consistent antioxidant response.

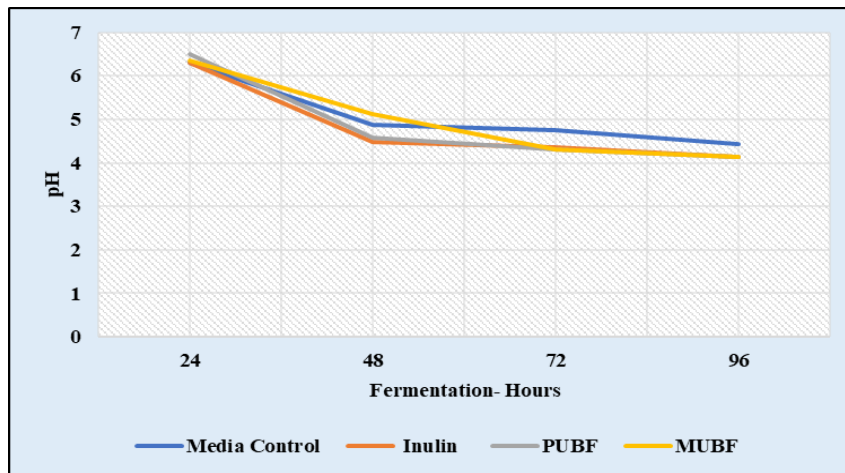
The rich nutrient and bioactive profile, along with high levels of resistant starch and dietary fiber, establishes unripe banana flour as a valuable functional ingredient, supporting further exploration of its prebiotic potential.

#### 4.4.5 Prebiotic Potential of PUBF and MUBF

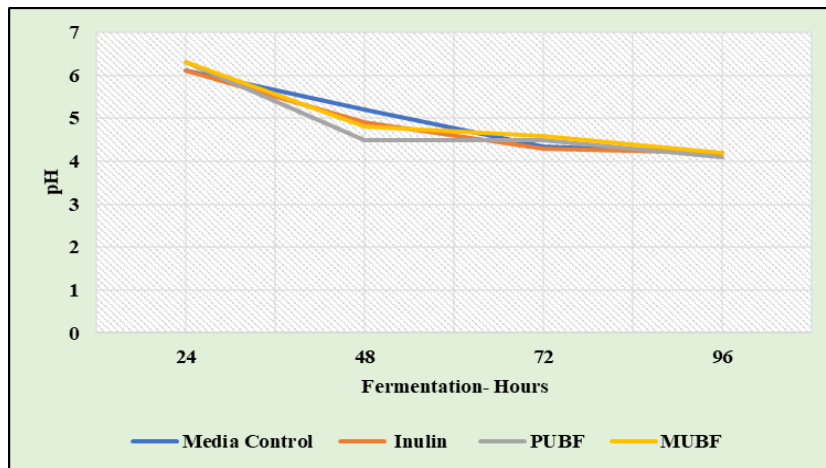
##### 4.4.5.1 Change in pH

The fermentation of unripe banana flour by the selected probiotic microflora (*Lactobacillus acidophilus*, *Bifidobacterium longum*, and *Lactobacillus paracasei*) produces short-chain fatty acids as secondary metabolites, leading to a decrease in the pH of the growth medium. The reduction in pH can be linked to the prebiotic efficacy of the unripe banana flour.

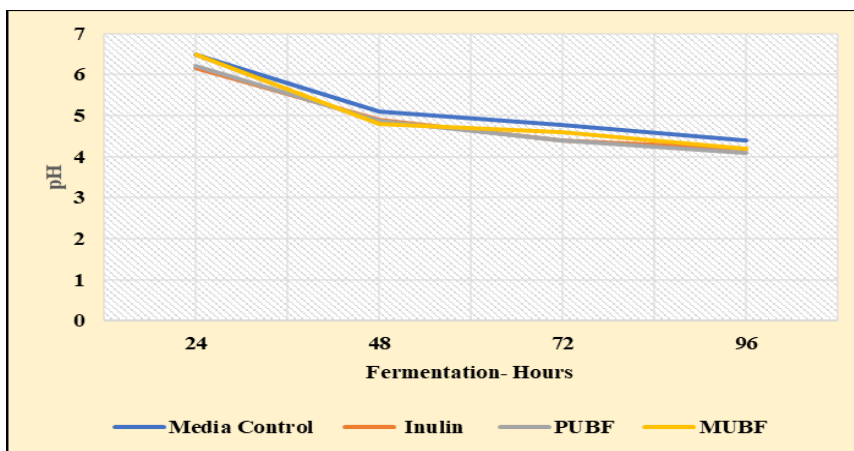
The changes in pH of the UBF-incorporated media were measured at 24- 96 hours and compared with inulin, the standard reference, and the media control, and findings are illustrated in Figures 48 to 50.



**Figure 48: Change in pH- PUBF and MUBF**  
*Lactobacillus acidophilus*



**Figure 49: Change in pH- PUBF and MUBF**  
*Bifidobacterium longum*



**Figure 50: Change in pH- PUBF and MUBF**  
*Lactobacillus paracasei*

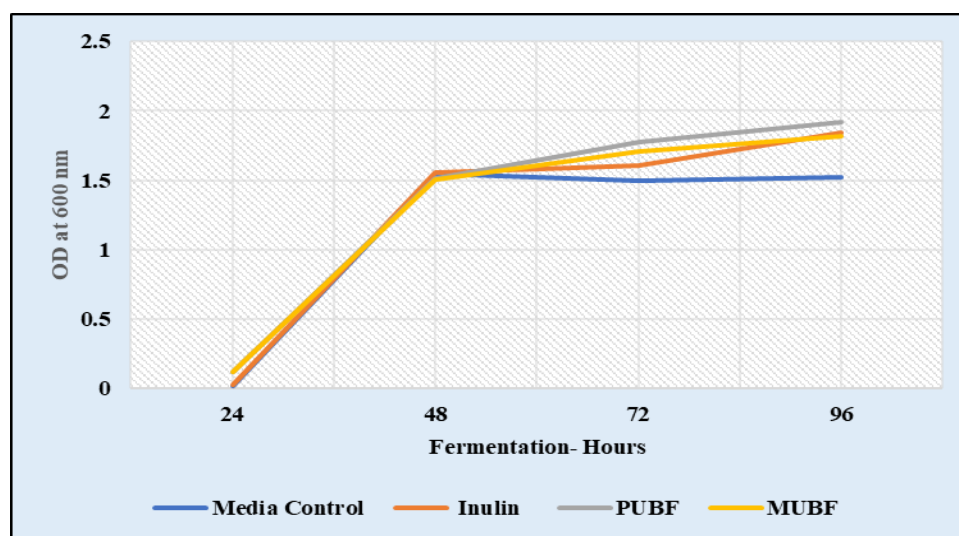
In the case of *Lactobacillus acidophilus* incorporated with PUBF, a decrease in pH from 6.5 to 4.13 was observed during the fermentation period of 24 – 96 hours. MUBF and inulin showed a similar decrease in pH values from 6.14 to 4.14. *Bifidobacterium longum* in the unripe banana flour incorporated growth media also exhibited a decrease in pH during fermentation, comparable to the reference standard of inulin. The fermentation of UBF-incorporated growth media by *Lactobacillus paracasei* was marked by a decrease in pH from 6 to 4 in 96 hours, with the reference standard inulin showing comparable results. This decrease indicates active fermentation by these strains, reflecting their ability to utilize the prebiotic substrates.

In the study by Powthong et al. (2020) of prebiotic effects from Saba, Pisang Awak, and Silver Bluggoe banana powders, pH changes were monitored over a 72-hour fermentation period. A significant pH decrease was noted, with *Lactobacillus casei* showing pH values from 3.65 to 4.05, and *Lactobacillus fermentum* ranging from 4.08 to 4.21 at 72 hours.

#### 4.4.5.2. Change in Optical Density

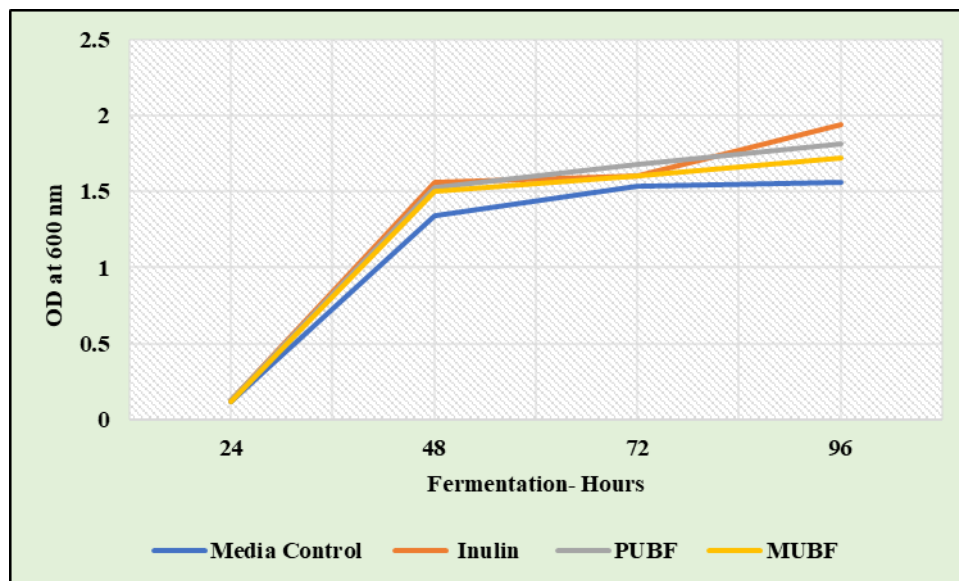
The absorbance at 600 nm measures the turbidity of the culture medium, serving as an indirect indicator of microbial growth. If the substrate has prebiotic potential, then the growth of microorganisms will be enhanced, resulting in a higher optical density (OD) value.

The optical density measurements are illustrated in Figures 51–53.

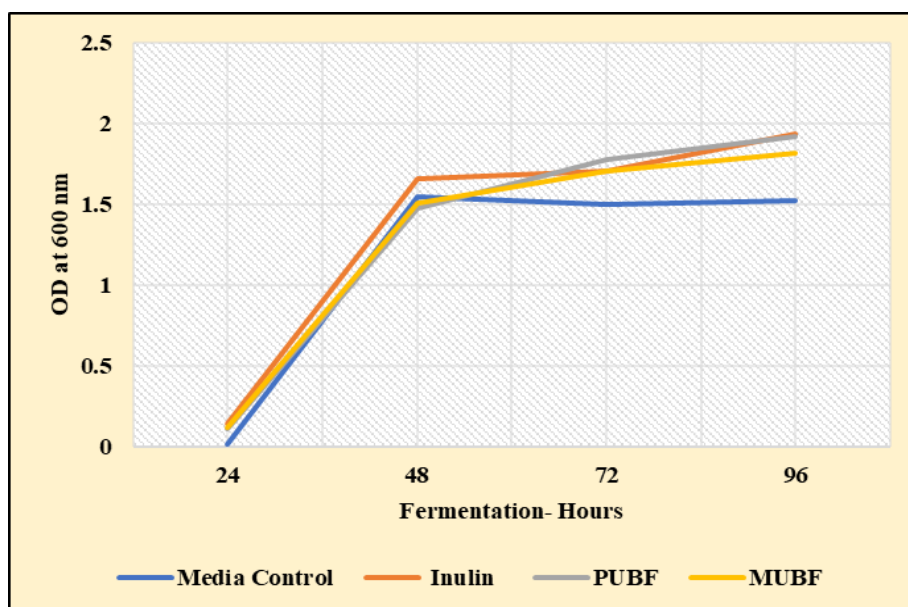


**Figure 51: Change in Optical Density - PUBF and MUBF**

*Lactobacillus acidophilus*



**Figure 52: Change in Optical Density - PUBF and MUBF**  
*Bifidobacterium longum*



**Figure 53: Change in Optical Density - PUBF and MUBF**  
*Lactobacillus paracasei*

The optical density (OD) of PUBF-incorporated media with *Lactobacillus acidophilus* increased from 0.117 to 1.918 from 24 to 92 hours. PUBF exhibited a similar trend for *Lactobacillus paracasei*.

In the inulin-incorporated growth media, *Bifidobacterium longum* had the highest OD value of 1.94 at 96 hours, and PUBF and MUBF had 1.818 and 1.719, respectively. The results suggest the potential prebiotic nature of the unripe banana flours- Peyan and Monthan, comparable to inulin.

#### 4.4.5.3. Colony Count

**Table XLVI**  
**Prebiotic potential of UBF - Colony Count method**

<i>Lactobacillus acidophilus</i> (log cfu / ml)				
Samples / Fermentation period- Hours	Media control Dextrose	PUBF	MUBF	Inulin
24	6.77± 0.01 <sup>a</sup>	6.84± 0.01 <sup>a</sup>	6.82± 0.01 <sup>a</sup>	6.84± 0.01 <sup>a</sup>
48	8.54± 0.01 <sup>c</sup>	8.64± 0.01 <sup>b</sup>	8.60± 0.01 <sup>b</sup>	8.72± 0.01 <sup>d</sup>
72	8.60± 0.03 <sup>c</sup>	8.70± 0.03 <sup>b</sup>	8.63± 0.03 <sup>b</sup>	8.64± 0.03 <sup>c</sup>
96	8.34± 0.03 <sup>b</sup>	8.64± 0.03 <sup>b</sup>	8.58± 0.03 <sup>b</sup>	8.43± 0.03 <sup>b</sup>
<i>Bifidobacterium longum</i> (log cfu / ml)				
24	6.69± 0.03 <sup>a</sup>	6.84± 0.01 <sup>a</sup>	6.82± 0.01 <sup>a</sup>	6.84± 0.01 <sup>a</sup>
48	8.64± 0.03 <sup>c</sup>	8.59± 0.03 <sup>b</sup>	8.54± 0.03 <sup>bc</sup>	8.87± 0.03 <sup>d</sup>
72	8.62± 0.03 <sup>c</sup>	8.62± 0.03 <sup>b</sup>	8.60± 0.03 <sup>c</sup>	8.80± 0.02 <sup>c</sup>
96	8.52± 0.03 <sup>b</sup>	8.56± 0.04 <sup>b</sup>	8.50± 0.04 <sup>b</sup>	8.57± 0.03 <sup>b</sup>
<i>Lactobacillus paracasei</i> (log cfu / ml)				
24	6.75± 0.03 <sup>a</sup>	6.79± 0.04 <sup>a</sup>	6.82± 0.01 <sup>a</sup>	6.82± 0.01 <sup>a</sup>
48	8.67± 0.03 <sup>c</sup>	8.69± 0.03 <sup>c</sup>	8.70± 0.03 <sup>c</sup>	8.80± 0.02 <sup>d</sup>
72	8.65± 0.03 <sup>c</sup>	8.66± 0.03 <sup>bc</sup>	8.65± 0.03 <sup>bc</sup>	8.64± 0.02 <sup>c</sup>
96	8.54± 0.03 <sup>b</sup>	8.58± 0.04 <sup>b</sup>	8.58± 0.04 <sup>b</sup>	8.57± 0.03 <sup>b</sup>

Significant increase in probiotic numbers during the fermentation period, 24-96 hours for each probiotic strain  
Mean Values carrying the same superscript in a **column** do not differ significantly (P<0.05, DMRT)

The colony count results are displayed in Table XLVI. Across all strains, a significant increase in cell counts was observed between 24 and 72 h, indicating active utilization of the test substrates. For *L. acidophilus*, PUBF and MUBF supported higher growth (8.70 and 8.63 log cfu/mL at 72 h) compared with dextrose (8.60 log cfu/mL), though slightly lower than inulin (8.64 log cfu/mL).

*B. longum* showed a pronounced response to inulin (8.87 log cfu/mL at 48 h; 8.80 log cfu/mL at 72 h). PUBF and MUBF also demonstrated growth-promoting effects, with peak counts of 8.62 and 8.60 log cfu/mL at 72 h. For *L. paracasei*, growth trends were comparable across substrates, with inulin showing the highest peak (8.80 log cfu/mL at 48 h). PUBF (8.69 log cfu/mL) and MUBF (8.70 log cfu/mL) performed similarly in sustaining growth at 48 h.

At 96 hours, a decline in CFU was observed across the samples, suggesting the microflora had entered the death phase of their growth curve. However, at 96 hours, UBF sustained probiotic populations over extended periods, reflecting gradual fermentation of resistant starch. Observed decrease in pH and increase in turbidity further corroborate the rise in colony-forming units.

Dietary fiber and resistant starches act as substrates for probiotics, resulting in SCFA, which offer beneficial metabolic effects (Mazhar et al., 2023). The chemical structure and physical form of dietary fibers influence the fermentation rate and, consequently, SCFA production (Cani, 2019).

In a research study by Powthong et al. (2020), changes in log CFU were observed across all concentrations (1–6% w/v) of banana during 0–72 hours of fermentation, with no significant effects. Each probiotic strain showed a significant increase from the initial count, reaching  $7.16 \pm 0.05$  to  $8.25 \pm 0.00$  CFU/mL within 72 hours.

#### 4.4.5.4. Prebiotic Index

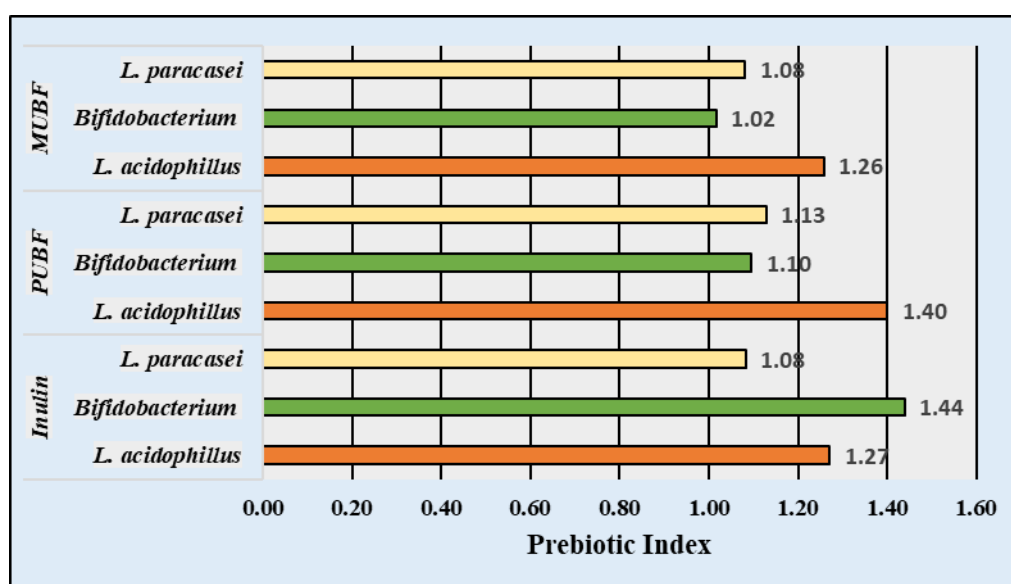
The prebiotic index ( $I_{preb}/PI$ ) was calculated by Palframan et al. (2003) method and the equation presented below. According to Figueroa-González et al. (2019), “It is defined as the ratio of probiotic growth in the presence of a prebiotic to probiotic growth in a control carbohydrate. A prebiotic index higher than one (1) means that the carbohydrate has a positive effect on the probiotic growth. If the prebiotic index is near to one (1), it indicates a low effectiveness of the evaluated carbohydrate”.

$$I_{preb} = \frac{\text{CFU of probiotics in prebiotic carbohydrate}}{\text{CFU of probiotics in control carbohydrate}}$$

PI of PUBF and MUBF are presented in Table XLVII and Figure 54.

**Table XLVII**  
**Prebiotic Index of UBF vs Inulin**

Samples / Period	<i>Lactobacillus acidophilus</i>			<i>Bifidobacterium longum</i>			<i>Lactobacillus paracasei</i>		
	PUBF	MUBF	Inulin	PUBF	MUBF	Inulin	PUBF	MUBF	Inulin
24	1.17	1.12	1.17	1.41	1.35	1.43	1.09	1.18	1.18
48	1.23	1.11	1.59	0.89	0.80	1.68	1.36	1.06	1.12
72	1.25	1.08	1.10	1.00	0.95	1.52	0.98	1.00	0.98
96	1.95	1.73	1.23	1.09	0.97	1.12	1.09	1.09	1.06
<b>Mean</b>	<b>1.40</b>	<b>1.26</b>	<b>1.27</b>	<b>1.10</b>	<b>1.02</b>	<b>1.44</b>	<b>1.13</b>	<b>1.08</b>	<b>1.08</b>



**Figure 54: Mean PI of UBF Vs Inulin**

The prebiotic index (PI) data were analyzed for *Lactobacillus acidophilus*, *Bifidobacterium longum*, and *Lactobacillus paracasei* over a 96-hour fermentation period using Peyan flour, Monthan flour, and inulin as substrates. The prebiotic index (Ipreb) values across 96 hours demonstrate a positive effect of all tested carbohydrates on probiotic growth, as all values exceeded 1. However, the degree of effectiveness varied between samples.

For *Lactobacillus acidophilus*, the mean PI over the fermentation period was highest with PUBF (PI=1.40), indicating that PUBF effectively promoted the growth of *L. acidophilus*. Throughout the fermentation, inulin consistently showed a higher mean PI of 1.44 for *Bifidobacterium longum* while PUBF and MUBF had PI values of 1.10 and 1.02, respectively. These results confirm inulin’s established role as an effective prebiotic, particularly for stimulating the growth of *Bifidobacterium* species. *L. paracasei* can utilize various substrates for growth, with a marginal preference for PUBF with a mean PI of 1.13 over Monthan and inulin, both at 1.08.

PUBF showed strong potential as a prebiotic substrate, particularly in promoting the growth of *Lactobacillus acidophilus*, with higher PI values than MUBF and inulin. Similar results across all substrates for *Lactobacillus paracasei* indicate its adaptability to various prebiotic sources, though PUBF showed a slight edge.

Unripe banana flour is an effective substrate for probiotics due to its abundant resistant starch, dietary fiber, cellulose, and hemicellulose. These findings suggest that banana flour, especially Peyan, could be explored as an alternative prebiotic ingredient, potentially offering specific advantages over traditional options like inulin.

#### 4.4.5.5. Inhibition of E coli growth

The antimicrobial activity of the fermented broth (100 µl) of *the microflora* at 96 hours is presented in Table XLVIII.

**Table XLVIII**  
**Inhibition of *E. coli* growth**

Microflora/ Zone of Inhibition (mm)	PUBF	MUBF	Inulin
<i>L. acidophilus</i>	13 ±0.3 <sup>b</sup>	11 ±0.3 <sup>a</sup>	11 ±0.5 <sup>a</sup>
<i>Bifidobacterium longum</i>	11 ±0.5 <sup>a</sup>	11 ±0 <sup>a</sup>	13 ±0.3 <sup>b</sup>
<i>L. paracasei</i>	12 ±0 <sup>a</sup>	12 ±0.5 <sup>b</sup>	11 ±0 <sup>a</sup>

Data presented are mean value ± standard deviation (n = 2)  
Mean Values carrying the same superscript in a **column** do not differ significantly (P<0.05, DMRT)

The fermentation supernatant of PUBF inoculated with *L. acidophilus* exhibited a 13 mm zone of inhibition, indicating effective antibacterial properties, while MUBF and inulin showed an 11 mm inhibition zone. Inulin with *Bifidobacterium longum* showed the highest zone of inhibition at 13mm, while PUBF and MUBF demonstrated zones of inhibition of 11

mm. The zone of inhibition for PUBF and MUBF with *Lactobacillus paracasei* was 12 mm, suggesting similar antimicrobial effects, while inulin's inhibition was slightly lower (11 mm). These results indicate that the inhibitory potential depends on both the extract type and microbial strain, with no uniform pattern across all tested organisms.

In a study by Powthong et al. (2020), the fermentation supernatant of *Lactobacillus acidophilus* with various banana varieties demonstrated inhibitory effects against *E. coli*. The Saba banana variety showed an inhibition zone of  $9.7 \pm 0.6$  mm, Pisang Awak banana powder recorded an inhibition zone of  $9.3 \pm 0.6$  mm, and Silver Bluggoe powder had an inhibition zone of  $8.7 \pm 0.6$  mm.

#### 4.4.6. Predicted GI of PUBF and MUBF

The starch hydrolysis curve is presented in Figure 55, and the predicted GI values of PUBF and MUBF are presented in Table XLIX.

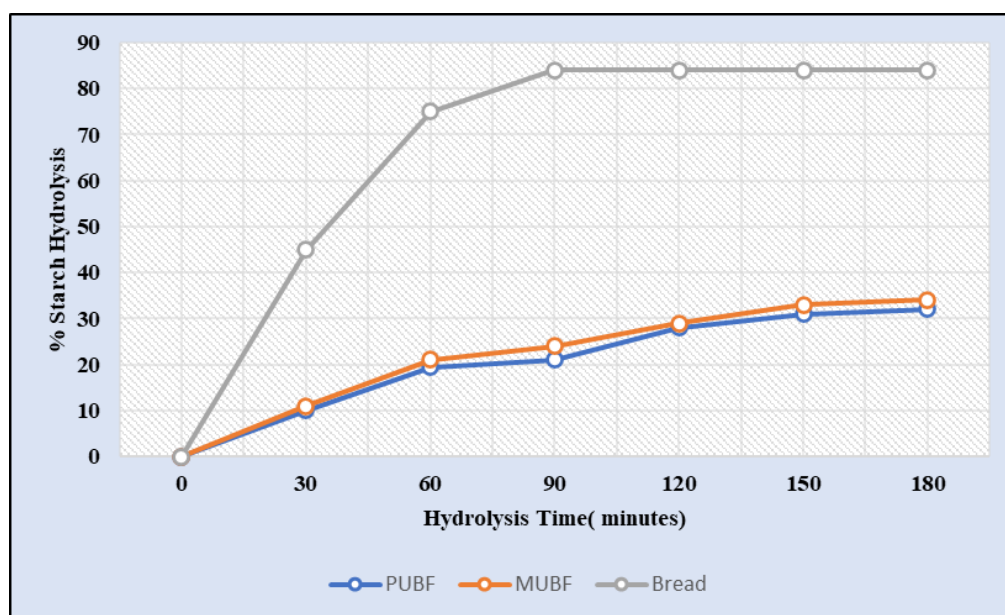


Figure 55: Starch Hydrolysis Curve of UBFs and Bread

Table XLIX

## Predicted GI of Unripe Banana Fours

Products	Hydrolysis Index	Predicted GI	GI Classification
PUBF	26.75 ± 0.75	54.39± 0.41	Low GI
MUBF	32.60± 0.25	57.60± 0.21	Medium GI

Values are Mean ± SD of duplicates.

Jenkins et al. (1988) initially proposed GI to assess the glycemic response triggered by carbohydrates in different food products. Based on the GI classification system, foods are categorized into three groups: high GI (>70), medium GI (55–70), and low GI (≤55). High-GI foods generate a greater postprandial glucose response, reflected by a larger area under the glucose curve, compared to an equivalent carbohydrate portion from low-GI foods (Di Cairano et al., 2022). Due to their potential benefits for diabetic individuals, low-GI foods have gained significant interest (Ni et al., 2022).

According to Venn et al. (2014), white bread is appropriate for assessing the glycemic impact of carbohydrate-rich foods, whereas glucose is commonly used for evaluating sugary foods. Bread was used as the reference carbohydrate, and the eGI of bread was found to be 94.61 %.

The hydrolysis indices of PUBF and MUBF were determined as 26.75 ± 0.75 and 32.60± 0.25, respectively. The starch hydrolysis rate peaked between 30 and 60 minutes, and the plateau stage was reached by 90 minutes for bread, whereas UBFs showed a slower and more gradual digestion rate. The eGI of unripe banana flours of the cultivars Peyan and Monthan was 54.39±0.41 and 57.60±0.21, categorizing them as low and medium-GI foods, respectively.

Zhang et al. (2023) have reported *in vitro* GI values of 43.15 for unripe and inferior banana flour from *Musa sapientum* Linn. ABB Dajiao variety.

The slow hydrolysis rate and low to moderate glycemic response of unripe banana flour highlight its potential as an adjunct in functional foods.

## Phase 5: Development and Evaluation of RTE and RTC Products Incorporated with PUBF and MUBF

The recipes incorporated whole wheat flour instead of refined all-purpose flour for product development. This substitution was made to improve the fiber and protein content of the products, thereby enhancing their nutritional value. Whole wheat flour is known for its higher content of vitamins, minerals, and dietary fiber compared to refined flour (Khalid et al., 2023)

### 4.5.1. Development and Evaluation of UBF Incorporated Jeera Cookies

#### 4.5.1.1. Standardized Recipe

The recipe and preparation method of Jeera cookies are presented in Table L and Figure 56.

**Table L**  
**Formulation of Jeera Cookies**

Ingredients	Cookies Variations			
	Control	UBF 15%	UBF 30%	UBF 50%
Whole Wheat Flour (g)	100	85	70	50
Unripe Banana Flour(g) PUBF/MUBF		15	30	50
Butter (g)	40	40	40	40
Salt (g)	0.5	0.5	0.5	0.5
Baking powder (g)	2	2	2	2
Milk (ml)	15	15	15	15
Jeera (g)	5	5	5	5
Yield- 8 Cookies				

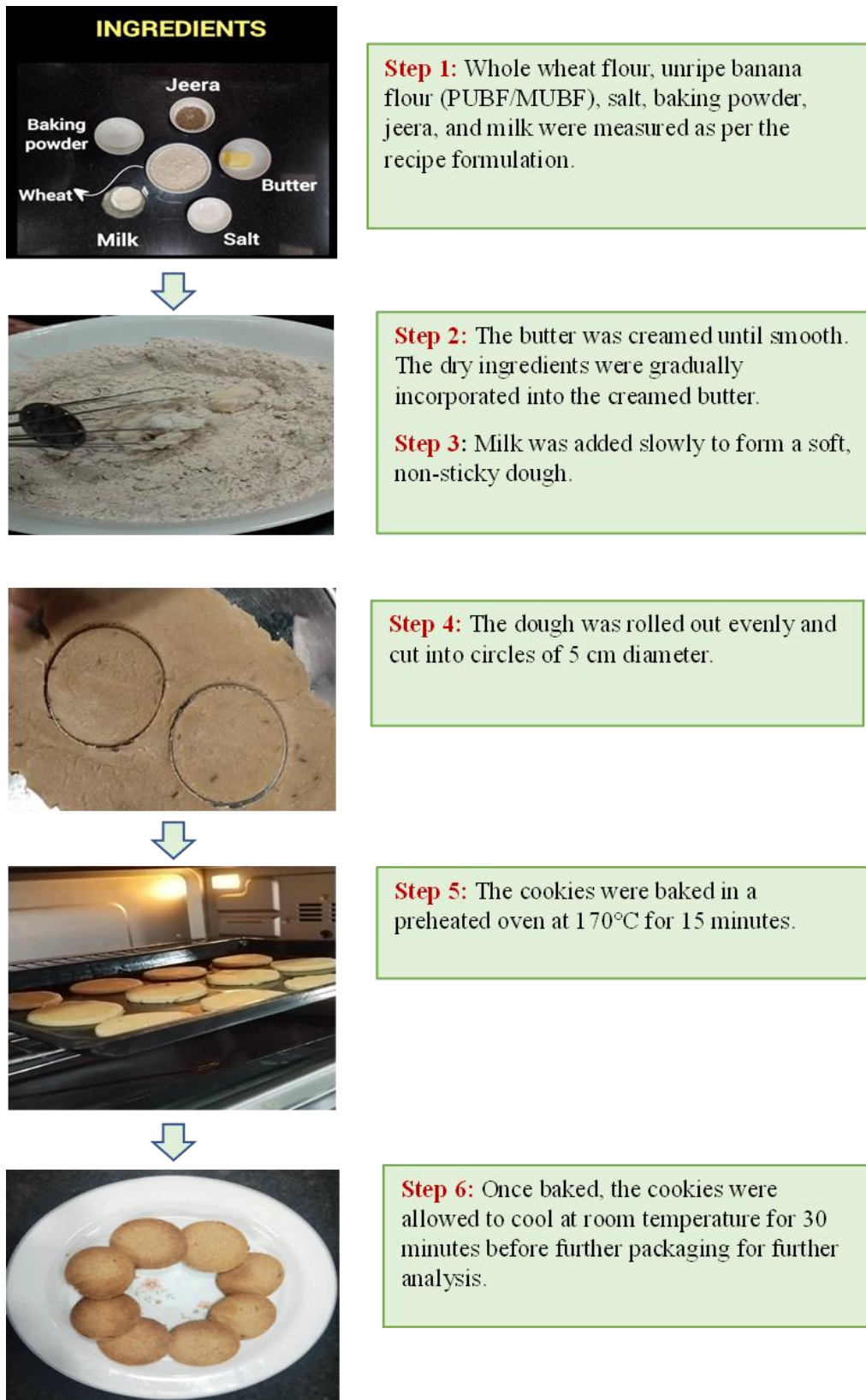


Figure 56: Preparation of Jeera Cookies



**PUBF 15%**



**MUBF 15%**



**PUBF 30%**



**MUBF 30%**



**PUBF 50%**



**MUBF 50%**



**Control - 100% Wheat**

**Plate 12: Jeera Cookies Variations**

Unripe banana flour in varying proportions was added to enhance the nutritional profile and offer functional benefits. The primary purpose of adding butter to the recipe was to stabilize air cells formed during mixing, which supports a consistent structure in the final product. Fat functions as a lubricant, enhancing the plasticity of cookie dough and helping to limit excessive gluten development during mixing. It contributes to the desirable eating qualities of cookies, significantly impacting their texture and flavor (Jacob & Leelavathi, 2006).

Milk was added to enhance both texture and flavor as it provides moisture and ensures a tender, soft crumb. Baking powder was added according to the recipe standards to improve the texture of the cookies (Canali et al., 2020). Fresh jeera (cumin) was integrated into the recipe to enhance the flavor profile of the cookies. One of the key aspects of the product formulation was the exclusion of added sugars. This was intended to minimize the glycemic load, making the cookies a healthier snack option.

#### 4.5.1.2. Sensory Scores and Acceptability of UBF Incorporated Jeera Cookies

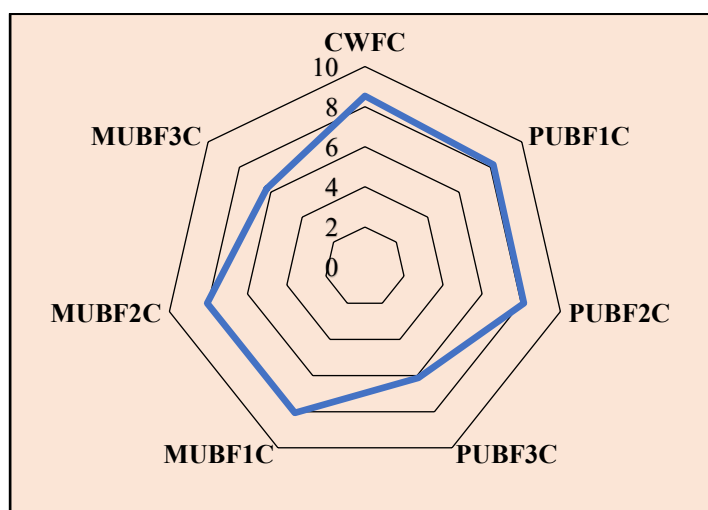
The sensory acceptability results of UBF-incorporated Jeera cookies are presented in Table LI and Figure 57.

**Table LI**  
**Mean Sensory Scores of UBF Incorporated Jeera Cookies**

Parameters	PUBF			MUBF			Control
	PUBF1C	PUBF2C	PUBF3C	MUBF1C	MUBF2C	MUBF3C	CWFC
	15%	30%	50%	15%	30%	50%	
Appearance	8.07±0.88 <sup>b</sup>	7.8±0.86 <sup>b</sup>	6.07±1.22 <sup>a</sup>	7.67±0.90 <sup>b</sup>	7.67±1.04 <sup>b</sup>	6.67±0.72 <sup>a</sup>	8.13±0.64 <sup>b</sup>
Taste	8.2±0.74 <sup>bc</sup>	8.6±0.70 <sup>bc</sup>	6.13±0.74 <sup>a</sup>	8.07±0.59 <sup>bc</sup>	7.93±0.88 <sup>b</sup>	6.27±0.88 <sup>a</sup>	8.6±0.50 <sup>c</sup>
Texture	8.20±0.77 <sup>b</sup>	8.20±0.56 <sup>b</sup>	7.27±0.79 <sup>a</sup>	8.2±0.41 <sup>b</sup>	8.27±0.88 <sup>b</sup>	7.07±1.10 <sup>a</sup>	8.33±0.48 <sup>b</sup>
Flavor	8.46±0.64 <sup>c</sup>	8.0±0.65 <sup>bc</sup>	7.4±0.91 <sup>a</sup>	8.2±0.41 <sup>bc</sup>	7.66±1.11 <sup>ab</sup>	7.13±0.99 <sup>a</sup>	8.47±0.51 <sup>c</sup>
Mouth Feel	8.46±0.64 <sup>b</sup>	7.93±0.70 <sup>b</sup>	7.27±0.88 <sup>a</sup>	8.33±0.48 <sup>b</sup>	7.87±0.91 <sup>b</sup>	7.13±0.99 <sup>a</sup>	8.47±0.51 <sup>b</sup>
After Taste	8.47±0.64 <sup>c</sup>	7.87±0.64 <sup>b</sup>	6.8±0.86 <sup>a</sup>	8.13±0.51 <sup>bc</sup>	7.87±0.91 <sup>b</sup>	6.73±0.96 <sup>a</sup>	8.53±0.51 <sup>c</sup>
Overall Acceptability	8.20±0.77 <sup>b</sup>	8.13±0.74 <sup>b</sup>	6.13±0.74 <sup>a</sup>	8.07±0.59 <sup>b</sup>	8.07±0.96 <sup>b</sup>	6.27±0.88 <sup>a</sup>	8.53±0.51 <sup>b</sup>

Values are Mean ± SD of 15 individual sensory scores.

Mean Values carrying the same superscript in a row do not differ significantly (P<0.05, DMRT)



**Figure 57: Overall Acceptability of Jeera Cookies**

The combined sensory attributes determine the overall acceptability of a product. Cookies containing 15% and 30% UBF incorporation demonstrated higher acceptability scores than those with 50% UBFs. The aftertaste was more pronounced in cookies with 50% incorporation, negatively impacting their acceptability. One-way ANOVA analysis indicated a significant difference among the cookies in all assessed attributes. The post hoc DMRT indicated a significant difference between control cookies and those with 50% UBF incorporation. PUBF/ MUBF 15% and 30% incorporations were comparable to the control, indicating the acceptance of the experimental cookies.

Amarasinghe et al. (2021) in their study reported that the cookie made with a blend of 70:30 wheat flour and banana flour was rated the most favorable by the panelists.

#### 4.5.1.3. Physical Characteristics of Jeera Cookies

The physical characteristics of the cookies are presented in Table LII.

**Table LII**  
**Physical Characteristics of Jeera Cookies**

Physical characteristics	PUBF 30%	MUBF 30%	Control
Weight (g)	16.23 ± 1.46 <sup>a</sup>	16.36 ± 1.5 <sup>a</sup>	16.48 ± 0.77 <sup>a</sup>
Bulk Density(g/cm <sup>3</sup> )	0.6 ± 0.0 <sup>a</sup>	0.63 ± 0.01 <sup>a</sup>	0.626 ± 0.6 <sup>a</sup>
Specific volume (cm <sup>3</sup> /g)	1.59 ± 0.01 <sup>a</sup>	1.56 ± 0.02 <sup>a</sup>	1.63 ± 0.04 <sup>a</sup>
Thickness (mm)	5.11 ± 0.50 <sup>a</sup>	5.01 ± 0.61 <sup>a</sup>	5.35 ± 0.59 <sup>a</sup>
Diameter (mm)	37.03 ± 0.67 <sup>a</sup>	36.45 ± 1.03 <sup>a</sup>	34.98 ± 1.47 <sup>a</sup>
Spread ratio (D/T)	7.35 ± 0.56 <sup>a</sup>	7.37 ± 0.86 <sup>a</sup>	6.48 ± 0.76 <sup>a</sup>

Values are Mean ± SD of 5 cookie determinants.

Mean Values carrying the same superscript in a row do not differ significantly (P<0.05, DMRT)

The diameter of the cookie is determined by the extent of its expansion, which ranged from 34.98 to 37.03 mm. The incorporation of unripe banana flour resulted in a significantly greater diameter. The thickness of the cookies was 5 - 5.35 mm, with no significant difference observed upon the addition of UBF. According to Detchewa et al. (2021), wheat cookies exhibited a diameter of  $3.24 \pm 0.05$  cm and a thickness of  $0.66 \pm 0.28$  cm.

The spread ratio of the control cookies was 6.48, and that of the UBF cookies was 7.35-7.37. An important characteristic to determine a cookie's quality is the spread ratio, and cookies with greater expansion are typically considered preferable (Suriya et al., 2017). The weight of the cookies was around 16g for all the variations. The cookies had a bulk density of  $0.6 \text{ g/cm}^3$ . In a research study, for wheat cookies supplemented with cassava and water chestnut flour, a similar value was reported (Bala et al., 2015).

The physical attributes of the cookies depicted no significant variation, depicting acceptable attributes with the control. At 30 % UBF replacement, the functional properties of the flour, such as water-holding capacity, oil absorption capacity, and starch composition, enabled the dough to maintain its structure and texture. Sensory evaluation confirmed that this level of incorporation was well-accepted, whereas higher levels impaired dough properties and reduced acceptability. Thus, moderate UBF replacement preserves both functional and organoleptic quality.

#### 4.5.1.4. Nutrient Composition of Jeera Cookies

**Table LIII**  
**Nutrient Composition of Jeera Cookies**

Nutrient composition (per 100g)	PUBF 30%	MUBF 30%	Control
Moisture (%)	$3.25 \pm 0.05^b$	$4.04 \pm 0.05^c$	$1.89 \pm 0.01^a$
Protein (%)	$6.55 \pm 0.16^a$	$6.98 \pm 0.16^a$	$7.75 \pm 0.082^b$
Ash (%)	$1.59 \pm 0.01^a$	$1.94 \pm 0.79^a$	$1.57 \pm 0.02^a$
Fat (%)	$23.07 \pm 0.06^a$	$24.80 \pm 0.69^b$	$23.91 \pm 0.34^{ab}$
Total Carbohydrate (%)	$61.56 \pm 0.54^a$	$65.23 \pm 0.58^b$	$63.58 \pm 0.58^b$
Total Sugars (g)	$4.54 \pm 0.25^b$	$4.90 \pm 0.77^b$	$3.09 \pm 0.26^a$
Dietary Fiber (g)	$11.11 \pm 0.60^b$	$10.23 \pm 0.37^b$	$8.54 \pm 0.33^a$
Resistant Starch (g)	$12.53 \pm 1.05^b$	$10.03 \pm 1.42^b$	$1.41 \pm 0.38^a$

Values are Mean  $\pm$  SD. Mean Values carrying the same superscript in a row do not differ significantly ( $P < 0.05$ , DMRT)

The nutrient profile of PUBF and MUBF cookies is presented in Table LIII. Cookies have a good shelf life as the moisture content is typically low. The moisture content of control wheat cookies was 1.89 %, and that of PUBF and MUBF cookies was 3.25% and 4.04 %, respectively. Unripe banana flour demonstrated a higher capacity for water absorption and retention compared to wheat flour, resulting in cookies made with unripe banana flour exhibiting greater moisture content than the control cookies.

The control cookies had 7.75% protein, while the cookies containing unripe banana flour had protein levels ranging from 6.55% to 6.98%. The observed reduction in protein content with UBF inclusion is significant and can be attributed to attenuation, as UBF has less protein than wheat flour. The protein content in the biscuit formulation consisting of 20% banana flour and 80% wheat flour was reported to be 7.89% (Asif-Ul-Alam et al., 2014)

The fat content in cookies ranged between 23% and 24% without any significant difference among them because the amount of fat used in the baked products was consistent. The findings align with other research on cookies, which reported fat content ranging from 24.12% to 24.85% (Ivanišová et al., 2019).

The control cookies contained 63.5 % carbohydrates. The carbohydrates in PUBF and MUBF cookies were found to be 61.56% and 65.23 %, respectively. The resistant starch content of the control cookies was 1.41 g/100g, whereas the UBF-incorporated cookies recorded a significant increase in the RS content. The UBF-incorporated cookies had an appreciable amount of RS in the 10- 13 g/100g range. Ratnasari et al. (2018) observed that replacing wheat flour with 75% unripe banana flour in cookies increased RS content by 14.60%.

The total dietary fiber content in the control wheat cookies was 8.54 g/100g, while it ranged from 10 to 11 g/100g in the UBF samples. Incorporating UBF flour resulted in a significant increase in dietary fiber. Thus, cookies made with UBF could serve as a substantial source of fiber. Adeola and Ohizua (2018) formulated cookies with Cardaba banana and composite flour and reported dietary fiber content ranging from 11.73 to 19.05 g/100 g.

Cookies made with unripe banana flour, rich in fiber and resistant starch, are a healthier option for diet-conscious consumers. These cookies qualify as high-fiber foods according to the European Commission (2006) guidelines, which demand that food containing more than 6 g of dietary fiber per 100 g be considered a high-fiber food. Their

fiber content may improve nutritional health by lowering the glycemic index and reducing the likelihood of colon cancer, diabetes, cardiovascular diseases, and other non-communicable diseases (Ayo-Omogie, 2023).

#### 4.5.1.5. Shelf Life of Cookies

The shelf life of the cookies, as determined by total plate count, peroxide value, and % free fatty acid, is presented in Tables LIV and LV.

**Table LIV**  
**TPC of UBF Cookies**

Days	TPC Cfug in Jeera Cookies			Standards
	PUBF 30%	MUBF 30%	Control	
0	<10	<10	<10	<10 <sup>5</sup> cfu/g*  <10 <sup>4</sup> cfu/g <sup>§</sup>
1	1 x 10 <sup>1</sup>	1 x 10 <sup>1</sup>	1 x 10 <sup>1</sup>	
3	1 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	
5	1 x 10 <sup>2</sup>	2 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	

\*PHLS Advisory Committee for Food and Dairy Products Gilbert et al., (2000).

§FSSAI standards for Functional Foods (FSSAI Appendix B)

**Table LV**  
**Peroxide Value and FFA of UBF Cookies**

Days	Peroxide Value in Jeera Cookies (meq/kg)			Standards*
	PUBF 30%	MUBF 30%	Control	
0	0.2± 0.0	0.2± 0.00	0.2± 0.0	<10 meq/kg
1	0.2± 0.0	0.2± 0.00	0.2± 0.0	
3	0.2± 0.1	0.3± 0.05	0.3± 0.1	
5	0.4± 0.1	0.5± 0.05	0.5± 0.0	
<b>% Free Fatty Acids in Jeera Cookies</b>				
0	0.02± 0.00	0.05± 0.00	0.05± 0.00	Acceptable threshold 0.5%,
1	0.06± 0.01	0.06± 0.01	0.06± 0.01	
3	0.06± 0.03	0.09± 0.03	0.08± 0.03	
5	0.14± 0.03	0.18± 0.01	0.14± 0.04	

Values are Mean ± SD \*FSSAI -Chapter 2

Total plate counts served as an indicator of microbiological safety and overall microbial load. The cookies prepared in this study had good microbiological quality, and the microbial load was within acceptable levels during the 5-day shelf-life study period. Since no preservatives were added, the shelf-life study period was restricted to 5 days.

In a research study, microbiological analysis of composite flour cookies showed that the TPC of these cookies ranged from  $0 \times 10^3$  to  $4.1 \times 10^3$  during 0 to 90 days of storage. (Kukade et al., 2017). The PHLS Advisory Committee for Food and Dairy Products established standards for the microbial safety of ready-to-eat foods, including baked products like cakes, bread, and biscuits. The maximum permissible limits are: Total Plate Count (TPC) less than be  $<10^5$  cfu/g, for yeasts and moulds  $<10^4$  cfu/g, total coliforms (TC) less than 200 MPN/g, and the absence of E. coli (Gilbert et al., 2000). According to FSSAI standards for Functional Foods in process hygiene criteria, the TPC should be less than  $1 \times 10^4$  cfu/g in foods meant for direct consumption.

Peroxide values increased from 0.2 to 0.5 meq/kg during storage. This increase is primarily attributed to lipid oxidation, which accelerates during storage due to exposure to oxygen, light, and other environmental factors. The FFA values of all products remained below the acceptable threshold of 0.5%, as specified by FSSAI. Manzocco et al. (2020) stated that a product’s storage durability is primarily influenced by its susceptibility to rancidity. Kaur et al. (2023) reported initial peroxide values of 0.45 and 0.50 meq/kg for sealed and unsealed salty cookies, rising to 3.70 and 4.29 meq/kg after 90 days.

#### 4.5.2. Development and Evaluation of UBF Incorporated Muffins

##### 4.5.2.1. Standardized Recipe

**Table LVI**  
**Formulation of Muffin**

Ingredients	Muffin Variations			
	Control	UBF 15%	UBF 30%	UBF 50%
Whole Wheat Flour (g)	100	85	70	50
Unripe Banana Flour(g) PUBF/MUBF	-	15	30	50
Butter (g)	30	30	30	30
Oil (g)	20	20	20	20
Sugar (g)	50	50	50	50
Baking powder (g)	2	2	2	2
Milk (ml)	90	90	90	90
Egg (Piece)	1	1	1	1
Vanilla essence (ml)	2	2	2	2
Yield: 12 Muffins				



**Step 1: The ingredients were weighed according to the recipe formulation.**



**Step 2: The dry ingredients (whole wheat flour, unripe banana flour, and baking powder) were sifted.**



**Step 3: Butter, oil, and sugar were creamed together until light and fluffy. Vanilla essence and egg were then added, and the mixture was beaten until the fat and egg were well combined.**



**Step 4: The Sifted dry ingredients were gradually incorporated into the wet mixture. Milk was added and mixed thoroughly until a smooth, flow-consistent batter was obtained.**



**Step 5: The batter was poured into muffin moulds.**



**Step 6: Baked in a preheated oven at 170°C for 15 minutes.**  
**Step 7: After baking, the muffins were removed from the oven and allowed to cool in the moulds for 5 minutes.**  
**Step 8: Transferred to a wire rack and cooled to room temperature before packaging for further analysis**

**Figure 58: Preparation Steps of Muffins**



**Control**



**PUBF 30%**



**MUBF 30%**



**PUBF 50%**

**Plate 13: Muffins Variations**

The recipe and preparation method of muffins are presented in Table LVI and Figure 58. Muffins were formulated with 15, 20, and 50% unripe banana flour replacing the wheat flour. Muffin batter is a diverse blend of components, typically high in sugar with varying amounts of fat, flour, eggs, and baking powder. Additional elements like emulsifiers, preservatives, and milk powder enhance texture and shelf life (Baixauli et al., 2007).

Whole Wheat Flour was chosen as the main ingredient to keep the snack a healthy option rich in fiber and other nutrients. The muffin formulation included 50 grams of sugar in the recipe.

Dana and Sonia (2024) highlighted the significant role of sucrose in bakery products, enhancing sweetness, regulating moisture retention, promoting air incorporation, stabilizing air bubbles, and restricting starch swelling during baking. These functions collectively aid in achieving a finer texture.

The recipe included 30 grams of butter and 20 grams of vegetable (sunflower) oil. The inclusion of cooking oil, alongside butter, was favored for its contribution to a light, non-greasy texture and enhanced flavor balance in the final baked product. In contrast, melted butter solidifies as it cools, resulting in a denser texture. Therefore, the combination of oil and butter was used to achieve an optimal balance of texture and taste in the muffins. Eggs were vital for binding the ingredients together and contributed significantly to the overall structure of the muffins by stabilizing foam, preventing the coalescence of air bubbles, and promoting a finer, more even crumb. The proteins in eggs helped set the structure during baking, ensuring that the muffins maintained their volume and shape. Milk was used to adjust the consistency and improve the softness of the final product. Milk proteins also assisted in browning, thereby adding to the flavor and appearance of the muffins.

#### 4.5.2.2. Sensory Scores and Acceptability of UBF Incorporated Muffin

The sensory acceptability results of UBF-incorporated muffins are presented in Table LVII and Figure 59.

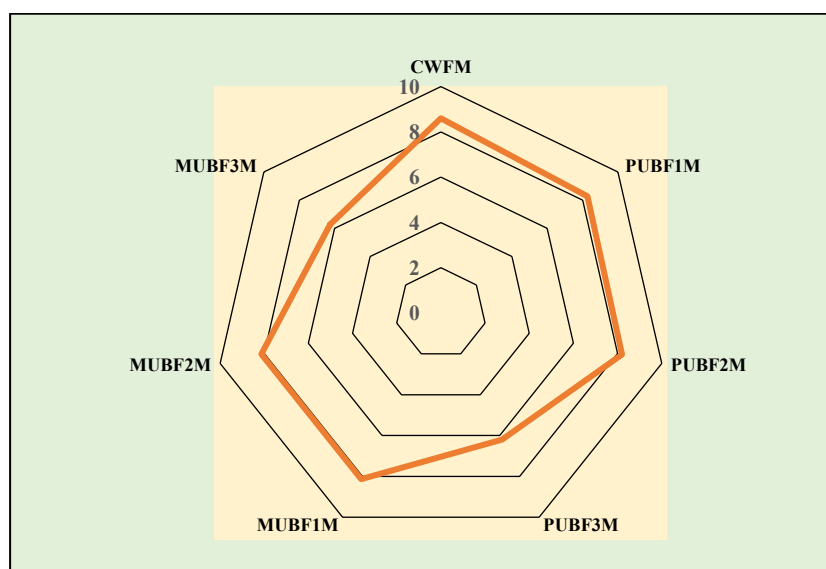
Table LVII

Mean Sensory Scores and Overall Acceptability of UBF Incorporated Muffins

Parameters	PUBF			MUBF			Control
	PUBF1M	PUBF2M	PUBF3M	MUBF1C	MUBF2M	MUBF3M	CWFM
	15%	30%	50%	15%	30%	50%	
Appearance	8.20±0.86 <sup>b</sup>	8.07±0.88 <sup>b</sup>	6.4±1.35 <sup>a</sup>	7.93±0.96 <sup>b</sup>	7.8±0.1.01 <sup>b</sup>	6.67±0.72 <sup>a</sup>	8.20±0.67 <sup>b</sup>
Taste	8.33±0.72 <sup>b</sup>	8.13±0.64 <sup>b</sup>	6.2±0.77 <sup>a</sup>	8.13±0.64 <sup>b</sup>	8.00±0.92 <sup>b</sup>	6.33±0.90 <sup>a</sup>	8.73±0.45 <sup>c</sup>
Texture	8.13±0.74 <sup>b</sup>	8.27±0.59 <sup>b</sup>	7.33±0.61 <sup>a</sup>	8.27±0.45 <sup>b</sup>	8.27±0.88 <sup>b</sup>	6.93±0.96 <sup>a</sup>	8.27±0.45 <sup>b</sup>
Flavor	8.4±0.73 <sup>d</sup>	8.07±0.59 <sup>cd</sup>	7.33±0.81 <sup>ab</sup>	8.27±0.45 <sup>cd</sup>	7.73±1.11 <sup>bc</sup>	7.06±0.96 <sup>a</sup>	8.4±0.50 <sup>d</sup>
Mouth Feel	8.4±0.73 <sup>bc</sup>	7.87±0.74 <sup>b</sup>	7.2±0.86 <sup>a</sup>	8.27±0.59 <sup>bc</sup>	7.80±0.94 <sup>b</sup>	7.13±0.91 <sup>a</sup>	8.53±0.51 <sup>c</sup>
After Taste	8.40±0.63 <sup>c</sup>	7.73±0.59 <sup>b</sup>	6.87±0.83 <sup>a</sup>	8.2±0.56 <sup>bc</sup>	7.8±1.01 <sup>b</sup>	6.67±0.90 <sup>a</sup>	8.47±0.51 <sup>c</sup>
Overall Acceptability	8.27±0.79 <sup>b</sup>	8.2±0.67 <sup>b</sup>	6.2 ±0.67 <sup>a</sup>	8.13±0.51 <sup>b</sup>	8.13±0.91 <sup>b</sup>	6.27±0.79 <sup>a</sup>	8.6±0.50 <sup>b</sup>

Values are the Mean ± SD of 15 individual sensory scores.

Mean Values carrying the same superscript in a row do not differ significantly (P<0.05, DMRT)



**Figure 59: Overall Acceptability of the Muffins**

Muffins with 15% and 30% UBF incorporation received higher acceptability scores compared to those with 50%, where a stronger aftertaste negatively impacted acceptance. One-way ANOVA showed significant differences across all attributes, and the DMRT test confirmed a significant distinction between control muffins and those with 50% UBFs. 15% and 30% UBF had similar overall acceptability compared to the control, indicating that these levels of UBF were well accepted.

#### 4.5.2.3. Physical Attributes of Muffins

Table LVIII presents the physical attributes of muffins prepared with wheat flour and UBF.

**Table LVIII**  
**Physical characteristics of Muffins**

Physical characteristics	PUBF 30%	MUBF 30%	Control
Weight (g)	25.79± 1.65 <sup>a</sup>	25.94± 1.81 <sup>a</sup>	25.82 ± 0.77 <sup>a</sup>
Volume (ml)	50.5± 0.02 <sup>a</sup>	48.5± 0.03 <sup>a</sup>	48.5 ± 0.38 <sup>a</sup>
Bulk density (g/cm <sup>3</sup> )	0.47 ± 0.03 <sup>a</sup>	0.56 ± 0.04 <sup>a</sup>	0.56 ± 0.02 <sup>a</sup>
Height (mm)	32.03 ± 0.71 <sup>a</sup>	33.18± 1.14 <sup>a</sup>	34.83 ± 1.23 <sup>a</sup>
Diameter (mm)	53.17± 0.31 <sup>a</sup>	54.95± 0.21 <sup>b</sup>	54.94± 0.76 <sup>b</sup>

Values are Mean ± SD of 5 muffin determinants.

Mean Values carrying the same superscript in a row do not differ significantly (P<0.05,DMRT)

The muffins had an average weight of 25 g, with volumes ranging between 48 and 50 mL. Bulk density values were recorded between 0.47 and 0.56 g/cm<sup>3</sup>. Muffins with UBF incorporation exhibited a slightly lower height compared to the control, while the diameter ranged from 53 to 54 mm. Overall, the products showed no statistically significant differences in the physical characteristics which authenticates the comparable UBF muffin product attributes.

Baixauli et al. (2007) examined the effects of substituting wheat flour with varying levels of resistant starch in muffins and found a significant reduction in volume, height, and porosity at 15% substitution or higher.

#### 4.5.2.4. Nutrient Composition of Muffins

Table LIX depicts the nutritional information of the 30% Peyan and Monthan flour-incorporated muffins.

**Table LIX**  
**Nutrient Composition of Muffins**

<b>Nutrient composition (per 100g)</b>	<b>PUBF 30%</b>	<b>MUBF 30%</b>	<b>Control</b>
<b>Moisture (%)</b>	21.53 ± 1.77 <sup>a</sup>	22.23 ± 0.86 <sup>a</sup>	25.16 ± 0.94 <sup>a</sup>
<b>Protein (%)</b>	5.87 ± 0.13 <sup>a</sup>	6.07 ± 0.12 <sup>ab</sup>	6.41 ± 0.08 <sup>b</sup>
<b>Ash (%)</b>	1.87 ± 0.66 <sup>a</sup>	1.77 ± 0.34 <sup>a</sup>	1.84 ± 0.11 <sup>a</sup>
<b>Fat (%)</b>	26.27 ± 1.28 <sup>a</sup>	29.35 ± 0.35 <sup>b</sup>	26.07 ± 1.61 <sup>a</sup>
<b>Total Carbohydrate (%)</b>	47.58 ± 1.16 <sup>ab</sup>	49.64 ± 1.74 <sup>b</sup>	43.89 ± 0.58 <sup>a</sup>
<b>Total Sugars (g)</b>	15.45 ± 0.25 <sup>b</sup>	16.18 ± 0.25 <sup>b</sup>	14.00 ± 0.25 <sup>a</sup>
<b>Dietary Fiber (g)</b>	4.65 ± 0.35 <sup>b</sup>	4.45 ± 0.35 <sup>ab</sup>	3.38 ± 0.30 <sup>a</sup>
<b>Resistant Starch (g)</b>	4.49 ± 0.56 <sup>b</sup>	4.17 ± 0.42 <sup>b</sup>	2.61 ± 0.54 <sup>a</sup>

Values are Mean ± SD of triplicates.

Mean Values carrying the same superscript in a row do not differ significantly (P<0.05, DMRT)

Muffins containing UBF had lower moisture content than the control. Protein levels in the UBF muffins ranged from 5.87 to 6.07 % while the wheat flour muffin contained 6.41 %. In a study by De S Viana et al. (2018), it was found that all bread formulations

containing green banana flour had lower protein values compared to the control made with wheat flour.

The fat content remained consistent across all samples. Total carbohydrates were 43 % in the control muffins, whereas the UBF muffins exhibited carbohydrate levels between 47 and 49%. Both dietary fiber and resistant starch levels in the UBF muffins were approximately 4 g/100 g, significantly higher than the control wheat muffin.

Radünz et al. (2020) documented green banana flour muffins containing a moisture content of 26% and 44% carbohydrates per 100 g. Juarez-Garcia et al. (2006) developed green banana flour bread that had higher starch content and dietary fiber, comprising 14.5% of the product's constituents.

#### 4.5.2.5. Shelf Life of Muffins

The shelf life of the muffins, as determined by total plate count, peroxide value, and % free fatty acid, is presented in Tables LX and LXI.

**Table LX**  
**TPC of Muffins**

Days	TPC (cfu/g)			Standards
	PUBF 30%	MUBF 30%	Control	
0	<10	<10	<10	< 10 <sup>5</sup> cfu/g*
1	1 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	<10 <sup>4</sup> -10 <sup>5</sup> cfu/g <sup>§</sup>
3	2 x 10 <sup>2</sup>	3 x 10 <sup>2</sup>	3 x 10 <sup>2</sup>	
5	5 x 10 <sup>2</sup>	7 x 10 <sup>2</sup>	5 x 10 <sup>2</sup>	

\*PHLS Advisory Committee for Food and Dairy Products (Gilbert *et al.*, 2000).

<sup>§</sup> FSSAI standards for Functional Foods, Egg-containing products (FSSAI Appendix B)

Table LXI

## Peroxide Value and FFA of UBF Muffins

Days	Peroxide Value (meq O <sub>2</sub> /kg)			Standards*
	PUBF 30%	MUBF 30%	Control	
0	0.44± 0.06	0.50± 0.06	0.60± 0.10	<10 meq/kg
1	0.80± 0.00	0.90± 0.10	0.90± 0.10	
3	1.10± 0.10	1.10± 0.10	1.20± 0.00	
5	1.50± 0.10	1.50± 0.10	1.80± 0.20	
<b>% Free Fatty Acids</b>				
0	0.03± 0.00	0.03± 0.00	0.07± 0.07	Acceptable threshold 0.5%
1	0.08± 0.03	0.11± 0.01	0.14± 0.03	
3	0.29± 0.01	0.32± 0.01	0.31± 0.03	
5	0.32± 0.01	0.33± 0.01	0.34± 0.00	

Values are Mean ± SD of triplicate \* FSSAI

The prepared muffin had a good shelf life of 5 days with microbiological quality standards determined by TPC. On day 5, the TPC ranged from  $5 \times 10^2$  for PUBF and  $7 \times 10^2$  for MUBF.

Kumar et al. (2021b) documented an increasing trend in TPC, and the results showed that the control muffin samples were deemed unacceptable by the 6th day, while muffins containing pure and encapsulated squalene were rejected on the 8th day.

The peroxide value and free fatty acid values were within the standard limits at the end of the shelf-life period.

### 4.5.3. Development and Evaluation of UBF Incorporated Baked Choco Cereal

#### 4.5.3.1. Standardized recipe

The composition of formulated baked choco cereal with unripe banana flour incorporation is shown in Table LXII, and the steps in preparation are depicted in Figure 60.

**Table LXII**

#### **Formulation of Baked Choco Cereal**

Ingredients %	Baked Choco cereal Variations			
	Control	UBF 15%	UBF 30%	UBF 50%
Whole Wheat Flour (g)	100	85	70	50
Unripe Banana Flour(g) PUBF/ MUBF	Nil	15	30	50
Cocoa Powder (g)	10	10	10	10
Baking powder (g)	0.25	0.25	0.25	0.25
Sugar (g)	8	8	8	8
Butter (g)	3	3	3	3

Baked choco cereal was developed using whole wheat flour, with unripe banana flour incorporated at levels of 15%, 30%, and 50% to create a product rich in dietary fiber, resistant starch, and bioactive compounds. Natural unsweetened cocoa powder was used to bring in a chocolate flavor. When combined with baking soda, an alkaline ingredient, the acidic nature of natural cocoa powder triggers a leavening reaction, helping the batter rise during baking. The preparation method involved adding a small amount of water to a dry mix, which hydrates the starch and protein polymers while acting as a plasticizer, followed by a thermal processing step. The developed baked choco cereal is crispy, ideal as a snack or as a breakfast food when dipped in milk.

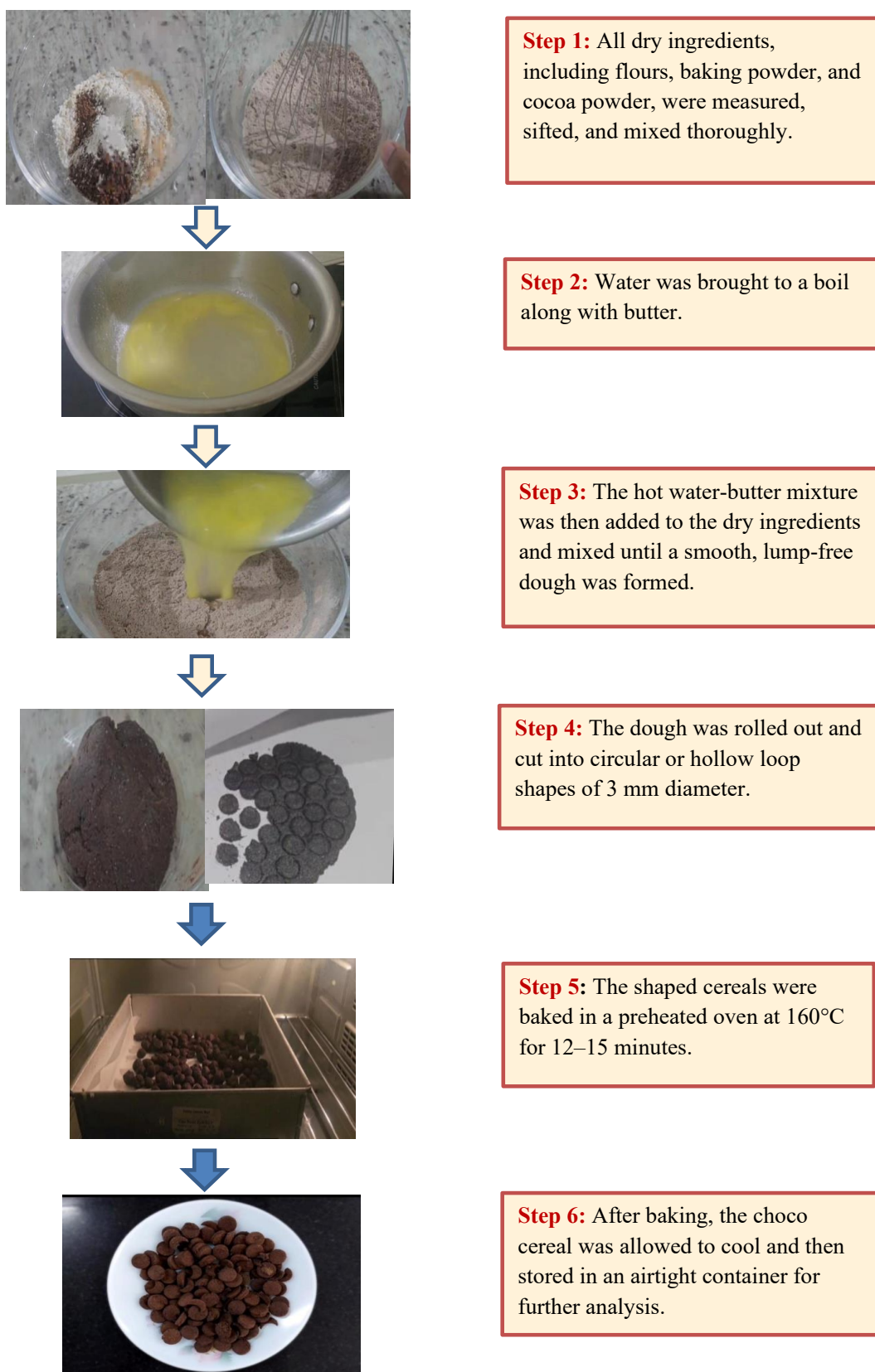


Figure 60: Preparation steps of Baked Choco Cereal



Control

30% PUBF

30% MUBF

Plate 14: Baked Choco Cereal Variations

#### 4.5.3.2. Sensory Scores and Acceptability of UBF Incorporated Baked Choco Cereal

The sensory acceptability results of UBF-incorporated baked choco cereal are presented in Table LXIII and Figure 61.

Table LXIII

Sensory Scores and Acceptability of UBF Incorporated Baked Choco Cereal

Parameters	PUBF			MUBF			Control
	PUBF1B	PUBF2B	PUBF3B	MUBF1B	MUBF2B	MUBF3B	CWFB
	15%	30%	50%	15%	30%	50%	
Appearance	8.07±0.79 <sup>b</sup>	7.66±0.81 <sup>b</sup>	6.47±0.51 <sup>a</sup>	7.93±0.96 <sup>b</sup>	7.73±0.96 <sup>b</sup>	6.33±0.72 <sup>a</sup>	7.93±0.70 <sup>b</sup>
Taste	8.06±0.59 <sup>b</sup>	7.66±0.82 <sup>b</sup>	6.20±0.56 <sup>a</sup>	7.53±0.74 <sup>b</sup>	7.87±0.83 <sup>b</sup>	6.06±0.67 <sup>a</sup>	7.73±0.96 <sup>b</sup>
Texture	7.73±0.79 <sup>b</sup>	7.67±0.90 <sup>b</sup>	6.87±0.64 <sup>a</sup>	7.93±0.70 <sup>b</sup>	7.93±0.88 <sup>b</sup>	6.53±0.74 <sup>a</sup>	8.13±0.51 <sup>b</sup>
Flavor	8.4±0.71 <sup>d</sup>	7.66±0.69 <sup>bc</sup>	7.26±0.77 <sup>ab</sup>	8.2±0.57 <sup>cd</sup>	7.66±1.07 <sup>bc</sup>	6.93±0.92 <sup>a</sup>	8.4±0.48 <sup>d</sup>
Mouth Feel	7.8±0.67 <sup>bc</sup>	7.73±0.70 <sup>bc</sup>	7.2±0.86 <sup>ab</sup>	8.13±0.51 <sup>c</sup>	7.73±0.96 <sup>bc</sup>	6.93±0.79 <sup>a</sup>	7.33±0.69 <sup>ab</sup>
After Taste	8.07±0.59 <sup>cd</sup>	7.47±0.51 <sup>b</sup>	6.47±0.51 <sup>a</sup>	7.87±0.64 <sup>bcd</sup>	7.67±1.17 <sup>bc</sup>	6.47±0.61 <sup>a</sup>	8.27±0.45 <sup>d</sup>
Overall Acceptability	8.2±0.77 <sup>c</sup>	7.80±0.56 <sup>c</sup>	6.20 ±0.67 <sup>a</sup>	7.87 ±0.64 <sup>c</sup>	7.07±0.70 <sup>b</sup>	6.13±0.74 <sup>a</sup>	8.2±0.77 <sup>c</sup>

Values are Mean ± SD of 15 individual sensory scores.

Mean Values carrying the same superscript in a row do not differ significantly (P<0.05, DMRT)

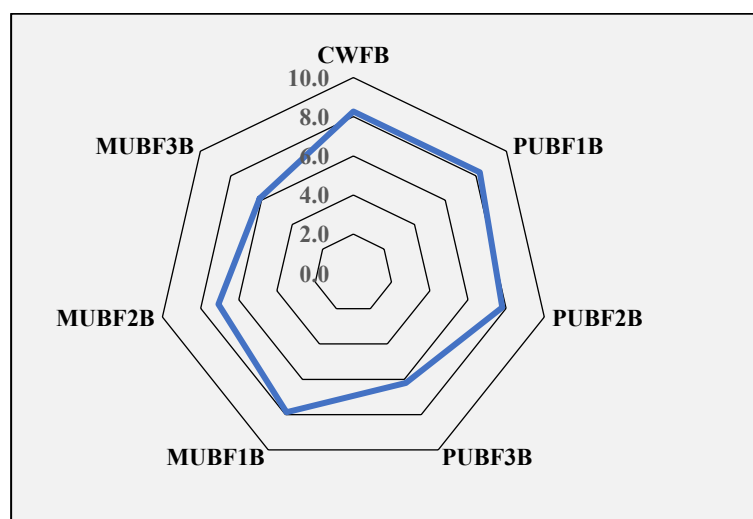


Figure 61: Overall acceptability of Baked Choco Cereals

The baked choco cereals incorporating 15% PUBF and MUBF achieved higher acceptability scores, comparable to those of control wheat flour cereals. The cereals with 30% UBF incorporation received acceptable scores of 7 and above. One-way ANOVA revealed significant differences across all evaluated attributes, and DMRT Post Hoc test confirmed a notable distinction between the control baked choco cereal and those containing 50% UBF.

#### 4.5.3.3. Nutrient composition of Baked Choco Cereal

Table LXIV depicts the nutritional information of the 30% Peyan and Monthan flour incorporated baked choco cereal.

Table LXIV

Nutritional Composition of Baked Breakfast Cereal

Nutrient composition (per 100g)	PUBF 30%	MUBF 30%	Control
Moisture (%)	3.00 ± 0.28 <sup>a</sup>	3.04 ± 0.28 <sup>a</sup>	3.20 ± 0.42 <sup>a</sup>
Protein (%)	5.55 ± 0.63 <sup>a</sup>	5.90 ± 0.14 <sup>a</sup>	6.80 ± 0.56 <sup>a</sup>
Ash (%)	1.38 ± 0.24 <sup>a</sup>	1.34 ± 0.33 <sup>a</sup>	1.28 ± 0.20 <sup>a</sup>
Fat (%)	2.87 ± 0.03 <sup>a</sup>	3.21 ± 0.90 <sup>a</sup>	2.90 ± 0.28 <sup>a</sup>
Total Carbohydrate (%)	73.84 ± 1.63 <sup>a</sup>	75.73 ± 0.63 <sup>a</sup>	75.74 ± 1.62 <sup>a</sup>
Total Sugars (g)	11.58 ± 0.40 <sup>a</sup>	11.52 ± 0.62 <sup>a</sup>	10.54 ± 0.62 <sup>a</sup>
Dietary Fiber (g)	9.85 ± 0.35 <sup>b</sup>	8.49 ± 0.78 <sup>a</sup>	8.27 ± 0.14 <sup>a</sup>
Resistant Starch (g)	6.27 ± 0.53 <sup>b</sup>	5.17 ± 0.42 <sup>b</sup>	1.24 ± 0.38 <sup>a</sup>

Values are Mean ± SD of triplicates.

Mean Values carrying the same superscript in a row do not differ significantly ( $P < 0.05$ , DMRT)

The baked choco cereals exhibited a moisture content of 3%. The cereal's protein varied between 5.5% and 6.8%. The total mineral content depicted no significant variation. The carbohydrates were quantified to be between 73% and 75%, while total sugars ranged from 10 to 11 g/100g. PUBF cereals had significantly higher fiber content. According to Codex standards (1997), the baked choco cereals qualify as high fiber foods.

The moisture content of composite flour breakfast cereals ranged from 3.36-3.61% in a research by Okafor and Usman (2013). Digestible carbohydrates, including starch and sugar, ranged from 63- 80% in breakfast cereals developed from sprouted and unspouted Ryegrass with maize (Lima et al., 2023).

Foods like breakfast cereals are low in resistant starch, less than 2.5% (Goni et al., 1996). The incorporation of UBF resulted in a notable rise in resistant starch compared to the wheat breakfast cereal. 30% PUBF and MUBF choco cereals presented an appreciable RS content of  $6.27 \pm 0.53$  and  $5.17 \pm 0.42$  g/100g, respectively.

Due to the health benefits associated with foods high in RS and their reduced glycemic impact, demand is increasing for RS-enriched foods (Birt et al., 2013). The developed breakfast cereal made with whole wheat flour and unripe banana flour offers a nutritionally balanced option with significant resistant starch content, making it a healthier choice.

#### 4.5.3.4. Shelf life of Baked Choco Cereal

The results of shelf-life studies of the muffins are presented in Tables LXV and LXVI.

**Table LXV**  
**TPC of Baked Choco Cereal**

Days	TPC of Baked Choco Cereal (cfu/g )			Standards
	PUBF 30%	MUBF 30%	Control	
0	<10	<10	<10	< 10 cfu/g* <10 <sup>4</sup> -10 <sup>5</sup> cfu/g <sup>§</sup>
30	1 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	
60	1 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	
90	3 × 10 <sup>2</sup>	3.6 × 10 <sup>2</sup>	3 × 10 <sup>2</sup>	

\*Edo et al., 2022, <sup>§</sup> FSSAI standards for Functional Foods (FSSAI Appendix B)

**Table LXVI**  
**Peroxide Value and FFA of UBF Baked Choco Cereal**

Days	Peroxide Value (meq O <sub>2</sub> /kg)			Standards*
	PUBF 30%	MUBF 30%	Control	
0	0.3± 0.0	0.2± 0.0	0.3± 0.1	<10 meq/kg
30	0.7± 0.5	1.0± 0.0	0.6± 0.41	
60	1.6± 0.1	1.5± 0.1	0.7± 0.9	
90	3.7± 0.1	4.1± 0.1	4.6± 0.9	
<b>% Free Fatty Acids</b>				
0	0.03± 0.00	0.05± 0.00	0.03± 0.00	Acceptable threshold 0.5%
30	0.07± 0.02	0.08± 0.00	0.14± 0.01	
60	0.29± 0.01	0.32± 0.03	0.32± 0.03	
90	0.36± 0.03	0.37± 0.04	0.42± 0.04	

Values are Mean ± SD of triplicates. \* FSSAI

The shelf life of baked choco cereal, as determined by microbiological standards, was found to be acceptable at  $3-3.6 \times 10^2$  cfu/g on the 90<sup>th</sup> day. The low moisture content and dry heat cooking process had rendered the product shelf-stable. As per the guidelines given by the Center for Food Safety on the microbiological standards for ready-to-eat foods, these counts fall within acceptable limits. The guidelines classify total viable counts below  $10^4$  cfu/g as satisfactory, between  $10^4$  and  $10^6$  cfu/g as acceptable, and above  $10^6$  cfu/g as unsatisfactory. (Edo et al., 2022)

Owheruo et al. (2023) reported a TPC of  $2.7-2.8 \times 10^2$  cfu/g in millet and yam-based breakfast cereal.

The peroxide value rose from 0.2–0.3 to 3.7–4.6 meq kg over 90 days in the baked breakfast cereal. The % FFA increased from 0.03–0.05 % to 0.36–0.42 % during the study period, but they were within the standard thresholds.

Singh et al. (2020) reported a significant impact of storage on FFA and PV in breakfast cereal, with FFA increasing from 0.25% to 0.61% and PV from 0.80 to 1.61 meq / kg over three months.

#### 4.5.4. Development and Evaluation of UBF Incorporated Noodles

##### 4.5.4.1. Standardized recipe

The composition of formulated noodles with unripe banana flour incorporation is shown in Table LXVII, and the steps in preparation are depicted in Figure 62.

**Table LXVII**  
**Formulation of Noodles**

Product Codes / Ingredients %	Noodles Variations			
	Control	UBF 15%	UBF 30%	UBF 50%
Whole Wheat Flour (g)	100	85	70	50
Unripe Banana Flour(g) PUBF/ MUBF	Nil	15	30	50
Olive Oil (g)	3	3	3	3
Guar gum (g)	0.25	0.25	0.25	0.25
Salt (g)	1	1	1	1
Warm Water	As required (40-50 ml of water for 100 g of flour)			

Wheat flour with UBF incorporated in varying proportions was extruded into noodles. Wheat flour is fundamental to noodle quality, with its protein playing a vital role in forming the matrix, thus making it difficult to completely substitute wheat in noodle production. The addition of non-conventional flours to wheat flour can significantly impact its functional properties. The functional characteristics of the unripe banana flour were found to be suitable, and hence, the replacement of wheat with UBF was possible. Incorporating UBF in the noodles, replacing wheat flour at 15, 30 and 50%, resulted in a product with enhanced dietary fiber, resistant starch, and phytonutrients.



Figure 62: Preparation steps of Noodles

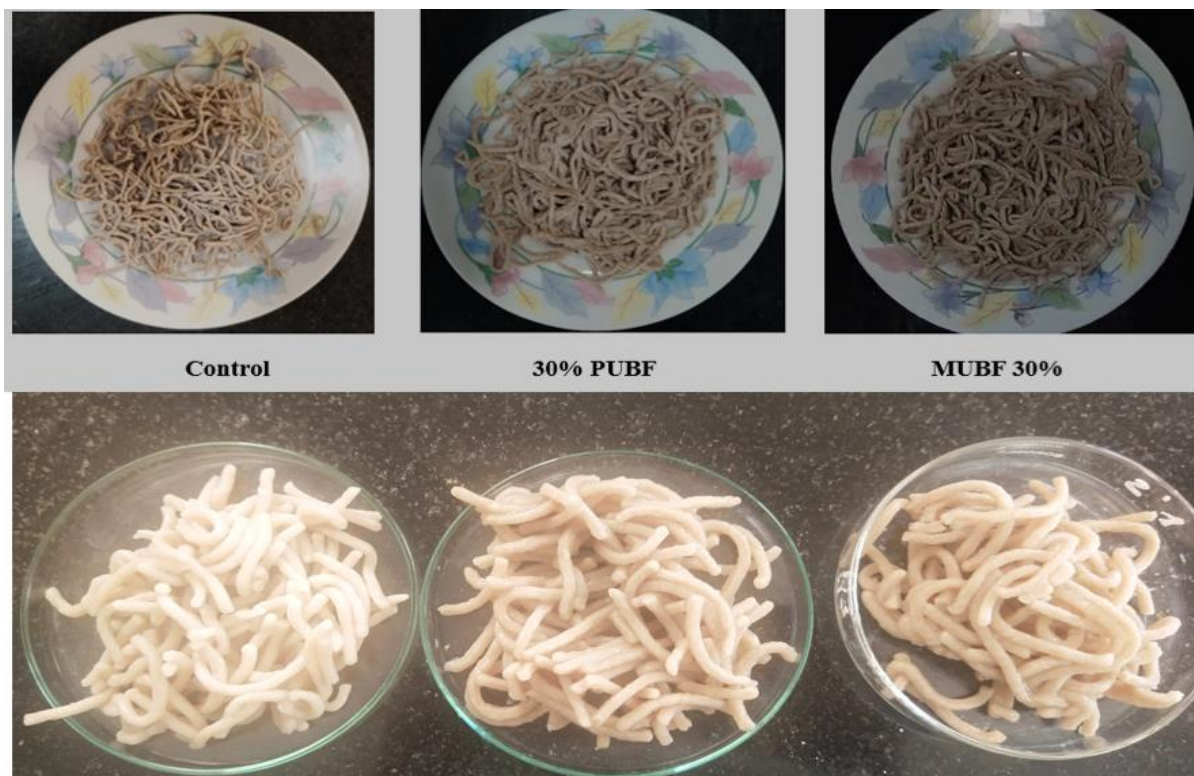


Plate 15: Dry Noodles and Cooked Noodles Variations

#### 4.5.4.2. Sensory Scores and Acceptability of UBF Incorporated Noodles

The sensory acceptability results of UBF-incorporated noodles are presented in Figure 63 and Table LXVIII.

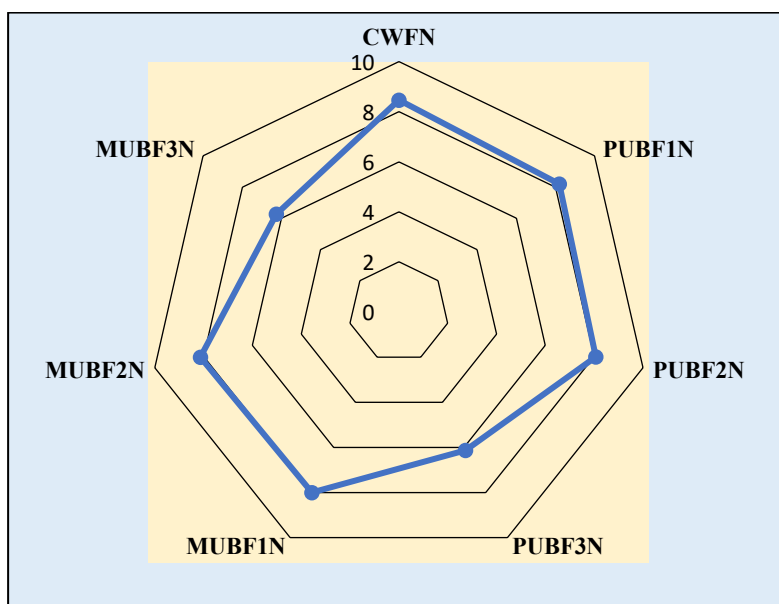


Figure 63: Overall Acceptability of Noodles

**Table LXVIII**  
**Sensory Scores and Acceptability of UBF Incorporated Noodles**

Parameters	PUBF			MUBF			Control
	PUBF1N	PUBF2N	PUBF3N	MUBF1N	MUBF2N	MUBF3N	CWFN
	15%	30%	50%	15%	30%	50%	
<b>Appearance</b>	8.13±0.91 <sup>b</sup>	7.93±0.79 <sup>b</sup>	6.47±1.40 <sup>a</sup>	8.07±0.79 <sup>b</sup>	7.87±0.99 <sup>b</sup>	6.73±0.70 <sup>a</sup>	8.07±0.79 <sup>b</sup>
<b>Taste</b>	7.93±0.79 <sup>bc</sup>	7.6±0.91 <sup>b</sup>	6.33±0.61 <sup>a</sup>	8.07±0.70 <sup>bc</sup>	7.93±0.96 <sup>bc</sup>	6.13±0.74 <sup>a</sup>	8.47±0.64 <sup>c</sup>
<b>Texture</b>	8.07±0.88 <sup>b</sup>	7.93±0.79 <sup>b</sup>	7.13±0.74 <sup>a</sup>	8.13±0.51 <sup>b</sup>	7.87±1.06 <sup>b</sup>	6.87±0.99 <sup>a</sup>	8.20±0.56 <sup>b</sup>
<b>Flavor</b>	8.33±0.78 <sup>c</sup>	8.0±0.63 <sup>bc</sup>	7.2±0.77 <sup>a</sup>	8.20±0.54 <sup>bc</sup>	7.6±1.08 <sup>ab</sup>	7.00±0.96 <sup>a</sup>	8.33±0.47 <sup>c</sup>
<b>Mouth Feel</b>	8.33±0.69 <sup>cd</sup>	7.80±0.65 <sup>c</sup>	7.20±0.83 <sup>ab</sup>	8.20±0.54 <sup>cd</sup>	7.73±0.92 <sup>bc</sup>	7.07±0.92 <sup>a</sup>	8.47±0.49 <sup>d</sup>
<b>After Taste</b>	8.13±0.74 <sup>cd</sup>	7.53±0.51 <sup>b</sup>	6.60±0.82 <sup>a</sup>	8.07±0.77 <sup>bcd</sup>	7.67±0.90 <sup>bc</sup>	6.53±0.91 <sup>a</sup>	8.40±0.50 <sup>d</sup>
<b>Overall Acceptability</b>	8.20±0.74 <sup>b</sup>	8.13±0.88 <sup>b</sup>	6.13 ±0.64 <sup>a</sup>	8.00 ±0.63 <sup>b</sup>	8.07±0.70 <sup>b</sup>	6.27±0.77 <sup>a</sup>	8.47±0.49 <sup>d</sup>

Values are Mean ± SD of 15 individual sensory scores.

Mean Values carrying the same superscript in a row do not differ significantly (P<0.05,DMRT)

The analysis of sensory scores indicates that the control noodles consistently outperformed other formulations across all evaluated parameters, making them the most acceptable variant. The highest overall acceptability was recorded for control (8.47±0.49), followed by 15 and 30% UBF samples, with no significant difference among them by DMRT post hoc test. However, 50% variation had a significantly lower preference. Overall, the use of UBF in noodle preparation at 15% and 30% shows promise in delivering a nutritious, functional food product with satisfactory sensory characteristics.

According to a study, varying the percentage of banana starch in the formulations did not significantly affect any of the sensory parameters, and all noodle samples had good acceptability. (Islam et al. 2024). In another research study, based on organoleptic evaluation, the incorporation of 45% unripe banana flour in noodles was deemed highly acceptable.

#### 4.5.4.3 Cooking Properties of Noodles

The cooking time and yield of the noodles are presented in Table LXIX.

**Table LXIX**

#### Cooking Properties of Noodles

Cooking properties	PUBF 30%	MUBF 30%	Control
Cooked weight (10 g dry noodles)	35.67 ± 1.13	34.16± 1.23	34.16 ± 1.23
Cooking time (min)	9± 0.6	9.3± 0.5	10.5 ± 0.5

Values are Mean ± SD of triplicates

The time taken to cook the control noodles was 10 min, and the addition of UBF had led to a slight drop in the cooking time. The addition of non-gluten flours weakens the gluten strength, disrupting the overall structure. This facilitates heat transfer during cooking, resulting in faster cooking times. In a research work on composite spaghetti, the cooking time decreased on increasing the levels of UBF (Osorio-Díaz et al., 2014)

The cooked weight of 10g dry noodles is 34-35g, thrice the yield.

#### 4.5.4.4. Nutrient Composition of Noodles

Table LXX indicates the nutrient composition of UBF-incorporated noodles.

**Table LXX**

#### Nutrient Composition of Noodles

Nutrient composition (per 100g)	PUBF 30%	MUBF 30%	Control
Moisture (%)	4.01 ±0.12 <sup>a</sup>	4.40 ±0.31 <sup>a</sup>	4.17±0.55 <sup>a</sup>
Protein (%)	4.95±0.01 <sup>a</sup>	5.35±0.03 <sup>b</sup>	6.28±0.09 <sup>c</sup>
Ash (%)	2.01±0.08 <sup>ab</sup>	3.11±0.86 <sup>b</sup>	1.26±0.23 <sup>a</sup>
Fat (%)	1.89 ±0.05 <sup>a</sup>	2.21±0.90 <sup>a</sup>	1.95±0.24 <sup>a</sup>
Total Carbohydrate (%)	76.95 ±1.48 <sup>ab</sup>	78.25±1.06 <sup>b</sup>	73.80 ±1.13 <sup>a</sup>
Total Sugars (g)	3.82 ±0.25 <sup>b</sup>	3.45 ±0.25 <sup>ab</sup>	2.73 ±0.26 <sup>a</sup>
Dietary Fiber (g)	7.25±0.21 <sup>b</sup>	7.10±0.28 <sup>b</sup>	6.27±0.24 <sup>a</sup>

Values are Mean ± SD of triplicates.

Mean Values carrying the same superscript in a row do not differ significantly (P<0.05,DMRT)

The moisture levels across the samples were relatively consistent,  $4.01 \pm 0.12\%$  to  $4.40 \pm 0.31\%$ . The control noodles had 6.28 % protein while UBF samples had lower values of 4.95% and 5.35%. This suggests that incorporating UBF slightly reduces the protein content compared to the control, but the UBF products had significantly higher mineral content.

Total fat was comparable across all samples, with no significant difference. The total carbohydrate content increased with the inclusion of UBF. Dietary fiber content was notably higher in noodles with UBF (7g/100g), compared to the control (6.27 g/100g). The increase in dietary fiber is a key nutritional benefit of adding UBF.

**Table LXXI**  
**Comparison of the Resistant Starch of UBF Noodles Dry and Cooked**

Samples	RS in Dry Noodles (g/ 100g)	RS in Cooked Noodles (g/100g)
30% PUBF	$36.01 \pm 0.14^b$	$11.95 \pm 0.07^b$
30% MUBF	$35.80 \pm 0.23^b$	$10.75 \pm 0.91^b$
Control	$12.28 \pm 0.94^a$	$2.1 \pm 0.14^a$

Values are Mean  $\pm$  SD of triplicates.

Mean Values carrying the same superscript in a column do not differ significantly ( $P < 0.05$ )

Wheat flour, the primary ingredient in noodles, contains resistant starch of less than 0.4 g/100 g. The preparation of instant noodles involves several processing stages, including dough formation and extrusion. Most studies indicate that cooking starch promotes the development of RS (Dhital et al., 2010).

RS in uncooked control dry noodles was 12.28 g/ 100g, and on cooking, the RS content was found to be 2.1g/ 100g. In UBFs, dry noodles' RS content was significantly high (36 g/ 100 g), and on cooking, the RS content reduced to 10-11 g/ 100g.

The observed reduction in resistant starch during cooking is primarily attributable to moist heat-induced gelatinization, wherein the native crystalline structure of starch granules is disrupted, increasing their susceptibility to enzymatic digestion. In noodles enriched with unripe banana flour, a significant fraction of RS was retained due to the intrinsic structural properties of banana starch and retrogradation-prone amylose fractions.

Islam et al. (2024) prepared instant wheat noodles incorporated with green banana starch. The study found that increasing banana starch significantly raised RS levels, with the control having 0.81 g/100 g and noodles with 11.75% banana starch containing 8.67 g/ 100 g. In a research work, cooked noodles with 10% and 20% green banana flour in white salted noodles had a resistant starch content of 7.16 and 10.92 %, respectively. 20% Hylon, a

commercial RS source incorporated in the white salted noodles, had 14.12% RS. (Li et al., 2022).

The incorporation of unripe banana flour (UBF) with wheat flour produces a dough with suitable strength and extensible texture, enabling the noodles to maintain a firm and elastic structure while also increasing the resistant starch (RS) content.

#### 4.5.4.5. Shelf Life of Noodles

The results of shelf-life parameters are presented in Tables LXXII and LXXIII.

**Table LXXII**

#### Total Plate count of Dry Noodles during Shelf life

Days	TPC cfu/g			Standards
	PUBF 30%	MUBF 30%	Control	
0	<10	<10	<10	<10 <sup>6</sup> cfu/g <sup>s</sup>
30	1 x 10 <sup>1</sup>	2 x 10 <sup>1</sup>	2 x 10 <sup>1</sup>	
60	1 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	
90	2 x 10 <sup>2</sup>	3 x 10 <sup>2</sup>	2 x 10 <sup>2</sup>	

<sup>s</sup>FSSAI standards for Functional Foods (Appendix B)

**Table LXXIII**

#### Peroxide Value and FFA of UBF Dry Noodles

Days	Peroxide Value (meq O <sub>2</sub> /kg)			Standards*
	PUBF 30%	MUBF 30%	Control	
0	0.20± 0.0	0.2± 0.0	0.2± 0.2	< 10 meq/kg
30	0.45± 0.05	0.7± 0.0	0.7± 0.3	
60	0.45± 0.1	0.9± 0.1	0.8± 0.3	
90	1.10± 0.1	1.30± 0.3	1.8± 0.3	
<b>% Free Fatty Acids</b>				
0	0.04 ± 0.01	0.06 ± 0.0	0.05 ± 0.0	Acceptable threshold 1.5%,
30	0.12 ± 0.01	0.19 ± 0.11	0.19 ± 0.11	
60	0.14± 0.03	0.25 ± 0.03	0.25 ± 0.11	
90	0.32 ± 0.01	0.36 ± 0.11	0.31 ± 0.03	

Values are Mean ± SD of triplicates \* FSSAI

Noodles are shelf-stable foods as they are low in moisture, and the microbial load was within the safe limits. The microbial quality of the control and UBF noodles was  $2-3 \times 10^2$  cfu/g. The peroxide value and free fatty acid showed an increasing trend, and at the end of 3 months, the peroxides were 1.10-1.8 meq O<sub>2</sub>/kg, and the % FFA was 0.3 %.

#### 4.5.5. Development and Evaluation of UBF Incorporated Pasta

##### 4.5.5.1 Standardized Recipe

The composition of formulated pasta with unripe banana flour incorporation is shown in Table LXXIV, and the steps in preparation are depicted in Figure 64.

**Table LXXIV**  
**Formulation of Pasta**

Ingredients	Pasta Variations			
	Control	UBF 15%	UBF 30%	UBF 50%
Whole Wheat Flour (g)	100	85	70	50
Unripe Banana Flour(g) PUBF/ MUBF	Nil	15	30	50
Olive Oil ( g)	3	3	3	3
Guar gum (g)	0.25	0.25	0.25	0.25
Salt (g)	1	1	1	1
Warm Water	As required (50-60 ml of water for 100 g of flour)			

Pasta was made by combining milled wheat and water with other ingredients like salt and olive oil, and was processed in a domestic continuous extruder equipped with various dies that shape the product. The pasta was then dried and packed. Whole wheat flour usually produces a denser pasta that requires slightly more water for the dough. It has a brownish-yellow color and is richer in vitamins and fiber than refined flour (Fuad & Prabhasankar, 2010). Guar gum, a water-soluble polysaccharide (Kaur et al., 2015), shields starch granules from shear forces during cooking, enhancing the texture of the final product. While oil is not essential for making pasta, its addition results in a smoother, silkier texture and facilitates easier extrusion from the pasta machine. Olive oil is typically used, as it also enhances the flavor.



**Step1:** All the ingredients were gathered and weighed as per recipe formulation.



**Step 2: Dough Preparation:** Whole wheat flour, unripe banana flour (PUBF/MUBF), olive oil, guar gum, salt, and warm water were combined and kneaded in a domestic pasta maker for 30 minutes to obtain a homogeneous dough.



**Step 3: Extrusion and Cutting:** The dough was extruded as rigatoni (16 mm diameter) using a domestic pasta maker and cut into 25 mm lengths as it emerged from the pasta roller.



**Step 4: Drying Process:** The extruded pasta was air-dried for 15 minutes, followed by drying in a tray dryer at 60°C for 3 hours.



**Step 5: Cooling and Storage:** The dried pasta was brought to room temperature and stored in LDPE zip bags at room temperature for further analysis.

Figure 64: Preparation steps of Pasta



Plate 16: Pasta Variations

#### 4.5.5.2. Sensory Scores and Acceptability of UBF Incorporated Pasta

Table LXXV and Figure 65 present the sensory scores and overall acceptability of UBF-incorporated Pasta

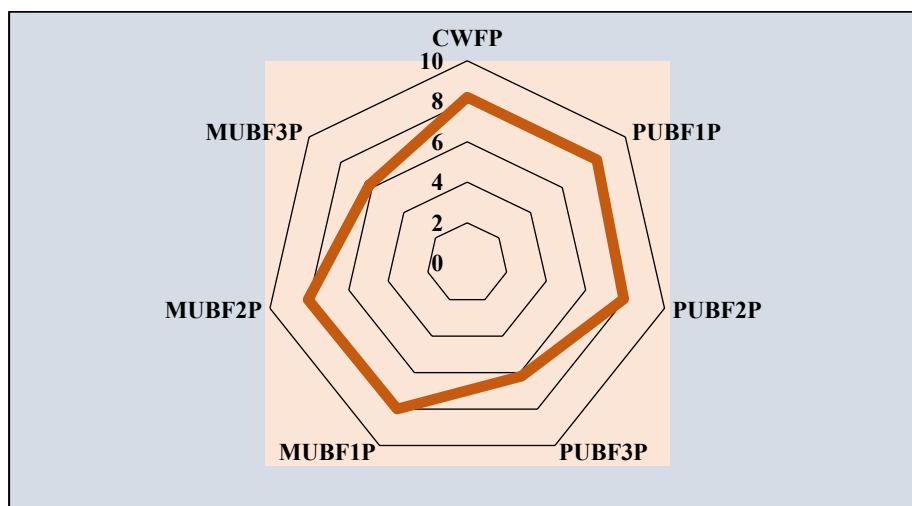
Table LXXV

Sensory Scores and Acceptability of UBF Incorporated Pasta

Parameters	PUBF			MUBF			Control
	PUBF1P	PUBF2P	PUBF3P	MUBF1P	MUBF2P	MUBF3P	CWFP
	15%	30%	50%	15%	30%	50%	
<b>Appearance</b>	8.07±0.88 <sup>b</sup>	7.67±0.48 <sup>b</sup>	6.80±0.56 <sup>a</sup>	7.93±0.70 <sup>b</sup>	7.73±0.88 <sup>b</sup>	6.47±0.51 <sup>a</sup>	7.93±0.70 <sup>b</sup>
<b>Taste</b>	8.00±0.75 <sup>bc</sup>	7.67±0.81 <sup>b</sup>	6.27±0.59 <sup>a</sup>	8.13±0.64 <sup>bc</sup>	7.87±0.99 <sup>bc</sup>	6.07±0.70 <sup>a</sup>	8.27±0.59 <sup>c</sup>
<b>Texture</b>	8.13±0.83 <sup>b</sup>	7.87±0.74 <sup>b</sup>	6.87±0.74 <sup>a</sup>	7.93±0.25 <sup>b</sup>	7.93±0.96 <sup>b</sup>	6.53±0.91 <sup>a</sup>	8.13±0.51 <sup>b</sup>
<b>Flavor</b>	8.4±0.82 <sup>d</sup>	8.06±0.67 <sup>cd</sup>	7.33±0.69 <sup>ab</sup>	8.27±0.57 <sup>cd</sup>	7.67±1.07 <sup>bc</sup>	6.93±0.92 <sup>a</sup>	8.40±0.50 <sup>d</sup>
<b>Mouth Feel</b>	8.4±0.61 <sup>d</sup>	7.66±0.59 <sup>bc</sup>	7.2±0.83 <sup>ab</sup>	8.13±0.61 <sup>cd</sup>	7.73±0.92 <sup>bc</sup>	6.93±0.92 <sup>a</sup>	8.33±0.47 <sup>d</sup>
<b>After Taste</b>	8.06±0.77 <sup>cd</sup>	7.46±0.49 <sup>b</sup>	6.40±0.71 <sup>a</sup>	7.86±0.80 <sup>bcd</sup>	7.66±0.86 <sup>bc</sup>	6.46±0.88 <sup>a</sup>	8.26±0.48 <sup>d</sup>
<b>Overall Acceptability</b>	8.20±0.74 <sup>b</sup>	7.93±0.57 <sup>b</sup>	6.20 ±0.54 <sup>a</sup>	8.00 ±0.63 <sup>b</sup>	8.07±0.85 <sup>b</sup>	6.20±0.74 <sup>a</sup>	8.20±0.54 <sup>b</sup>

Values are Mean ± SD of 15 individual sensory scores.

Mean Values carrying the same superscript in a row do not differ significantly (P<0.05)



**Figure 65: Overall Acceptability of the developed Pastas**

Products with a 15% incorporation of unripe banana flour were most preferred by panellists. Since products with 30% incorporation received acceptable scores above 7, they were chosen for further study due to their enhanced nutritional and bioactive content. The score for the appearance of the 50% incorporation was below acceptability. On cooking, a more pronounced darkening of the pasta was observed, making the product less acceptable. The banana flour pasta made had a darker color compared to the wheat control, which was considered an undesirable change, but consumers may perceive a darker color as enhanced nutrition.

Biernacka et al. (2020) partially substituted wheat flour with banana powder to develop pasta. This addition affected the pasta's color and cooking properties, resulting in a brighter uncooked pasta compared to the control, while cooked banana pasta was darker. Furthermore, the optimal cooking time decreased.

#### 4.5.5.3. Cooking properties of Pasta

**Table LXXVI**

**Cooking Properties of Pasta**

Cooking properties	PUBF 30%	MUBF 30%	Control
Cooked weight (per 10 g dry pasta)	22.42± 0.53	24.3 ± 0.83	27.22± 0.53
Cooking time (min)	14± 0.5	15± 0.23	14± 0.5

Values are Mean ± SD of triplicates

The cooking yield of the pasta was 22-24g per 10g. The cooking time was calculated based on the disappearance of the white colour in the pasta's central core, as evaluated after squeezing it between two glass slides, and it was recorded to be 14-15 minutes. In a research study, a higher cooked weight of 33-35% was reported. (Gull et al., 2016).

#### 4.5.5.4. Nutrient Composition of Pasta

**Table LXXVII**  
**Nutrient Composition of Pasta**

Nutrient composition (per 100g)	PUBF 30%	MUBF 30%	Control
Moisture (%)	3.74 ±0.14 <sup>a</sup>	5.06 ±0.61 <sup>ab</sup>	5.41±0.49 <sup>b</sup>
Protein (%)	4.20±0.19 <sup>a</sup>	4.40±0.25 <sup>ab</sup>	5.20±0.23 <sup>b</sup>
Ash (%)	2.06±0.05 <sup>ab</sup>	2.49±0.46 <sup>b</sup>	1.43±0.13 <sup>a</sup>
Fat (%)	3.11 ±0.03 <sup>a</sup>	2.92 ± 0.46 <sup>a</sup>	3.02±0.11 <sup>a</sup>
Total Carbohydrate (%)	78.35 ±0.58 <sup>b</sup>	80.41 ±1.16 <sup>b</sup>	70.97±0.58 <sup>a</sup>
Total Sugars (g)	2.90 ±0.51 <sup>a</sup>	2.72 ±0.25 <sup>a</sup>	2.72 ±0.26 <sup>a</sup>
Dietary Fiber (g)	6.56±0.34 <sup>a</sup>	5.5±0.50 <sup>a</sup>	5.45±0.20 <sup>a</sup>

Values are Mean ± SD of triplicates.

Mean Values carrying the same superscript in a row do not differ significantly (P<0.05, DMRT)

Table LXXVII indicates the nutrient composition of UBF-incorporated pasta. The pasta's moisture content varied between 3.74% and 5.41%. The control pasta had 5.2% protein while the UBF pasta had 4%. The fat content was consistent across all samples. The total carbohydrate content in UBF was statistically significant compared to the control. All samples, made with whole wheat flour, had a notable fiber content of 5-6 g/100g. In a research work, green banana incorporated pasta had 74% carbohydrate and 2% fiber (Zanonadi et al., 2012).

**Table LXXVIII**  
**Comparison of Resistant Starch in Dry Pasta and Cooked**

Samples	RS in Dry Pasta (g/ 100g)	RS in Cooked Pasta (g/100g)
<b>PUBF 30%</b>	36.30 ± 0.47 <sup>b</sup>	12.5 ± 0.32 <sup>b</sup>
<b>MUBF 30%</b>	37.0 ± 1.27 <sup>b</sup>	11.1 ± 0.5 <sup>b</sup>
<b>Control</b>	15.12 ± 0.46 <sup>a</sup>	3.7 ± 0.72 <sup>a</sup>

Values are Mean ± SD of triplicates. One-way ANOVA followed by Duncan Multiple Range Test (DMRT) .

Mean Values carrying the same superscript in a column do not differ significantly (P<0.05)

The dry UBF pasta had 36-37 g/100g of resistant starch, which is significantly higher than the control pasta. The cooking process led to disintegration and a decrease in RS content to 11-12 g/100g in UBF pasta and to 3 g/100g in the control. Incorporating UBF increased RS content. The formation of resistant starch is affected by processing conditions and storage duration (Kaur et al., 2023a). Cooling promotes the development of retrograded starch (Haralampu, 2000), and the steps in the preparation and extrusion of pasta would have increased the resistant starch content. The cooking process enhances digestibility by promoting starch gelatinization and hydrolysis. As a result, the amount of resistant starch in the product decreases after cooking, due to the conversion of RS into more digestible forms.

#### 4.5.5.5. Shelf Life of Pasta

The results of shelf-life parameters are presented in Tables LXXIX and LXXX.

**Table LXXIX**  
**Shelf Life of Dry Pasta- TPC**

Days	TPC cfu/g			Standards <sup>§</sup>
	<b>PUBF 30%</b>	<b>MUBF 30%</b>	<b>Control</b>	
<b>0</b>	<10	<10	<10	<b>&lt;10<sup>5</sup> cfu/g</b>
<b>30</b>	0 x 10 <sup>1</sup>	1 x 10 <sup>1</sup>	1 x 10 <sup>1</sup>	
<b>60</b>	1 x 10 <sup>2</sup>	2 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	
<b>90</b>	1 x 10 <sup>2</sup>	2 x 10 <sup>2</sup>	1 x 10 <sup>2</sup>	

<sup>§</sup> FSSAI standards for Functional Foods (FSSAI Appendix B)

**Table LXXX**  
**Peroxide Value and FFA of UBF Dry Pasta**

Days	Peroxide Value (meq O <sub>2</sub> /kg)			Standards*
	PUBF 30%	MUBF 30%	Control	
0	0.25± 0.05	0.2± 0.0	0.25± 0.05	<10 meq/kg
30	0.65± 0.05	0.5± 0.1	0.50± 0.10	
60	0.8± 0.00	0.9± 0.1	1.00± 0.10	
90	1.7± 0.10	1.9± 0.1	1.9± 0.10	
% Free Fatty Acids				
0	0.06 ± 0.03	0.07 ± 0.01	0.07 ± 0.01	Acceptable threshold 0.5%,
30	0.13 ± 0.01	0.14 ± 0.03	0.14 ± 0.03	
60	0.23± 0.00	0.25 ± 0.03	0.25 ± 0.03	
90	0.38 ± 0.09	0.39 ± 0.07	0.42 ± 0.03	

Values are Mean ± SD of triplicate \* FSSAI

Microbiological quality standards for pasta products are important to ensure food safety and consumer health. Typically, pasta products, especially dried pasta, have a low moisture content (below 13%), which naturally inhibits the growth of microorganisms. For dried pasta, due to its low water activity, total viable counts are generally expected to be very low. Acceptable levels for total viable counts are typically below 10<sup>4</sup> cfu/g, indicating good microbial quality. The microbial load, as determined by TPC, remained within the standard acceptable value. The peroxide value and free fatty acid values over the shelf life period of 3 months were within acceptable standards.

In the study by Jalgaonkar et al. (2017), after six months of storage, the free fatty acid (FFA) content in pearl millet-wheat pasta increased from 0.48% to 0.82%, while the peroxide value (PV) rose from 2.10 meq/kg to 5.79 meq/kg of oil.

#### 4.5.6. Pearson Correlation Coefficient between Dietary Carbohydrate Components of the RTE and RTC Products

Table LXXXI

Pearson Correlation Coefficient between Dietary Carbohydrate Components of the RTE and RTC Products

	Total Carbohydrate	Total Dietary Fiber	Total Sugar	Resistant Starch
Total Carbohydrate	1			
Total Dietary Fiber	0.59405	1		
Total Sugar	-0.69311	-0.41544	1	
Resistant Starch	0.773121	0.411401	-0.64104	1

In RTE and RTC products prepared with unripe banana flours- PUBF and MUBF, total carbohydrates presented a strong positive association with resistant starch ( $r = 0.773$ ) and a moderate correlation with dietary fiber ( $r = 0.594$ ). The sugar influenced by recipe formulation showed a strong negative correlation with total carbohydrates ( $r = -0.693$ ) and resistant starch ( $r = -0.641$ ).

#### 4.5.7. Summary of Overall acceptability and Percent Daily value of the RTE and RTC products

Table LXXXII represents the overall acceptability of the RTE and RTC products.

Table LXXXII

Overall acceptability of the products

Overall Acceptability		PUBF 30%	MUBF 30%	Control
RTE	Jeera Cookies	8.13±0.74	8.07±0.92	8.53±0.51
	Muffin	8.20±0.67	8.13±0.91	8.60±0.48
	Baked Choco cereal	7.80±0.56	7.07±0.70	8.20±0.77
RTC	Noodles	8.13±0.88	8.07±0.70	8.47±0.50
	Pasta	8.07±0.85	7.93±0.57	8.20±0.54

Based on sensory analysis and the higher potential for UBF incorporation, 30% PUBF and MUBF were selected for nutritive value analysis over 15%. The RTE and RTC products with 30% PUBF and MUBF showed no significant difference from the control, indicating comparable acceptability to their respective wheat flour counterparts. A detailed summary of the estimated nutritive values for these products is provided in Table LXXXIII.

Table LXXXIII

## Nutrients and Percent Daily Value for the RTE/ RTC Products per Serving

Products	Serving Size	Energy (Kcal)	%DV	Carbs (g)	% DV	Sugars (g)	Dietary Fiber(g)	% DV	Protein (g)	Total Fat (g)	% DV	RS (g)
<b>Cookies</b>												
Control (Wheat)	30	151	8	17	6	1	2	9	2	7	9	0.4
PUBF 30%	30	159	8	19	7	2	3	12	2	7	9	4
MUBF 30%	30	167	8	20	7	2	3	11	2	8	10	3
<b>Muffin</b>												
Control (Wheat)	60	309	15	26	10	8	2	6	4	17	22	2
PUBF 30%	60	314	16	29	10	9	3	11	4	16	20	3
MUBF 30%	60	335	17	30	11	10	2	9	4	17	22	3
<b>Baked Choco Cereal</b>												
Control (Wheat)	30	126	6	23	8	3	2	9	2	1	1	0.4
PUBF 30%	30	126	6	22	8	4	3	11	2	1	1	2
MUBF 30%	30	123	6	23	8	3	2	9	2	1	1	2
<b>Noodles</b>												
Control (Wheat)	60	219	11	44	16	2	4	13	4	1	2	7
PUBF 30%	60	228	11	46	17	2	4	15	3	1	2	22
MUBF 30%	60	229	11	47	17	2	4	13	3	1	2	21
<b>Pasta</b>												
Control (Wheat)	60	213	11	43	15	2	3	11	3	2	2	9
PUBF 30%	60	231	12	47	17	2	4	15	2	2	2	22
MUBF 30%	60	234	12	48	17	2	4	13	2	2	2	22

\*Based on FDA 2023 guidelines ; Energy calculation - FAO 2003

RS per serving is listed, though no FDA reference standard is available

The Daily Values (DV) presented in nutrient labeling, as recommended by the FDA, serve as an essential tool for consumers to gauge the nutrient content of food items relative to a total daily diet. Established based on a standard 2,000-calorie daily intake, which applies to adults and children over four years of age, DVs provide a baseline for assessing nutrient contributions from various food sources. Such information empowers consumers to make informed dietary choices and to compare the nutritional profiles of different products effectively. The Daily Value and Percent Daily Value (%DV) complement each other. Daily value represents the recommended daily intake limits for nutrients, while %DV indicates the proportion of nutrients in a single serving of a packaged food or dietary supplement relative to daily dietary needs. According to established guidelines, a nutrient content of 5% DV or less per serving is classified as low, whereas a value of 20% DV or more per serving is considered high. (FDA, 2024)

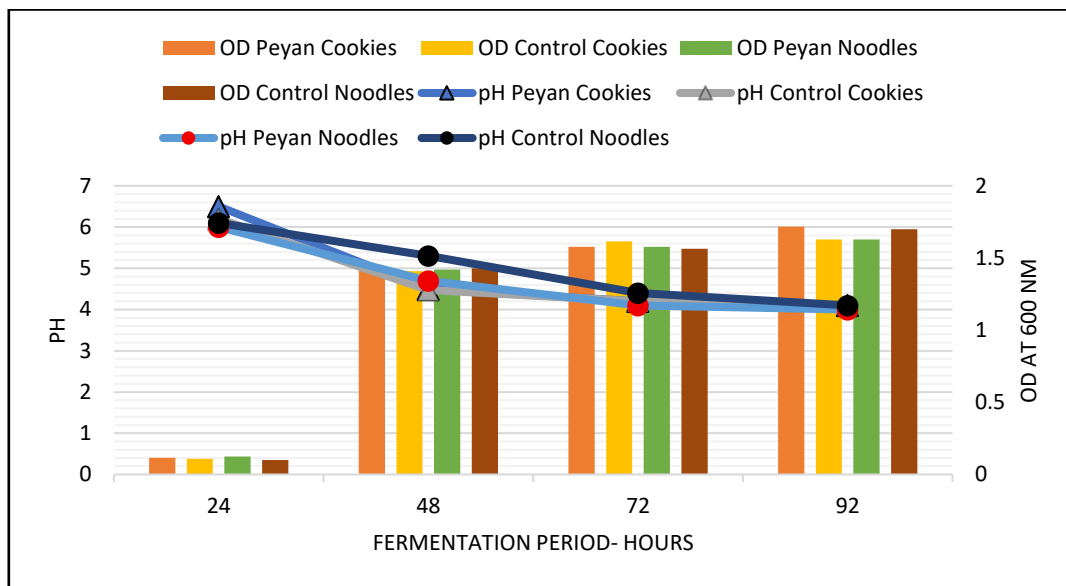
Jeera cookies provided 11–12% DV of dietary fiber, surpassing the 9% observed in the control. Similarly, the formulated noodles and pasta contained 11–13% DV of dietary fiber. Overall, the RTE and RTC products demonstrated a significantly higher dietary fiber content. The combination of high fiber and resistant starch further positions these products as convenient functional foods with potential health benefits.

## Phase 6: Assessment of Prebiotic Potential, Predicted GI, and Purchase Intent of Developed Ready-to-Eat and Ready-to-Cook Products

### 4.6.1. Prebiotic Potential of PUBF-based Cookies and Noodles

Product formulations with unripe banana flour from the PUBF variety incorporated at a level of 30% in both Jeera cookies (ready-to-eat category) and Noodles (ready-to-cook category) were selected for the prebiotic potential study based on their sensory acceptability score, high resistant starch content, low added sugar, and high dietary fiber.

The pH and OD data are presented in Figures 66-68.



**Figure 66: Change in pH and OD in cookies and noodles**

#### *Lactobacillus acidophilus*

Fooks and Gibson (2002) observed that the reduction in pH to three or lower would entirely inhibit the growth of *E. coli*, while the growth of *C. jejuni* and *S. enteritidis* is completely inhibited at pH values of 4 or below.

Given that the developed food products, PUBF cookies and noodles, achieve a final pH of 4 after 72 hours, they effectively create an environment that inhibits the growth of harmful pathogens. This indicates that PUBF cookies and noodles can serve as good prebiotics, supporting beneficial gut bacteria while suppressing pathogenic strains

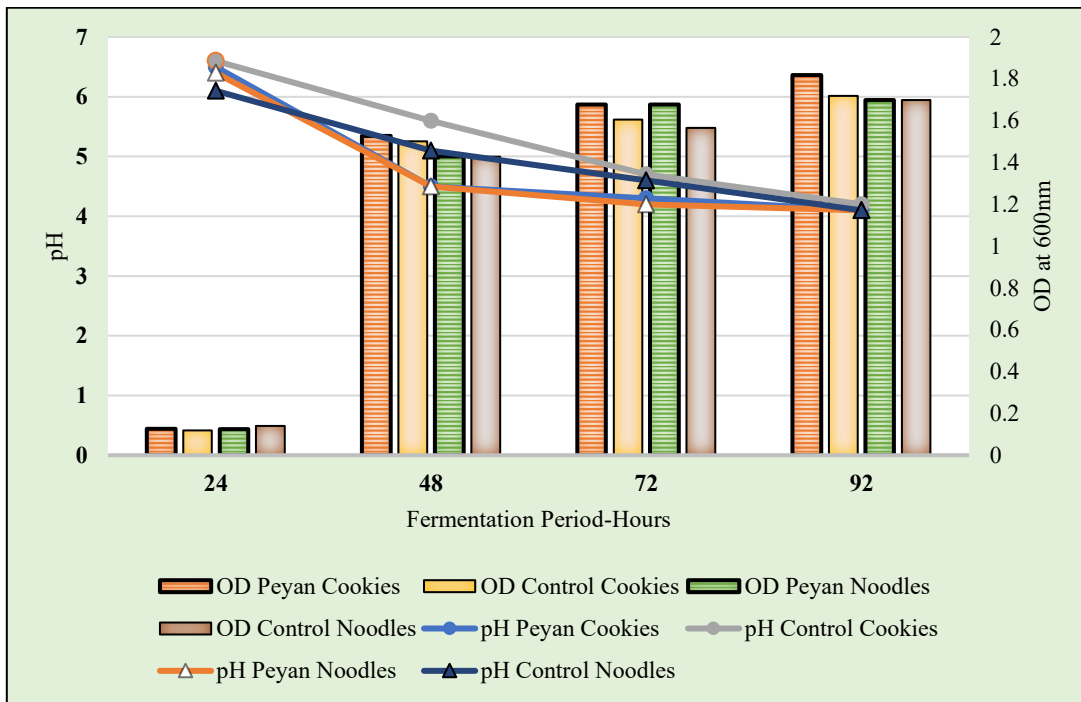


Figure 67: Change in pH and OD in cookies and noodles

*Bifidobacterium longum*

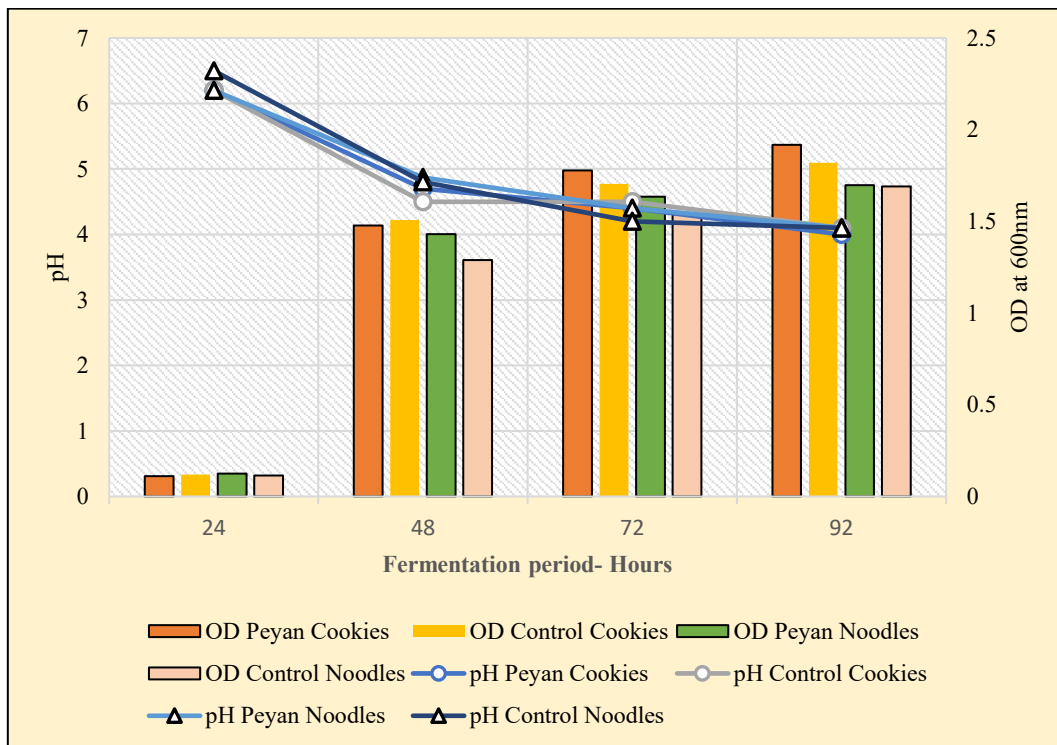


Figure 68: Change in pH and OD in cookies and noodles

*Lactobacillus paracasei*

The optical density for PUBF cookies increased from 0.127 to 1.818 over 96 hours, while the control cookies recorded an increase from 0.119 to 1.719. The PUBF noodles and control noodles also recorded a similar trend. The sustained increase in OD over 72 hours suggests that this formulation provides an optimal prebiotic environment for the growth of beneficial bacteria, outperforming both the control and reference standard- inulin. The gradual increase in bacterial density across all samples highlights the effectiveness of prebiotics in promoting microbial proliferation, with PUBF Cookies showing promise as a functional food for enhancing gut health.

**Table LXXXIV**

**Prebiotic Potential determined by the Colony Count method in Cookies and Noodles**

<i>Lactobacillus acidophilus</i> (log cfu/ml)				
Samples / Fermentation period in hours	PUBF Cookies	Control Cookies	PUBF Noodles	Control Noodles
24	6.83± 0.01 <sup>a</sup>	6.82± 0.01 <sup>a</sup>	6.82± 0.01 <sup>a</sup>	6.80± 0.01 <sup>a</sup>
48	8.68± 0.01 <sup>c</sup>	8.66± 0.01 <sup>c</sup>	8.65± 0.01 <sup>c</sup>	8.62± 0.01 <sup>c</sup>
72	8.77± 0.01 <sup>d</sup>	8.70± 0.01 <sup>c</sup>	8.75± 0.01 <sup>d</sup>	8.68± 0.01 <sup>d</sup>
96	8.50± 0.01 <sup>b</sup>	8.48± 0.01 <sup>b</sup>	8.53± 0.01 <sup>b</sup>	8.43± 0.01 <sup>b</sup>
<i>Bifidobacterium longum</i> (log cfu/ml)				
24	6.83± 0.01 <sup>a</sup>	6.79± 0.01 <sup>a</sup>	6.78± 0.01 <sup>a</sup>	6.70± 0.01 <sup>a</sup>
48	8.65± 0.01 <sup>c</sup>	8.69± 0.01 <sup>c</sup>	8.63± 0.01 <sup>c</sup>	8.65± 0.01 <sup>c</sup>
72	8.75± 0.01 <sup>d</sup>	8.65± 0.01 <sup>bc</sup>	8.70± 0.01 <sup>d</sup>	8.63± 0.01 <sup>c</sup>
96	8.53± 0.01 <sup>b</sup>	8.60± 0.01 <sup>b</sup>	8.53± 0.01 <sup>b</sup>	8.53± 0.01 <sup>b</sup>
<i>Lactobacillus paracasei</i> (log cfu/ml)				
24	6.79± 0.03 <sup>a</sup>	6.78± 0.03 <sup>a</sup>	6.78± 0.03 <sup>a</sup>	6.77± 0.03 <sup>a</sup>
48	8.63± 0.03 <sup>c</sup>	8.71± 0.03 <sup>c</sup>	8.70± 0.03 <sup>c</sup>	8.63± 0.03 <sup>b</sup>
72	8.73± 0.03 <sup>d</sup>	8.65± 0.03 <sup>bc</sup>	8.65± 0.03 <sup>bc</sup>	8.63± 0.03 <sup>b</sup>
96	8.52± 0.03 <sup>b</sup>	8.58± 0.03 <sup>b</sup>	8.59± 0.03 <sup>b</sup>	8.58± 0.03 <sup>b</sup>

Significant increase in probiotic numbers during the fermentation period, 24-96 hours for each probiotic strain  
Mean Values carrying the same superscript in a **column** do not differ significantly (P<0.05, DMRT)

The growth-promoting potential of UBF-incorporated cookies and noodles was evident from the enhanced proliferation of *Lactobacillus acidophilus*, *Bifidobacterium longum*, and *Lactobacillus paracasei* between 24 and 72 h. All strains reached peak counts at 72 h, with UBF cookies (8.77 log cfu/mL for *L. acidophilus*, 8.75 log cfu/mL for *B. longum*, and 8.73 log cfu/mL for *L. paracasei*) and noodles (8.75, 8.70, and 8.65 log cfu/mL, respectively) showing marginal but consistent increases over controls. The subsequent decline at 96 h reflects substrate depletion or accumulation of inhibitory metabolites, a typical trend in in vitro fermentation. The statistical analysis (DMRT, P<0.05) confirmed significant differences in growth during the active fermentation period, supporting the hypothesis that UBF acts as a functional ingredient capable of modulating beneficial gut microbiota. Overall, the results demonstrate that UBF enhances the prebiotic potential of cookies and noodles by providing fermentable carbohydrates, particularly resistant starch.

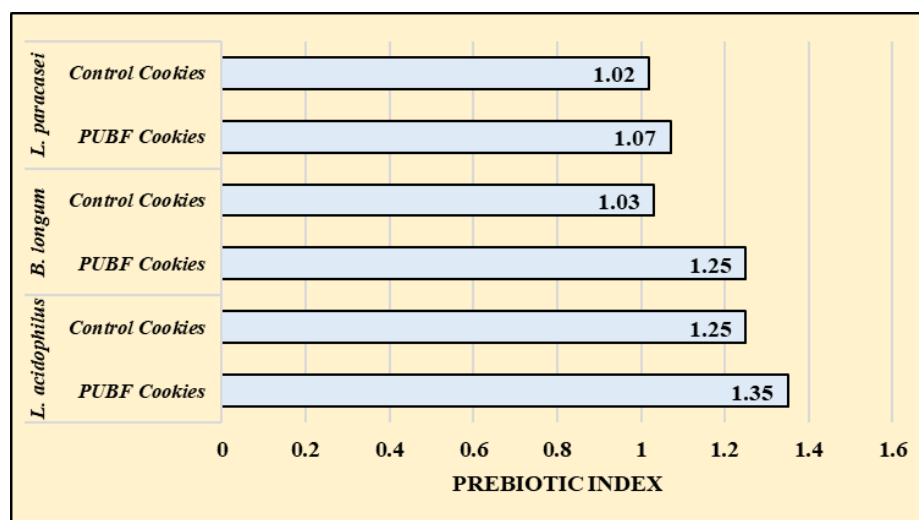
Tables LXXXV and LXXXVI, Figures 69 and 70 depict the prebiotic index of cookies and noodles.

**Table LXXXV**  
**Prebiotic Index of Cookies**

Samples/ Fermentation period in hours	<i>L. acidophilus</i>		<i>Bifidobacterium longum</i>		<i>L. paracasei</i>	
	PUBF Cookies	Control Cookies	PUBF Cookies	Control Cookies	PUBF Cookies	Control Cookies
24	1.15	1.10	<b>1.39</b>	1.24	1.20	1.04
48	1.37	1.29	1.00	0.93	1.00	1.06
72	<b>1.45</b>	1.25	1.31	0.96	1.00	0.96
96	1.41	1.36	1.31	0.97	1.09	1.03
Mean	<b>1.35</b>	1.25	<b>1.25</b>	1.03	<b>1.07</b>	1.02

**Table LXXXVI**  
**Prebiotic Index of Noodles**

Samples/ Fermentation period in hours	<i>L. acidophilus</i>		<i>Bifidobacterium longum</i>		<i>L. paracasei</i>	
	PUBF Noodles	Control Noodles	PUBF Noodles	Control Noodles	PUBF Noodles	Control Noodles
24	1.12	1.07	1.22	1.20	1.04	1.01
48	1.26	1.17	1.00	0.95	1.04	0.91
72	1.40	1.20	<b>1.31</b>	1.19	1.00	0.91
96	<b>1.50</b>	1.18	1.00	1.00	<b>1.06</b>	1.02
Mean	<b>1.32</b>	1.16	<b>1.13</b>	1.09	<b>1.03</b>	0.96



**Figure 69: Mean Prebiotic Index of Cookies**

The PUBF cookies showed a higher prebiotic index compared to the control throughout the fermentation period, with the highest PI observed at 48 hours (1.45). This suggests that the unripe banana flour in PUBF cookies promoted the growth of *L. acidophilus*, particularly during prolonged fermentation.

For *B. longum*, the control cookies exhibited a decreasing PI trend over time, PUBF cookies maintained a relatively consistent PI, with a peak value at 48 hours (1.31). This stability indicates the potential of unripe banana flour to support the growth of *B. longum* under fermentation conditions.

The prebiotic index of PUBF cookies for *L. paracasei* remained stable across the fermentation period, with values around 1.00-1.09. Overall, the mean PI values across the fermentation periods for PUBF cookies were higher than those for the control, suggesting enhanced prebiotic effects due to the inclusion of unripe banana flour.

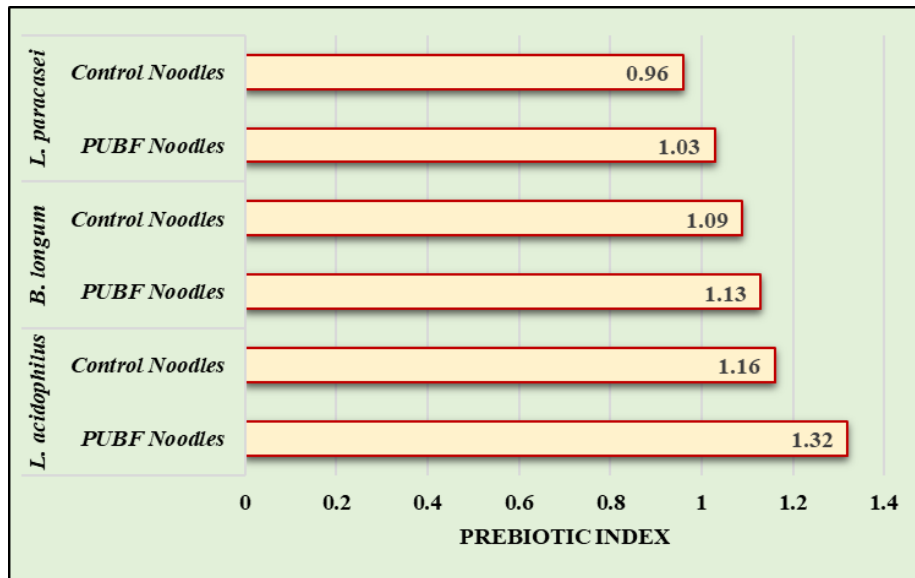


Figure 70: Mean Prebiotic Index of Noodles

PUBF noodles displayed higher PI values compared to the control, with a peak at 72 hours (1.50), which was the highest recorded PI across all samples. This indicates strong support for *L. acidophilus* proliferation by PUBF, which acts as a prebiotic substrate.

The PI of PUBF noodles for *B. longum* varied slightly, with the highest recorded at 48 hours (1.31). The PI for PUBF noodles with reference to *L. paracasei* showed moderate stability, with a slight increase at 72 hours (1.06).

Table LXXXVII

Correlation between RS, TDF, and PI of PUBF Cookies and Noodles

Variables	PI-1	PI-2	PI-3
TDF	0.7359	0.6748	0.8809
RS	0.8724	0.8391	0.7495

PI-1 *L. acidophilus*, PI-2 *B. longum*, PI-3- *L. paracasei*

The results of the correlation between the prebiotic index and dietary carbohydrate components further illustrate the complex interactions between dietary components and microbial activity. The prebiotic index positively correlated with dietary fiber, suggesting that dietary fiber supports the growth of beneficial microbes contributing to prebiotic effects. A strong positive correlation of PI with RS reinforces the role of resistant starch in enhancing prebiotic potential.

The study demonstrates that PUBF cookies and noodles incorporating unripe banana flour exhibit significant prebiotic potential compared to their control counterparts. These findings indicate that unripe banana flour could be beneficial in formulating prebiotic functional foods. The consistency observed in PI values, particularly for *L. acidophilus*, emphasizes the flour's prebiotic efficacy, especially in longer fermentation durations.

#### 4.6.2. Predicted GI of PUBF Cookies and Noodles

Figure 71 represents the starch hydrolysis curve of PUBF-based RTE and RTC products, and Table LXXXVIII shows the predicted glycemic index.

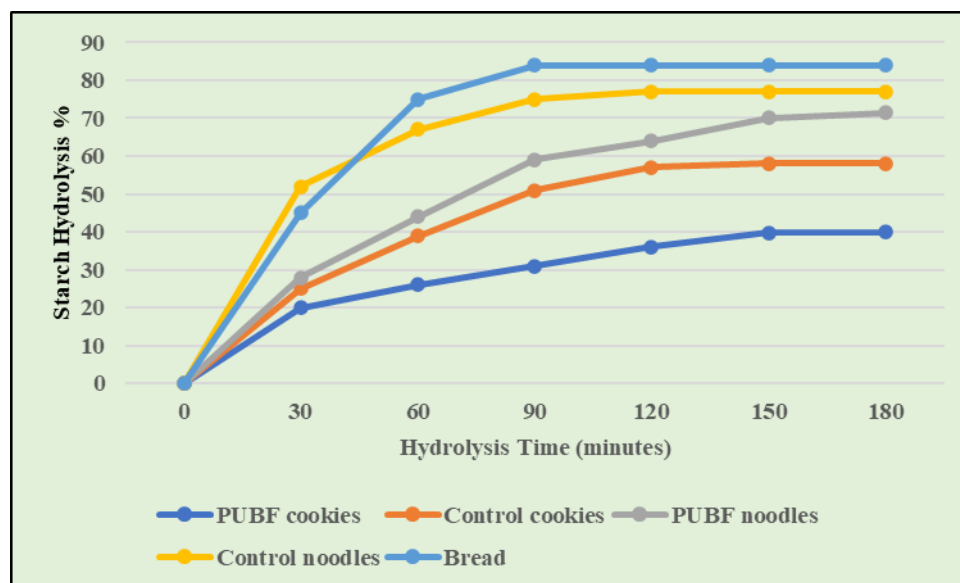


Figure 71: Starch Hydrolysis Curve

**Table LXXXVIII**  
**Hydrolysis Index and Predicted GI**

Products	Hydrolysis Index	Predicted GI	GI Classification
PUBF Cookies	42.15± 0.3	<b>62.85± 0.85</b>	<b>Medium GI</b>
Wheat Cookies (Control)	60.05± 1.55	72.67± 0.27	High GI
PUBF Noodles Cooked	43.50± 0.5	<b>63.28± 0.27</b>	<b>Medium GI</b>
Wheat Noodles Cooked (Control)	68.95± 0.5	77.56± 0.02	High GI
Bread *(Reference food)	100	94.61± 0.02	High GI

Values are Mean ± SD of duplicates.

The estimated glycemic index (eGI) values of the cookies and noodles incorporating PUBF unripe banana flour (PUBF) compared to control wheat-based products showed significant differences in glycemic response. The PUBF cookies exhibited an eGI of 62.85±0.85, indicating a moderate glycemic impact, while the control cookies had a higher eGI of 72.67±0.27. This reduction in eGI for PUBF cookies suggests that the inclusion of unripe banana flour may confer beneficial properties that moderate postprandial blood glucose levels.

In a research study by García-Solís et al. (2017), 85% plantain flour and 15% cornstarch cookies were prepared, and a glycemic index of 34.7 % was reported. Olawoye et al. (2023) developed Cardaba banana flour cookies with a predicted glycemic index ranging between 53 and 83, observing a progressive decline in GI with higher levels of Cardaba banana starch.

Noodles made with PUBF had a hydrolysis index of 43.50±0.5 and eGI of 63.28±0.27 compared to the control noodles, which had a markedly higher HI (68.95±0.5) and eGI (77.56±0.02). The lower eGI of the PUBF noodles indicates that adding UBF can enhance the overall nutritional profile of the noodles by potentially reducing the glycemic response.

Tangthanantorn et al. (2021) studied the RS and GI of fresh noodles substituted with Namwa banana(ABB) flour. Increasing banana flour substitution from 0% to 40% lowered the GI from 77.05 to 62.62 while raising RS content from 5.56% to 23.31%, classifying the noodles as an intermediate GI food.

Table LXXXIX

## Pearson Correlation Coefficient between Dietary Carbohydrate Components and GI

	Total Carbohydrates	TDF	RS	GI
Total Carbohydrates	1			
TDF	0.5058	1		
RS	0.9146	0.5972	1	
GI	-0.5997	-0.8629	-0.8148	1

RS shows a strong negative correlation with GI ( $r = -0.8148$ ), reinforcing its known role in lowering the glycemic response. TDF has an even stronger negative correlation ( $-0.8629$ ) with GI, which aligns with expectations since fiber slows glucose absorption. The positive correlation ( $r=0.5972$ ) between RS and TDF may be attributed to RS being one of the various components that constitute dietary fiber.

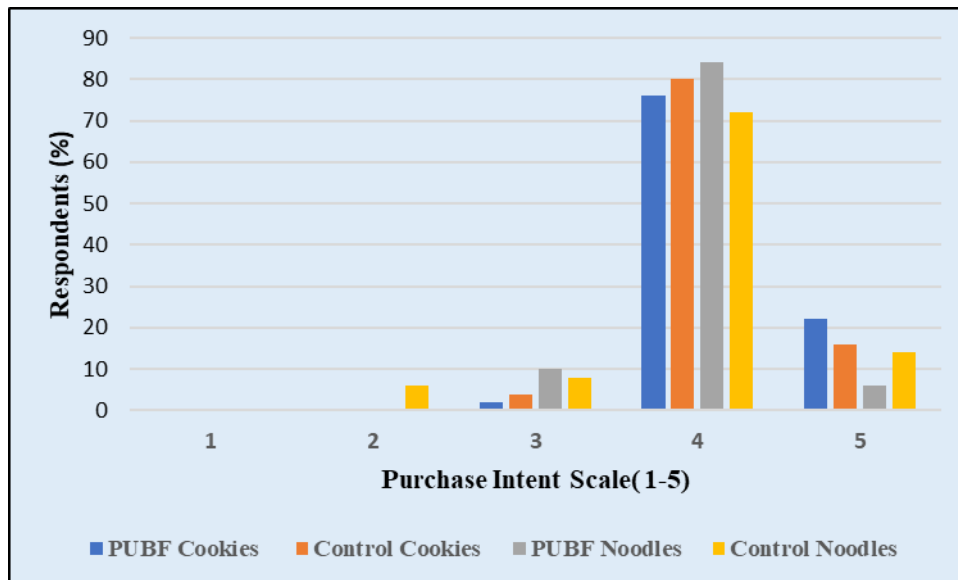
Resistant starches exhibit functions similar to dietary fiber in the large. The Pearson correlation coefficient between total carbohydrates and glycemic index (GI) is  $-0.5997$ , indicating a moderate negative correlation. This suggests that higher total carbohydrate content does not necessarily lead to a higher GI. This trend is likely influenced by the composition of carbohydrates, such as the presence of resistant starch and dietary fiber, which slows digestion and reduces the glycemic response.

These findings highlight the importance of incorporating unripe banana flour into food products to lower their glycemic impact, which could be advantageous for consumers seeking to manage blood sugar levels. The mechanisms underlying these observations involve the fiber content and the resistant starch in unripe banana flour, which can slow carbohydrate digestion and absorption.

Thus, PUBF is a potential functional ingredient in cookies and noodle formulations, promoting healthier dietary options. The jeera cookies and noodles made with *Musa paradisiaca* PUBF unripe banana flour fall under medium GI, suggesting they could serve as a healthy alternative.

#### 4.6.3. Purchase Intent of 30% PUBF-based Cookies and Noodles

The purchase intention choice opted by the consumers towards the developed RTE and RTC foods, primarily based on the sensory attributes, is presented in Figure 72.



**Figure 72: Consumers' Purchase Intent**

Numerous studies have highlighted that consumers' purchase intentions are significantly influenced by intrinsic-sensory attributes of food like taste and aroma, and extrinsic factors, including its origin and health-related claims. Research indicates that consumers regard sensory attributes as a key factor in their purchasing decisions (Corallo et al., 2019).

The consumer purchase intent survey based on tasting the cookies and noodles prepared, involving 50 participants, revealed that products containing 30% unripe banana flour (PUBF) had favorable responses. 76% rated PUBF cookies a score of 4 ("probably would purchase") and 22% scored 5 ("definitely would purchase"). For PUBF noodles, 84% of participants reported "probably would purchase" and 6% stated "definitely would purchase," which is slightly lower than the control noodles (14%).

These results highlight the potential of unripe banana flour as a functional ingredient in cookies and noodles, indicating that PUBF products possess satisfactory taste, texture, flavor, and quality. The preference ratings indicate the successful integration of functional ingredients without compromising consumer acceptability, aligning with prior research on banana flour's role in enhancing the nutritional profile of RTE and RTC products.