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Development of Indian-Almond and Jackfruit Flour-Based Biscuit and Analysis of Proximate, Sensory, and Shelf-Life

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Abstract– . Indian almond (*Terminalia catappa*) and jackfruit (*Artocarpus heterophyllus*) are widely grown fruits in Sri Lanka, yet the market lacks value-added products incorporating these. This research aims to address this gap by developing biscuit formulations using Indian almond and jackfruit flour. Six biscuit samples were prepared using varying ratios of Indian almond flour, jackfruit flour, and wheat flour. A sensory evaluation was conducted with 30 panelists using a 5-point Likert scale. Statistical analysis, employing Friedman and Tukey Pairwise Comparisons tests (One-way ANOVA), was performed to identify significant differences in sensory attributes among the samples. Based on sensory evaluation results, a formulation comprising 40% jackfruit flour, 40% Indian almond flour, and 20% wheat flour was determined as the most preferred, Additionally, the texture profile of the selected sample was analyzed, In texture profile analysis, a compression test was conducted with the selected sample, control and commercially available cracker using Brookfield texture analyzer. There, hardness work (5.10 mJ), Adhesiveness (0.04 mJ), and fracturability (875.60 g with 1% of load sensitivity) were obtained for comparison with values of control and controller samples. . In proximate analysis moisture content (3.80%), Crude fat (13.46%), Crude protein (1.75%), Crude fiber (3.91%), Total ash (1.905%) and Carbohydrate (79.09%) were determined. In evaluating the shelf life evaluation tests for total plate count and yeast and mold count were conducted weekly for four weeks and From this time period the total plate count and the yeast and mould count remained well under the maximum permissible level(<2.0×105 cfu/g yeast and mould is <1.0×104 cfu/g.).then shelf life of biscuit is more than one months.

Keywords: Biscuit, Indian almond, Jackfruit, proximate analysis

1 INTRODUCTION

Terminalia catappa., commonly known as Indian almond in English, Kottamba in Sinhala, and Amandi in Tamil, is abundantly found along the coast of Sri Lanka. The Sri Lankan Ayurvedic pharmacopoeia recommends various parts of this plant for the treatment of several ailments. These include diarrhoea, gonorrhoea, as well as various skin conditions like scabies. The traditional medicinal uses of different parts of *Terminalia catappa*. have been valued for their therapeutic properties in addressing these health issues [1, 2].

The almond tree is a deciduous tree that typically reaches a height of 3-8 meters. It produces an ellipsoid-shaped fruit with a bluntly pointed apex, measuring approximately 7.51 cm in length and 5.05 cm in thickness. The fruit changes color from green to purplish yellow upon ripening and encloses a hard shell or nut, protecting the delicate edible seed inside. While the ripe mesocarp of the fruit is mostly consumed by children, the valuable seed within contains oil [3].

It is found naturally in the subtropical and tropical zones of the Indian and Pacific Oceans and is commonly planted throughout the tropics. This tree is well adapted to coastal environments, including rocky shores and edges of mangrove swamps. It is a fast-growing species, particularly in its early years, and can be used for soil stabilization and coastal protection. The Indian-almond plant produces nuts and timber, with kernel yields estimated at about 5 kg per tree per year and timber yields at 15-20 m per hectare per year. Short-term crops can also be interplanted during the first 2-3 years after establishment. While it has moderate potential for invasiveness into disturbed seaside habitats, It is still widely used and valued in agroforestry systems. It is an underutilized crop that belongs to the Combretacea family. This plant has been identified as an important medicinal plant owing to its antioxidant and therapeutic properties against cancer and diabetes as proven in numerous pharmacological studies [4].

Jackfruit (*Artocarpus heterophyllus Lam*) is a significant evergreen tree that is widely grown in India, Bangladesh, Sri Lanka and many parts of Southeast Asia. It belongs to the Moraceae family and can easily be accessed for its fruit since it grows to a medium-sized tree, typically reaching 28 to 80 feet in height. The fruit, which can weigh from 3.5 to 25 kg, is borne on the side branches and main branches of the tree. There are two main varieties of jackfruit: one is small, fibrous, and soft, while the other is crisp and crunchy but not very sweet. Even though the large seeds of this non-leguminous plant are difficult to digest, they are also edible. Jackfruit cotyledons are a good source of starch and protein.

This research aims to develop a nutritious and sustainable biscuit using Indian-almond and jackfruit flour, which are underutilized crops in Sri Lanka and other countries. The biscuit will be evaluated for its nutritional composition, sensory attributes, and shelf life. The goal is to promote the use of these crops in the food industry and encourage sustainable agriculture practices. The findings can be used to develop and market these biscuits as a healthy snack option and to promote environmentally friendly agriculture practices in Sri Lanka.

2 METHODOLOGY

2.1 Experimental site

The experiment was conducted in laboratories at the faculty of technological studies, Uva Wellassa University.

2.2 Raw materials

- Wheat flour
- Jackfruit flour
- Indian almond flour
- Sugar
- Baking powder
- Butter
- Vanilla flavor
- Fresh milk

2.3 Materials Collection

The Indian almond seeds used in this study were acquired from an exporter in Polgahawela. The remaining materials, including jackfruit seed, wheat flour, sugar,margarine, fresh milk, and baking powder, were procured from a market in Badulla

2.4 jackfruit flour preparation

As for jackfruit flour, the collected seeds underwent a hot water wash at 60°C for 10 minutes to facilitate the removal of the seed coat. After draining the water, the seed coats were removed, and the seeds were cut into smaller pieces. To further reduce moisture, the cut jackfruit seeds were sun-dried for 2 hours before being oven-dried at 55°C for 24 hours in a dry air oven until dried. The dried jackfruit seeds were then ground into flour using a grinder, and the resulting jackfruit flour was stored in an airtight container to maintain its quality and prevent moisture absorption.

2.5 Indian-almond flour preparation

The collected seeds were thoroughly cleaned to remove any impurities. Subsequently, they were dried in a hot air oven at 65°C for 12 hours to reduce their moisture content. Once dried, the seeds were ground into flour using a grinder, and the resulting Indian almond flour was stored in an airtight container to preserve its freshness and prevent moisture absorption.

2.6 Preparation of Biscuits.

100% wheat flour was used as the control sample. Indian almond seed flour and jackfruit seed flour are mixed in the following ratio, and the ingredients used for biscuit preparation are shown in Table 1

Table 01. Formulation of Composite Ingredients of Biscuits in Six Treatments

Ingredient	Control	1	2	3	4	5
Wheat flour	100.00 g	0.00 g	0.00 g	0.00 g	0.00 g	20.00 g
Indian Almonds flour	0.00 g	0.00 g	50.00 g	75.00 g	25.00 g	40.00 g
Jackfruit flour	0.00 g	100.00 g	50.00g	25.00g	75.00g	40.00g
Sugar	40.00 g	40.00 g	40.00 g	40.00g	40.00g	40.00g
Baking powder	1/2 tsp	1/2 tsp	1/2 tsp	1/2 tsp	1/2 tsp	1/2 tsp
Butter	55.00 g	55.00 g	55.00 g	55.00g	55.00g	55.00g
Vanilla flavor	1/4 tsp	1/4 tsp	1/4 tsp	1/4 tsp	1/4 tsp	1/4 tsp
Fresh milk	2 tsp	2 tsp	2 tsp	2 tsp	2tsp	2tsp

The biscuit-making process involved precise measurements of ingredients using an analytical balance (AS 310.R2 PLUS, RADWAG®, Poland). Sugar was ground into a fine powder using an electric grinder. A mixture of wheat flour, rice powder, sugar flour, baking powder, and margarine was combined in a bowl and thoroughly mixed. During mixing, milk and flavorings were incorporated to form the dough. The dough was then placed on a flat surface, flattened to a thickness of 3-4 mm using a rolling pin, and cut into desired shapes using a biscuit cutter. These shapes were then baked in an oven at 170 ℃ for 15 minutes. After baking, the cookies were allowed to cool to room temperature, after which they were packed into low-density polyethylene (LDPE) bags with a gauge of 200 and securely sealed. Subsequently, the prepared and packed biscuits were stored at room temperature for both immediate analysis and for assessing their shelf life.

Preparation of composite flour

↓

Premixing (margarine and sugar)

↓

Mixing (Cream, flour, fresh milk and baking powder)

↓

Sheeting (3-5 mm thick)

↓

Molding

↓

Baking (at 170 °C, 15 min)

↓

Cooling (35 °C)

↓

Packaging (LDPE)

↓

Storage (at room temperature)

Fig.1. Flow diagram of biscuit making process

2.7 Sensory Evaluation

A 5-point Likert scale test was conducted using 30 untrained panelists for evaluating 6 samples: 120(control-100% wheat flour), 270(100% jackfruit flour), 320,(50% Indian almond +50% jackfruit flour),450(75% jackfruit flour+25% Indian almond flour)520(25% jackfruit flour+75% Indian almond flour), and 630(40% jackfruit flour+40% Indian almond flour+20% wheat flour). The ballot sheet consisted of 5 sensory parameters: Appearance, texture, flavor, odour, and overall acceptability. The resulting data from the evaluation was analyzed using Friedman test and Tukey pairwise comparison tests (One way ANOVA) with use of Minitab statistical software.

2.8 Statistical analysis

Nonparametric Friedman test was used under 0.05 significant level. Done by Minitab 19 statistical software

2.9 Proximate analysis

- Crude protein (%) - Kjeldhal method (AOAC, 2016)
- Crude fat (%) - Soxhlet method (AOAC, 2016)
- Moisture (%) - An electronic moisture analyzer (MA 110.R, RADWAG, Poland)
- Ash (%) - Muffle furnace (AOAC, 2016)

- Crude fiber (%)-(AOAC, 2016)
- Determination of Total carbohydrates (%) -Total carbohydrates value was obtained by subtracting sum of moisture %, fat, protein %,and ash% from 100.

2.10 Shelf life analysis

Total plate count analysis and yeast and mould analysis were carried out, Shelf life analysis was done according to that.

2.11 Texture profile analysis

Texture profile analysis was conducted using Brookfield texture analyzer.

(TexturePro CT V1.8 Build 31). A compression test was conducted using probeTA7 with following settings:

Target: 3.0 mm

Load Cell: 1500.00 g

Hold Time: 0 s

Trigger Load: 20.00g

Test Speed: 2.00 mm/s

Return Speed: 2 mm/s

# of Cycles: 2.0

3 RESULTS AND DISCUSSION

3.1 Sensory Evaluation

This table presents the outcomes of a Friedman test conducted to analyze the sensory characteristics of six samples using a 5-point Likert scale test with 30 untrained panelists. The sensory characteristics assessed include color/appearance, body/texture, flavor, odor/aroma, and overall acceptability. The p-values for each characteristic indicate the statistical significance of differences among the samples. The results suggest a significant difference in sensory attributes among the four formulations of biscuit samples evaluate

Table 02. Results of Friedman test for sensory characteristics of different samples

Sensory characteristics		P-value
1.	Color/appearance	0.000
2.	Body/ texture	0.000
3.	Flavour	0.000
4.	Odour/Aroma	0.000

5.	Overall acceptability	0.000

Values that do not share a letter are significantly different (within columns). P<0.05

H0: There is no significant difference between the sensory attribute of six formulations of biscuit samples at a 5% level of significance

H1: There is a significant difference between the sensory attributes of four formulations of biscuit samples at a 5% level of significance If P ≤ α=0.05; H0 is rejected. Therefore, it was revealed statistically that there is a significance difference between four samples in terms of all the evaluated attributes.

1= dislike very much

2=dislike moderately

3=neither like or dislike

4=like moderately

5=like very much

The radar diagram, ingeniously derived from the mean attribute values spanning the sample spectrum, emerges as an illuminating graphical representation that distills the collective inclinations of the panelists. This visual aid is pivotal in identifying the sample that reigns supreme in terms of specific sensory attributes.

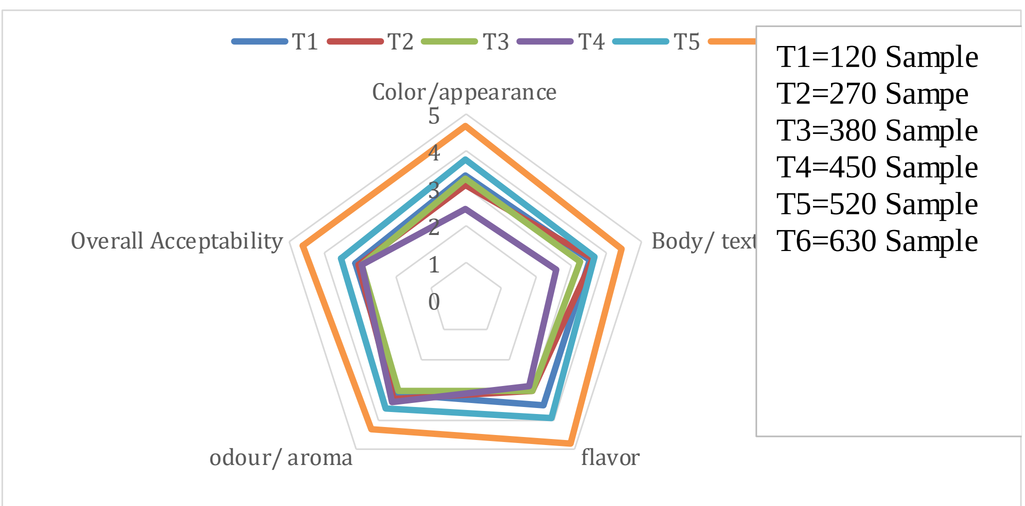

Fig.2. - Overall sensory profile for developed biscuit sample

The integration of Tukey Pairwise comparison, seamlessly embedded within the framework of the One-way ANOVA analysis, functions as an invaluable tool to untangle the potential disparities hidden within pairs of mean values.

Table 03. Mean and standard deviation of sensory characteristics of different samples

Sensory characteristics	120	270	380	450	520	630
Color	3.233 ± 1.251^{a}	3.200 ± 1.63^{bc}	3.200 ± 0.887^{bc}	2.567 ± 1.073^{c}	3.800 ± 1.064^{b}	4.633 ± 0.765^{a}
texture	3.433 ± 1.431^{b}	3.467 ± 1.137^{b}	3.100 ± 1.029^{bc}	2.600 ± 0.894^{c}	3.467 ± 0.860^{b}	4.267 ± 0.583^{a}
Flavour	3.333 ± 1.213^{bc}	3.100 ± 1.155^{bc}	3.000 ± 1.203^{c}	2.833 ± 1.020^{c}	3.767 ± 0.679^{b}	4.600 ± 0.724^{a}
Odour	3.033 ± 1.033^{b}	3.267 ± 1.258^{b}	3.233 ± 1.135^{b}	3.233 ± 1.251^{b}	3.733 ± 0.907^{ab}	4.367 ± 0.850^{a}
Overall acceptability	3.133 ± 1.074^{b}	3.200 ± 1.126^{b}	2.900 ± 0.923^{b}	3.033 ± 1.273^{b}	3.433 ± 1.073^{b}	4.600 ± 0.675^{a}

Different letters in the same row indicate the values are significantly different ($p<0.05$)

Interestingly, our comprehensive investigation delves into a captivating narrative concerning the dynamic interplay between Sample 630, the undisputed favorite, and Sample 520. While the apex position of Sample 630 across the board is undeniable, an engaging revelation surfaces: Sample 520 emerges as the most proximate counterpart to 630, especially in the realm of sensory attributes beyond taste, as elegantly detailed in Table 08. While Sample 630 enjoys unrivaled popularity, this intriguing parallelism suggests that despite the latter's preeminence, the two formulations share a degree of commonality, a phenomenon warranting further exploration and appreciation.

On the opposite end of the spectrum, a distinctive story unfolds with Sample 450. This particular sample stands apart with its comparatively lower mean values, notably evident in attributes such as Color, Texture, and Flavour. This striking divergence reinforces the uniqueness of Sample 450's sensory profile, reinforcing the robustness of our statistical observations.

In synthesis, the radar diagram acts as a visual oracle of preferences, while the scientific rigor of Tukey Pairwise comparison lends depth to the nuances of mean values. The intricate relationships unveiled between Sample 630, 520, and 450 illuminate the intricate dance of sensory attributes within the multifaceted tapestry of biscuit formulations.

3.2 Proximate analysis

The proximate analysis results for our Indian-almond and jackfruit flour-based biscuit are truly exciting and open up a world of possibilities. The remarkably low moisture content of 2.22% is a testament to our adept manufacturing processes, ensuring a prolonged shelf-life and the preservation of the biscuit's crisp and appealing texture. The high crude fat content of 27.89% is a standout feature of our biscuit. Fat, besides contributing to flavor and texture, is a substantial source of energy. This high fat content could potentially position our biscuit as an energy-boosting snack, perfect for individuals with active lifestyles. The protein content, though not exceptionally high at 8.43%, still adds to the overall nutritional profile of the biscuit. Protein is crucial for muscle repair and growth, making our biscuit a sensible choice for those seeking a snack that offers both taste and nutrition. The presence of 3.676% crude fiber is a definite positive. Fiber is essential for digestive health and is often lacking in many modern diets. Our biscuit could address this gap, appealing to health-conscious consumers seeking a tasty snack with added digestive benefits. The total ash content of 0.714% indicates a reasonable mineral composition, contributing to the overall nutritional value. Further exploration into fortification strategies could potentially enhance the mineral content, making our biscuit even more nutritionally robust. Carbohydrates, constituting 58.05% of the biscuit, provide a substantial source of energy. This composition aligns well with the dietary needs of a broad consumer base, catering to those looking for a satisfying and energizing snack option.

The proximate analysis results highlight the immense potential of our Indian-almond and jackfruit flour-based biscuit. Its low moisture content, high fat content, and reasonable protein and fiber levels position it as a unique and nutritionally attractive product in the market. Further research into fortification and flavor enhancement will undoubtedly bolster its appeal, making it a noteworthy contender in the realm of healthy and delicious baked goods.

Table 04- Proximate analysis results

Proximate constituent	630(selected sample)
Moisture (%)	2.22
Crude fat (%)	27.89
Crude protein (%)	8.43
Crude fibre (%)	3.676
Total ash (%)	0.714
Carbohydrate (%)	58.05

3.3 Texture profile analysis

Texture profile analysis was conducted using Brookfield texture analyzer (Texture Pro CT V1.8 Build 31)

The outcomes of the Texture Profile Analysis (TPA) conducted on the two biscuit samples using the Brookfield texture analyzer (Texture Pro CT V1.8 Build 31) offer substantial insights into their textural properties. These samples are referred to as the "Controller sample" and the "Selected sample," and their TPA results have been carefully examined to discern the contrasts in their textures.

Table 05- Texture profile analysis

	120(Controller sample)	630(selected sample)
Hardness Cycle 1:(g)	5624.00	2656.00
Resilience:	0.00	0.00
Fracturability:(g	1205.00	1739.00
Hardness Cycle 2:(g)	3505.00	0.00
Cohesiveness:	0.98	0.00
Springiness: (mm)	2.79	3.18
Gumminess:(g)	5496.00	0.00
Chewiness (Mj)	150.40	0.00
Sample Length:(mm)	7.42	7.46

The hardness measurements for Cycle 1 reveal a notable disparity between the Controller and Selected samples. The Controller sample recorded substantially higher values, measuring 5624.00 g, compared to the Selected sample's value of 2656.00 g. A similar trend is observed in Cycle 2, where the Controller sample's hardness remained considerably elevated at 3505.00 g, while the Selected sample exhibited a hardness of 0.00 g. This difference underscores the Controller sample's more rigid and resistant texture.

Both samples displayed zero resilience and cohesiveness in their textural attributes, suggesting a lack of ability to recover their original shapes and maintain their internal structure during compression.

The parameter of fracturability exhibited noteworthy variation between the two samples. The Selected sample demonstrated higher fracturability at 1739.00 g, compared to the Controller sample's value of 1205.00 g. This implies that the Selected sample had a greater tendency to fracture upon the application of force, potentially indicating a more brittle texture.

An interesting observation arises from the gumminess and chewiness measurements. The Controller sample registered considerable values for both, with gumminess at 5496.00 g and chewiness at 150.40 Mj. In contrast, the Selected sample presented zero values for both attributes, signifying a distinct lack of gumminess and chewiness in its texture. Regarding springiness, the Selected sample exhibited slightly superior springiness with a value of 3.18 mm, while the Controller sample recorded 2.79 mm. This suggests that the Selected sample had a greater ability to regain its original shape after compression.

The TPA outcomes illuminate prominent textural disparities between the Controller and Selected samples. The Controller sample showcased a tougher, chewier, and gummier texture, whereas the Selected sample displayed a texture that was notably less chewy, less gummy, and more prone to fracturing. These findings provide valuable insights for understanding the nuanced textural attributes of the biscuit samples, which could be essential for refining their formulation and production processes to align with specific textural preferences and requirements.

3.4 Shelf-life analysis

Table 06- Shelf-life analysis

Test	1st week	2nd week	3rd week	4th week
Total Plate Count(cfu/g)	N/A	N/A	N/A	1×10^2
Yeast and Mold (cfu/g)	N/A	1×10^1	1×10^2	1×10^2

Microbial analysis was performed weekly over a four -week period to assess the shelf life of the biscuits. Both total plate count and yeast and mold count methods were employed. According to WHO standards (1994) the maximum permissible limits in bakery products (cake, bread, and biscuits) for total plate count is $<2.0\times10^5$ cfu/g yeast and mold is $<1.0\times10^4$ cfu/g. From this time the total plate count and the yeast and mold count remained well under the maximum permissible level. This absence of microbial growth is likely attributed to several factors. The biscuits have an exceptionally low moisture content, a critical factor for microbial proliferation. Additionally, the baking process involved subjecting the biscuits to temperatures as high as 170°C, which would have acted to eliminate any existing microorganisms. The biscuits were stored within zip lock bags, providing a hermetic environment that prevented potential contaminants from infiltrating. It is important, however, to continue monitoring the product's stability over time, considering the potential for altered storage conditions to affect the product's microbiological status.

4 CONCLUSION

Based on the conducted research, the development of biscuit formulations using Indian almond and jackfruit flour has proven to be a successful venture. The carefully determined formulation comprising 40% jackfruit flour, 40% Indian almond flour, and 20% wheat flour emerged as the most preferred variant based on a comprehensive sensory evaluation. This formulation not only achieved a desirable sensory profile but also showcased promising texture attributes, including appropriate hardness, adhesiveness, and fracturability, making it a favorable choice. The proximate analysis revealed the biscuit to be a high nutritional, rich in fiber, and low-calorie product, meeting contemporary dietary preferences. Additionally, the utilization of Indian almond and jackfruit flour in this value-added product presents a significant step towards reducing postharvest losses of these fruits and promoting their year-round availability, fostering sustainability in the agri-food sector.

This research underscores the potential for addressing health concerns through the consumption of the developed biscuit product. The maintained low total plate count and yeast and mold count within permissible levels over a period of four weeks indicate a robust shelf life of more than one month, ensuring the product's quality and safety for extended durations. The positive outcomes achieved in this study not only promote the utilization of Indian almond and jackfruit flour for value addition but also contribute to the reduction of postharvest losses and the creation of a nutritious, market-ready biscuit that aligns with the current health-conscious consumer demands, ultimately benefiting both producers and consumers alike.

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