Development and Nutritional Evaluation of Jackfruit Seed-Based Toffee

Prof. M. S. Ansari [1], Prof. V. S. Wadmare [2], Ms. S.P. Punjabi[3], Ms. A.A. Kharote[4], Ms. P.K. Lokhande[5], Mr. P.V. Pandagale[6], Ms. P.A. Zoting[7], J.A. Bhori[8], S.R. Gajbhiye[9]

[1,2]Assistant Professor, Affiliated to Mahatma Phule Krishi Vidyapeeth Rahuri, Department of Food Engineering, K.K.Wagh College of Food Technology, Nashik-422003. (M.S)

[3,4,5,6,7,8,9]B.Tech. Food Tech, Affiliated to Mahatma Phule Krishi Vidyapeeth Rahuri, Department of Food Engineering, K.K.Wagh College of Food Technology, Nashik-422003.(M.S)

Abstract- Jackfruit (Artocarpus heterophyllus Lam.), one of the largest tropical fruits, is known for its rich nutrient content and possible health benefits. While the sweet pulp has been extensively used in traditional and modern foods, its seeds—accounting for nearly 10–15% of the fruit weight—are usually neglected and thrown away. These seeds, however, are abundant in starch, protein, dietary fiber, essential minerals, and bioactive compounds, positioning them as a potential ingredient for functional foods. The present study aimed to formulate a novel nutrient-rich confectionery product by incorporating jackfruit seed flour, almond flour, almond butter, and jaggery in varying proportions to produce a healthier toffee alternative.

Three formulations were prepared and evaluated for sensory properties, nutritional composition, and consumer acceptability. Protein content was estimated using the Kjeldahl method, while proximate analyses—including moisture and ash content—were performed to assess the product's stability and nutritional quality. In addition, microbiological tests were conducted to confirm the safety and hygienic quality of the prepared toffee samples. Sensory evaluation covered texture, flavour, and aroma, with the balanced formulation (Sample C: 40 g jackfruit seed flour, 30 g almond flour, 10 g almond butter, and 20 g jaggery) achieving the highest overall acceptability.

Findings demonstrated that incorporating jackfruit seed flour not only improved the nutritional profile of the confectionery but also ensured product safety and quality. This study highlights the potential of jackfruit seed flour as a functional ingredient in confectionery products, supporting both consumer health and sustainable food innovation by valorizing a commonly discarded by-product.

Keywords: Jackfruit seeds, functional foods, sustainable confectionery, protein estimation, proximate analysis, microbiological safety, sensory evaluation

I.INTRODUCTION

Sweets are consumed globally for their enjoyable taste and indulgence, yet they are often criticized for being high in sugar and unhealthy fats, offering little to no nutritional benefit. As consumer awareness of health and wellness increases, there is a increasing interest in healthier confectionery alternatives that not only satisfy taste buds but also provide nutritional value (Ali et al., 2021; Choudhury et al., 2023). Incorporating underutilized, nutrient-dense ingredients into sweets is an innovative approach to meet this demand, transforming conventional treats into health-promoting foods.

Jackfruit (Artocarpus heterophyllus Lam.), belonging to the Moraceae family, is one of the largest and most widely consumed tropical fruits globally. Native to the Western Ghats of India, it is now cultivated extensively across South and Southeast Asia, Africa, and other tropical regions. Renowned for its enormous size, unique flavor, and versatility, jackfruit has earned global recognition as a potential "superfood" due to its rich nutritional composition and health-promoting properties (Kushwaha et al., 2021; Banerjee et al., 2022).

The fruit is a good source of carbohydrates, fiber, and essential vitamins (A, C, and B-complex), and minerals such as potassium, calcium, magnesium, and iron. While the pulp is widely consumed fresh or processed into value-added products like chips, jams, and desserts, the seeds—constituting approximately

10–15% of the fruit's weight—are often discarded, representing a significant underutilized nutritional resource. Scientific studies indicate that jackfruit seeds contain 13–18% protein, 65–70% starch, and substantial amounts of dietary fiber, minerals, and antioxidants (Singh et al., 2022; Patel & Naik, 2023). Moreover, these seeds are contain bioactive compounds such as flavonoids, saponins, and lignans, jacalin, and artocarpin, which are linked to antioxidant, anti-inflammatory, antimicrobial, and anticancer properties (Gupta et al., 2021; Shukla et al., 2024).

Traditionally, jackfruit seeds have been incorporated into local cuisines by boiling, roasting, or grinding them into flour. With the growing interest in plant-based diets and functional foods, jackfruit seeds are now being explored as ingredients in baked goods, extruded snacks, plant-based protein products, and confectionery items (Reddy et al., 2022; Yadav et al., 2023). Utilizing these seeds in food formulations not only enhance nutritional quality but also promote sustainability by reducing post-harvest losses and contributing to circular food systemsapproach aligns with global initiatives to increase food security and minimize agricultural waste.

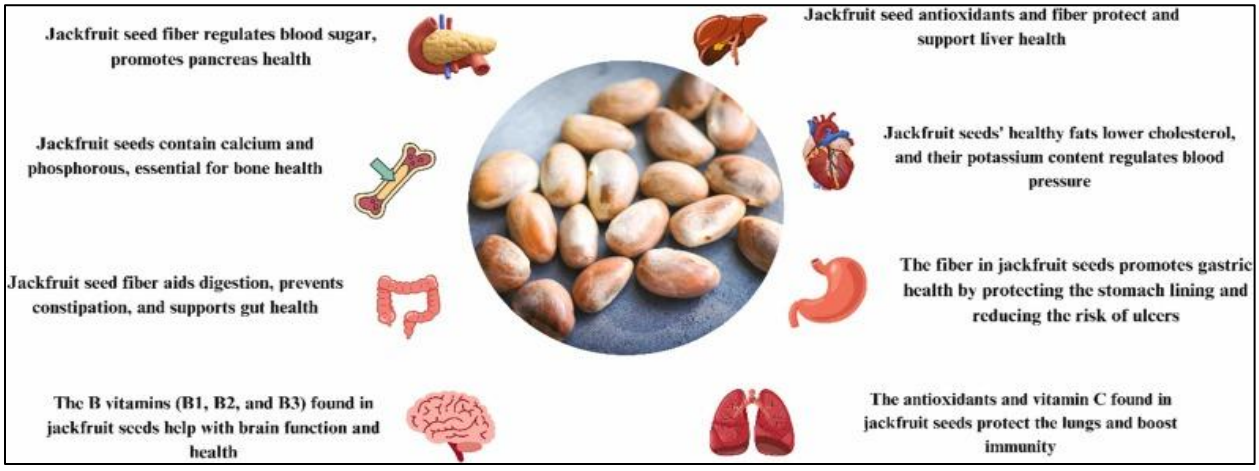
Most commercially available toffees are manufactured using refined sugar, artificial flavors, and unhealthy fats, providing "empty calories" with negligible health benefits. To address this issue, the present study focuses on developing a nutrient-rich toffee using jackfruit seed powder, almond flour, almond butter, and jaggery. Each ingredient offers unique nutritional and functional advantages:

• Jackfruit seed powder provides protein, dietary fiber, and antioxidants.

• Almond flour and almond butter contribute healthy fats, protein, vitamin E, and enhance texture and mouthfeel.

• Jaggery, a natural sweetener, provides essential minerals such as iron, magnesium, and potassium while improving binding and flavor (Khan et al., 2021; Bhattacharya & Raychaudhuri, 2022).

By combining these ingredients, the research aims to formulate, standardize, and evaluate a healthy, functional toffee that meets modern consumer expectations for both nutrition and taste. In addition to creating a nutritionally improved confectionery, this study highlights the potential of transforming underutilized food resources, like jackfruit seeds, into commercially viable and sustainable functional foods.



II.PURPOSE OF THE STUDY

The main goal of this study is to develop and evaluate a nutrient-rich functional toffee using jackfruit seed powder, almond flour, jaggery, and almond butter as the primary ingredients. Conventional toffees are typically made with refined sugar and unhealthy fats, offering minimal nutritional value and contributing to health concerns such as obesity, diabetes, and dental issues. By incorporating underutilized and nutrient-dense ingredients, this research aims to create a healthier and more functional confectionery alternative.

Specifically, the study seeks to:

1. Utilize jackfruit seed powder as a sustainable ingredient to enhance protein, starch, and dietary fiber content while reducing food waste by converting discarded seeds into a value-added product.

2. Incorporate almond flour and almond butter to improve the quality of protein, provide healthy fats, and enhance sensory properties such as creaminess, texture, and flavor.

3. Replace refined sugar with jaggery to deliver natural sweetness along with essential minerals and antioxidants, improving the overall nutritional profile.

4. Compare multiple formulations of toffees with varying proportions of jackfruit seed powder and almond flour to identify the most nutritionally balanced and organoleptically appealing product.

5. Evaluate consumer acceptability through sensory analysis, making sure that nutritional improvements maintain taste, texture, and appeal.

By addressing these objectives, the study contributes to the development of functional foods and demonstrates how traditional confectionery can be transformed into a health-oriented product that aligns with modern consumer preferences for both nutrition and taste

III.INGREDIENTS AND THEIR HEALTH BENEFITS

Jackfruit Seed Powder:

Jackfruit seeds are a nutrient-dense ingredient, naturally rich in starch, protein, dietary fiber, and essential minerals. They also contain bioactive compounds with antioxidant properties, which can help support immune function and reduce oxidative stress (Swami et al., 2012; Mohan et al., 2019; Abuajah et al., 2015). In confectionery applications, jackfruit seed powder not only enhances the texture of products but also imparts a mild nutty flavor while increasing carbohydrate and fiber content, contributing to better digestive health (Adeyeye & Afolabi, 2012; Gupta & Sharma, 2019). Its protein content makes it an excellent functional ingredient for creating nutritionally enriched snacks.

Almond Flour:

Almond flour, produced by grinding blanched almonds, is high in protein, monounsaturated fats, dietary fiber, vitamin E, and various minerals (Alasalvar & Shahidi, 2008; Bolling et al., 2011). Regular consumption of almonds has been associated with cardiovascular benefits, improved antioxidant status, and enhanced satiety (Kapoor et al., 2013; Khan et al., 2017). In toffees, almond flour contributes a soft, smooth texture and nutty flavor, enhancing both mouthfeel and overall sensory appeal (Venkateswara et al., 2015; Singh & Kaur, 2016).

Almond Butter:

Almond butter is rich in healthy fats, high-quality protein, and vitamin E, offering antioxidant protection and supporting brain and heart health (Bolling et al., 2011; Bolling & Chen, 2015). Its creamy consistency improves the texture of confectionery products, providing a smooth mouthfeel and increasing consumer acceptability (Anwar et al., 2008).

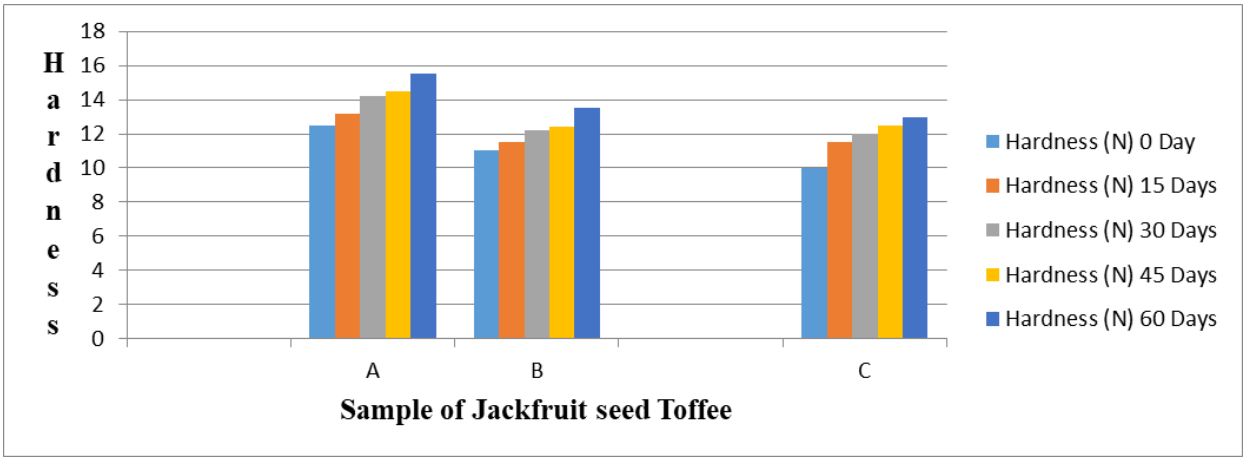
Jaggery:

Jaggery is a natural, unrefined sweetener that provides essential minerals such as iron, magnesium, and potassium. Beyond imparting sweetness, jaggery promotes digestion, provides instant energy, and serves as a natural binding agent in confectionery formulations (Kumar et al., 2011; Bhattacharya & Raychaudhuri, 2018; Farooq et al., 2017). Its inclusion in toffee makes it a healthier alternative to refined sugar while enhancing flavor and nutritional value.

Comparative Formulation and Nutritional Profile of Jackfruit Seed Toffee Samples

Sample	Jackfruit seed powder (g)	Almond flour (g)	Almond butter (g)	Jaggery (g)	Texture	Flavor &Aroma	Nutritional highlights
A	50	20	10	20	Dense, slightly dry	Mild nutty, balanced sweetness; aroma earthy & cocoa-like	High carbohydrates and fiber; lower protein; rich in starch
B	40	30	10	20	Soft, creamy, nutty	Stronger almond flavor; sweet with	Higher protein and healthy fat; moderate fiber; softer texture

						caramel notes; aroma nutty	
C	40	30	10	20	Soft, smooth, well balanced	Harmonious nutty and cocoa-like flavor; aroma pleasant and inviting	Balanced carbohydrates, protein, fiber, and healthy fats; optimal sensory appeal



Graph No. 1:- Hardness Jackfruit Seed-Based Toffee

Notes on formulation:

• Sample A emphasizes jackfruit seed powder, giving it a firmer texture and higher carbohydrate/fiber content.

• Sample B is almond-forward, resulting in higher protein, creamy texture, and richer nutty flavor.

• Sample C strikes a balanced composition, offering optimal nutrition, texture, and sensory acceptability.

Flowcharts of Toffee Preparation:

Stepwise Process for Each Sample:

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Soaking of Jackfruit Seeds (overnight)

↓

Peeling of Jackfruit Seeds

↓

Roasting of Peeled Seeds

↓

Grinding to Jackfruit Seed Powder

↓

Preparation of Almond Flour
(Blanching → Drying → Grinding of almonds)

↓

Mixing of Dry Ingredients
(Jackfruit seed powder + Almond flour + Cocoa/Coffee powder if used)

↓

Melting of Jaggery

↓

Addition of Almond Butter

↓

Incorporation of Dry Mix
(Roasted powders + almond flour mixture into jaggery–butter blend)

↓

Cooking / Concentration
(Till semi-solid, glossy mass)

↓

Molding / Spreading
(Onto greased trays or molds)

↓

Cooling & Setting
(At room temperature)

↓

Cutting

↓

Packaging

Preparation Process of Jackfruit Seed Toffees:

The jackfruit seed toffees were prepared in the Food Processing Technology laboratory at K.K. Wagh College of Food Technology, Nashik using jackfruit seed flour, almond flour, almond butter, and jaggery powder as the primary ingredients. The process began with soaking jackfruit seeds overnight to soften their outer layer, followed by careful peeling to remove the brown seed coat. The seeds were then roasted to enhance flavor and reduce moisture content before being ground into a fine powder, forming the jackfruit seed flour. Almond flour was prepared separately by blanching almonds to remove their skin, drying them, and grinding into a fine powder.

For the toffee preparation, the dry ingredients—jackfruit seed flour and almond flour—were mixed thoroughly to ensure uniformity. Jaggery was melted over low heat, and almond butter was incorporated to create a smooth and creamy base. The dry mix was gradually added to the jaggery–butter blend and cooked until a semi-solid, glossy consistency was achieved. The mixture was then spread onto a greased tray or poured into molds and allowed to cool and set at room temperature. Once set, the toffees were cut into uniform pieces and packaged to preserve freshness and quality.

FigureNo. 01: Roasting and peeling of jackfruit seeds

Protein Digestion and Estimation (Kjeldahl Method):

Digestion:

A 0.2 g sample of the toffee was accurately weighed into each digestion tube. To each tube, 4 g of potassium sulfate and 1 g of copper sulfate (as a catalyst mixture) were added, followed by 20 ml of concentrated sulfuric acid (H_2SO_4). The tubes were heated at 450 °C until the solution became clear, indicating complete digestion. All connections to the digestion unit were secured according to standard procedures.

Neutralization and Distillation:

Once cooled, 10 ml of distilled water was added to the digested sample. The mixture was made alkaline with the careful addition of 40% NaOH solution. A conical flask containing 100 ml of 2% boric acid solution, with a pre-prepared mixed indicator, was positioned to absorb the released ammonia during distillation. The distillation apparatus was set up with the condenser outlet submerged in the boric acid solution.

Indicator Preparation:

The mixed indicator was prepared by dissolving 0.1 g of methyl red in 50 ml ethanol and 0.095 g methylene blue in 50 ml ethanol. Equal volumes of both solutions were combined to yield the final indicator.

Distillation:

Ammonia gas (NH_3) evolved upon addition of NaOH to the digestion tube. This gas was absorbed by the boric acid solution, producing a visible color change, signaling the presence of nitrogen.

Titration:

The boric acid solution containing the absorbed ammonia was titrated with 0.01 N H_2SO_4. The endpoint was identified by a color transition from green to violet-pink, and the titration readings were meticulously recorded for protein estimation.

Equipment Required

- Hot air oven, grinder, hot plate or gas burner, stainless steel pans
- Measuring cylinders, beakers, glass rods, spatulas
- Silicone molds or stainless steel trays

OBSERVATIONS

Texture:
The toffees exhibited an appealing chewy consistency, firm enough to maintain shape but soft for easy consumption. Almond flour and almond butter contributed to a smooth, creamy texture, while jackfruit seed powder provided structural integrity. Samples with higher almond content were noticeably creamier, whereas those richer in jackfruit seed powder had a slightly grainier mouthfeel.

Flavor:
The overall flavor was sweet and nutty, enhanced by jaggery, which imparted a natural caramel-like sweetness. Jackfruit seed powder contributed subtle chocolatey notes that complemented the almond flavor. The sample with a balanced ratio of almond and jackfruit seed powder received the highest sensory preference, while almond-heavy samples had a more pronounced nutty flavor.

Aroma:
The toffees emitted a warm and inviting aroma. Roasted jackfruit seeds provided a light cocoa-like fragrance, almonds contributed a nutty scent, and jaggery imparted an earthy sweetness. The balanced sample was perceived as having the most harmonious aroma, whereas the almond-rich sample was noticeably nuttier.

Figure No. 02: “Final prepared toffee sample”

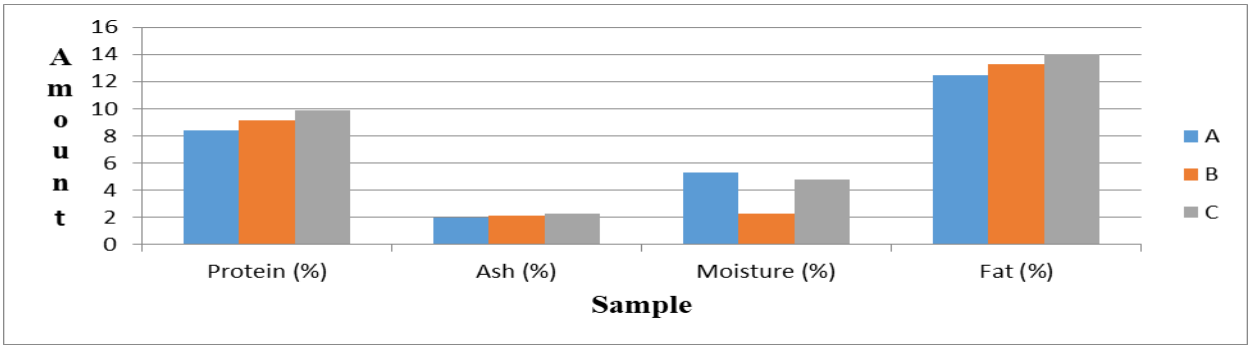
RESULTS & DISCUSSION

Nutritional Composition
The final nutritional profile of the toffee per 100 g was as follows:

Nutrient	Value (per 100 g)
Protein	11.3 g
Fibre	5.6 g
Fat	20.2 g
Carbohydrates	42.8 g
Ash (minerals)	2.2 g
Moisture	6.4 g
Energy	430–450 kcal

Proximate Analysis:
Proximate analysis was performed to determine protein, fat, moisture, ash, and carbohydrate contents:

Parameter	Sample A	Sample B	Sample C
Protein (%)	8.42	9.15	9.87
Ash (%)	1.96	2.14	2.28
Moisture (%)	5.31	5.07	4.82
Fat (%)	12.45	13.28	14.03



Graph No. 2:- Nutritional Analysis of Jackfruit Seed-Based Toffee

Health Implications

The developed jackfruit seed and almond-based toffee offer a better alternative to regular sugar-rich sweets. It delivers a meaningful contribution of protein and dietary fiber, which enhances satiety and supports digestive well-being. The inclusion of almond flour and almond butter introduces beneficial unsaturated fats, vitamins, and minerals, promoting cardiovascular health. With a moderate caloric content (~430–450 kcal/100 g), the product offers an energy-dense snack option while providing superior nutritional value compared to conventional toffees. Additionally, the use of jaggery as a natural sweetener contributes essential minerals such as iron, magnesium, and potassium, while avoiding the negative effects associated with refined sugar consumption. Collectively, these attributes position the formulated toffee as a functional snack that addresses both taste and health.

CONCLUSION

The study demonstrates that the proportions of jackfruit seed powder and almond flour significantly influence the nutritional and sensory quality of the toffee. Sample C, formulated with a moderate level of jackfruit seed powder and higher almond flour, exhibited the most balanced profile, combining desirable texture, flavor, and protein content. Protein analysis via the Kjeldahl method confirmed that increasing almond content enhances the overall protein level of the product.

The integration of jaggery not only improved binding and consistency but also contributed micronutrients, further enhancing the healthfulness of the toffee. These results are consistent with prior research highlighting the benefits of using nut flours and underutilized seeds in functional confectionery development (Swami et al., 2012; Alasalvar & Shahidi, 2008). Overall, this study confirms that traditional confectionery can be reimagined as a nutrient-rich, functional product without compromising consumer acceptability, providing a promising approach for healthier snack alternatives.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Disclosure

All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Prof. M. S., Ansari, Prof. V. S. Wadmare investigation, data curation, conceptualization, writing – original draft, resources. Ms. S.P. Punjabi: investigation, data curation and conceptualization. Ms. A.A. Kharote: formal analysis, data curation, writing – original draft. Ms. P.K. Lokhande and Mr. P.V. Pandagale, Ms. P.A. Zoting,Ms J.A. Bhori, Ms S.R. Gajbhiye: formal analysis, data curation, conceptualization, methodology, software, writing – original draft, writing – review and editing. Giovanna Ferrentino: writing – review and editing.

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