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Development of High-Protein Functional Food Using Jackfruit as an Innovative Meat Substitute

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KEYWORDS

High-protein product, Jackfruit, Meat alternatives, Sensory evaluations, Value addition.

ABSTRACT:

Introduction: Jackfruit, in its raw form, is often an underrated vegetable despite its ability to provide a meat-like texture. In this experiment, an effort was made to develop a high-protein product by combining protein-rich vegetarian ingredients with jackfruit to create a meat substitute with a similar texture and nutritional value.

Objective: A high-protein product was created using jackfruit as the main ingredient to replicate a meat-like texture, while maintaining a completely plant-based composition.

Methods: To boost the protein content of the product (Kofta), ingredients such as soya chunks, lentils, watermelon seeds, and other protein-dense components were incorporated. Three different formulations were created, and initial protein estimates were calculated based on raw ingredients. Following this, sensory evaluations were conducted, and the samples were sent for laboratory protein analysis.

Result: The sensory results showed that all three formulations were well accepted by the evaluation panel, with only slight differences in scores. VAJK-3 received the highest Overall Acceptability score of 8.09, followed closely by VAJK-2 (8.0) and VAJK-1 (7.9). In the first phase, estimated raw protein levels were highest in VAJK-3 (18%), followed by VAJK-1 (16%) and VAJK-2 (13.63%). However, after processing and lab analysis, the protein values decreased: VAJK-1 retained 8.82%, VAJK-3 had 8.37%, and VAJK-2 had 7.57%. In the second phase, VAJK-1 demonstrated a significant improvement in protein content according to lab analysis, indicating that the formulation or processing methods had been effectively enhanced. This positions VAJK-1 as a particularly promising protein-rich option among the three.

Conclusion: With jackfruit-based products gaining popularity in recent years, there's substantial potential for innovation through value addition using both jackfruit and its byproducts. Such developments could play a key role in advancing plant-based meat alternatives and contributing to future food security.

I. Background:

Jackfruit, scientifically known as *Artocarpus heterophyllus*, is a tropical fruit tree native to southwest India. It is widely grown across India, especially in states like Kerala, Tamil Nadu, and Odisha. Known for being high-yielding, hardy, and low-maintenance, the jackfruit tree is incredibly versatile and valued for its distinct flavor. Numerous studies highlight its significance in food, medicine, and the creation of various value-added products. However, despite its many advantages, jackfruit remains underutilized in mainstream food systems (Hamid, 2020). This is largely due to challenges in processing, distribution, and a lack of awareness regarding its culinary uses and nutritional or medicinal benefits (Ahiduzzaman, 2024).

In Odisha, jackfruit plays an essential role in local cuisine and agriculture, contributing to the economy and supporting sustainable farming practices. India is the world's leading producer of jackfruit, with an annual output of around 1.3 million metric tons (Kumar, M., & Menon, S. V., 2022). The major contributors to this figure are Kerala, Tamil Nadu, and Odisha. In Odisha alone, where the fruit is widely cultivated—especially in tribal regions—annual production is estimated at about 100,000 metric tons (Dash, S. S., 2021). It is both

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a dietary staple and an important economic crop in the state.

Jackfruit can be consumed in its ripe or unripe form and serves a wide range of culinary purposes. Ripe jackfruit has a naturally sweet, tropical taste and is commonly eaten fresh, blended into smoothies, or used in desserts. It can also be preserved through drying or canning (Fabil et al., 2024). On the other hand, unripe jackfruit has a neutral flavor and fibrous texture, making it a popular plant-based substitute for meat in dishes like curries, stir-fries, and tacos.

The market for jackfruit-based value-added products is rapidly expanding, fueled by the growing demand for sustainable, plant-based foods (Islam, M. J. et al., 2021). Items like jackfruit chips, pickles, and canned versions are becoming increasingly popular due to their nutritional benefits and environmental appeal (Aswin, Bhasin., & Mazumdar, 2022).. As interest in vegetarian and vegan lifestyles continues to grow, jackfruit has emerged as a go-to meat alternative, particularly in ready-to-eat foods and snacks (Kalse, S. B. et al., 2022). The industry is expected to keep growing as companies explore new ways to process and package jackfruit, helping ensure year-round availability and creating new opportunities for farmers and businesses, especially in India and Southeast Asia (Pathak, N., 2022).

Jackfruit is highly nutritious and offers various health benefits. It is rich in natural sugars like fructose, making it an excellent energy source. The tree is also valued for its wood, which is used in furniture due to its attractive grain and color (Ranasinghe, 2019). The fruit exhibits numerous medicinal properties, including anti-bacterial, anti-diabetic, antioxidant, anti-inflammatory, and anti-parasitic effects (Islam, M. R. et al., 2023). It is packed with carbohydrates, vitamins, minerals, dietary fiber, and carboxylic acids. The seeds are especially nutrient-rich, containing essential minerals like manganese, magnesium, potassium, calcium, iron, and lectins, thereby playing a vital role in rural nutrition.

A 100-gram portion of young jackfruit provides about 51 kilocalories, 9.4 grams of carbohydrates, 2.8 grams of fiber, and 2.6 grams of protein. It is also a good source of vitamin C, supplying roughly 14 milligrams per serving. The seeds, too, are nutritious, delivering approximately 133 kilocalories, 6.6 grams of protein, 1.5 grams of fiber, and 25.8 grams of carbohydrates. When boiled or roasted, these seeds serve as a filling addition to meals (Nansereko, S., & Muyonga, J. H., 2021). The high fiber content in unripe jackfruit aids digestion and supports gut health. Additionally, antioxidants like flavonoids and carotenoids help combat oxidative stress, improve skin health, and reduce inflammation. Its potassium content contributes to heart health by helping regulate blood pressure. The demand for jackfruit and its processed products is increasing, driven by the rising preference for plant-based diets (Brahma & Ray, 2022). Value-added products such as frozen jackfruit, dehydrated jackfruit, jackfruit flour, and ready-to-eat (RTE) meals are gaining popularity, making jackfruit alucrative option in the food.

Value-Added Products

Jackfruit Kofta

To create nutritious and innovative jackfruit-based dishes, three unique varieties of jackfruit koftas were developed, each incorporating a different protein-rich ingredient. The **Jackfruit-Soybean Kofta** uses soybean as its main protein component, offering a wholesome, plant-based protein option. The **Jackfruit-Watermelon Seed Kofta** includes watermelon seeds, which not only add protein but also contribute beneficial fats. The **Jackfruit-Moong Dal Kofta** features moong dal (green gram), known for being a light, easily digestible source of protein. All three kofta variations are served with a rich, flavourful gravy made from tomatoes, cashew paste, almond paste, and a mix of traditional Indian spices, enhancing both the taste and nutritional profile of the dish.

Purpose of Food Product Development

- To create a nutritious, high-protein recipe using Jackfruit as a main ingredient.
- To ensure the product meets sensory expectations such as taste, texture, and aroma and meet the goal of plant based meat alternative.
- To strike a balance between consumer preference, nutritional value, food safety, cost-effectiveness, and regulatory compliance.

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II. Methodology:

The aim of the study was to develop value-added Jackfruit kofta products using various formulations. The goal was to achieve a meat-like texture with enhanced protein content, offering a nutritious plant-based alternative to traditional meat. The choice of kofta was driven by the need to create a main course dish suitable for lunch and dinner, with a gravy-based preparation. Jackfruit was selected as the core ingredient and was fortified with three protein-rich components to enhance its nutritional value. To mimic a meaty flavor using a vegan source like jackfruit, it was used as the filling in the kofta, ensuring its unique identity remained intact. Techniques such as grating and shredding were employed to improve its texture.

Although jackfruit is a promising meat substitute, its widespread use is limited due to the challenges involved in cleaning and processing. This jackfruit-based kofta aims to overcome those barriers, making it more accessible and appealing.

The product was designed to meet one-sixth of the Recommended Dietary Allowance (RDA). To promote a healthier option, air-frying was chosen over traditional deep-frying methods to reduce fat content.

The study was undergone in two phases based on highest protein content of the sample in phase I the product was further formulated to enhance the protein value in Phase II.

Phase 1: Study on Base formulations:

Stage I: Concept Development

The primary ingredient in our value-added Kofta product is jackfruit (*Artocarpus heterophyllus*). To boost the protein content of the recipe, three unique variations were created, each featuring a different protein-rich ingredient .To increase the nutritional profile, particularly the protein level, three separate formulations were designed, each incorporating a specific high-protein component.

- **Sample 1: Soybean**

Soybeans provide about 36–40% protein and contain all essential amino acids, making them a complete protein source. With a Protein Digestibility-Corrected Amino Acid Score (PDCAAS) of 1.0, they are highly suitable for vegetarian and vegan diets. Grated soya chunks (20g) were used in stuff for this formulation.

- **Sample 2: Lentils (Moong Dal)**

Lentils contain approximately 22–25% protein. When paired with cereals, they form a complete amino acid profile. Lentils are also easily digestible and promote effective protein absorption. Moong dal (30g) paste was used both in stuff and gravy as the protein component.

- **Sample 3: Watermelon Seeds**

Watermelon seeds are protein-rich and offer a well-balanced amino acid profile. They are highly nutritious and adaptable for use in various food applications. The paste (40g) is used in kofta coating, stuff and gravy.

All three variants featured a consistent base formulation that included jackfruit, chhena (cottage cheese), potato, cornflour, and sattu. Each was served with a protein-enriched gravy made from cashew, almond, and chhena paste.

Stage 2: Protein Estimation

- Theoretical protein values for each formulation were calculated using data from *Nutritive Value of Indian Foods* by C. Gopalan (2007).
- Each sample was carefully designed to ensure sufficient protein contribution from its specific protein source (soybean, lentil, or watermelon seed), with exact ingredient quantities recorded for accurate nutritional estimation.

Table3.1 Comparative study of ingredients proportions for different Value added Jackfruit Kofta Formulations

Ingredients	Formulation 1	Formulation 2	Formulation 3
	Amount(g)	Amount(g)	Amount(g)

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Stuffing			
Jackfruit	10	10	10
Binding			
***Soyabean (grated)**	**20***		
***Moong Dal (paste)**		**30***	
***Watermelon Seeds**			**40***
Chhena	28	30	28
Boiled Potato(mashed)	10	28	10
Cornflour	5	10	5
Sattu Powder	12	5	12
Gravy			
Tomato Puree	6	6	6
Onion Paste	5	5	5
Garlic Paste	2	2	2
Cashew Paste	5	5	5
Almond Paste	5	5	5
Chhena Paste	5	5	5

***Indicates main protein sources for formulations**

Stage 3: Procurement and Processing of Jackfruit and other ingredients

Fresh whole jackfruit and other ingredients were sourced from the local market. The outer skin of jackfruit was removed, and the edible parts were chopped into small pieces. These pieces were then washed in turmeric water, boiled until soft, and finely minced to attain a texture similar to meat.

Stage 4: Standard Recipe Preparation

Jackfruit and other ingredients were processed and prepared for recipe preparation which has been depicted below in flowchart.

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Figure 3.1 Flowchart of standard recipe preparation

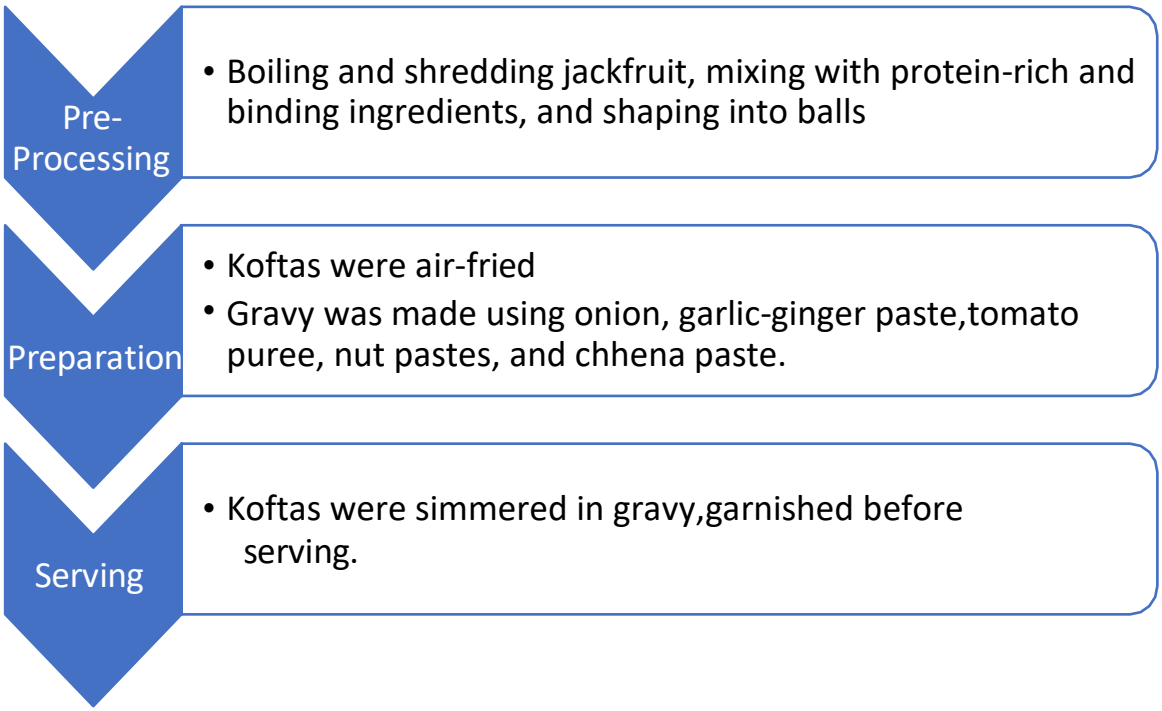

Plate 1: Processed Jackfruit

Plate 2: Minced Jackfruit

Plate 3: Moulded Kofta

Plate 4: Sensory evaluation

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Stage 5: Scorecard Preparation

- A 9-point Hedonic Rating Scale was designed to assess key sensory attributes such as taste, texture, aroma, appearance, and overall acceptability.
- This scale provided a structured method to objectively capture and analyze panelists' preferences.

Stage 6: Sensory Evaluation

- The evaluation was carried out in a controlled setting with semi trained panelists of ten in number.
- Each sample was assessed based on predefined sensory parameters, and panelists were instructed to evaluate using the hedonic scale.

Stage 7: Lab Sample Submission

- A 100g portion of each sample was sealed in a sterile, airtight container, clearly labeled, and transported under hygienic and temperature-controlled conditions for laboratory-based sensory and microbial testing.

Stage 8: Data Analysis

- The sensory scores were recorded and organised:
    - Mean scores of protein indicated overall preference
    - Standard deviation was used to evaluate consistency across panelists

Phase -2

After the Stage I results were released, the highest protein concentration was found in **Sample1**,

i.e. **VAJK-1**. To further increase the protein content, some finely ground soy chunk powder (40 grams) was added to the stuffing and binding of kofta. Further, the protein analysis was done in Kjeldahl method to get the accuracy in analysis. Other protein sources were chenna and sattu.

Plate 5: Samples for Lab analysis

III. Result and analysis:

In the experimental phase 1, three different samples were formulated by incorporating protein-rich ingredients such as groundnut, watermelon seeds, sattu, soya chunks, whey protein, and soy protein concentrates. Three different samples of Kofta with curry gravy were prepared, each incorporating various protein-rich sources in both the kofta and the gravy to enhance the overall protein content of the product. All other ingredients in both the kofta and the gravy were kept constant, and the preparation procedures were standardized to ensure consistency across samples.

Table4.1: Average Mean Scores of different Sensory Attributes (Value Added Jackfruit Kofta, VAJK)

Sample	Colour	Texture	Appearance	Taste	Overall Acceptance
VAJK-1	7.8±0.03	8.1±0,05	7.9±0.03	7.9±0,04	7.9±0.02
VAJK-2	8.2±0.02	8.1±0,03	8.2±0.05	8.2±0.01	8±0
VAJK-3	8±0.04	8.18±0,04	8±0.02	8±0.03	8.09±0.5

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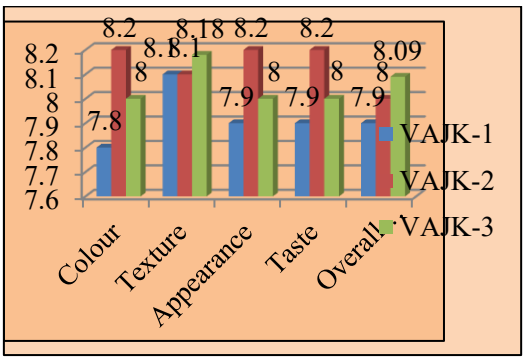
As shown in Table 4.1, under the Colour category, VAJK-2 received the highest score (8.2), indicating it had the most visually appealing appearance. VAJK-3 followed closely with a score of 8.0, while VAJK-1, although slightly lower at 7.8, still fell within the acceptable range. In terms of Texture, all three samples performed comparably, with VAJK-3 having a slight edge at 8.18, and both VAJK-1 and VAJK-2 scoring 8.1.

For Appearance, VAJK-2 was again rated highest at 8.2, followed by VAJK-3 (8.0) and VAJK-1 (7.9), suggesting that VAJK-2 had the most attractive overall presentation. In the Taste category, VAJK-2 also led with a top score of 8.3, making it the most flavorful, while VAJK-3 scored 8.18 and VAJK-1 received 8.0.

Finally, in terms of Overall Acceptability, VAJK-3 ranked the highest with a score of 8.09, followed by VAJK-2 (8.0) and VAJK-1 (7.9). The differences among the samples were minor, indicating that all three were well received by the panel.



Figure–4.1: Sensory Evaluation of Value Added Jackfruit Kofta (VAJK)

The following table 4.2 presents the estimated and laboratory analysis values of Kofta samples during two steps of the experiment: the ***First stage*** **and the** ***Second Stage*****,** with the later incorporating the **Kjeldahl method** for improved accuracy.

Table4.2: Estimated and Lab Protein Value of Value Added Jackfruit Kofta, VAJK (percentage)

	Sample1		**Sample2**		**Sample3**	
FirstStage	**Estimated Value**	**Lab Analysis Value**	**Estimated Value**	**Lab Analysis Value**	**Estimated Value**	**Lab Analysis Value**
	16	8.82	13.63	7.57	**18**	**8.37**
Second Stage(With Kjeldahl Method)						
	26.61	**22.27**				

According to Table 4.2 in Stage I, the raw protein percentages were highest in VAJK-3 (18%), followed by VAJK-1 (16%), and VAJK-2 (13.63%). However, when analyzed in the laboratory post-processing VAJK-1 retained 8.82 per cent protein, VAJK-2 had **7.57** per cent, and VAJK-3 had 8.37 per cent.

In Stage 2, a further evaluation of **VAJK-1** was conducted, after reformulation and enhancement in protein value with incorporation of additional amount of Soya chunks. Interestingly, the lab protein percentage increased significantly to 22.27 per cent with the raw protein at 26.61.

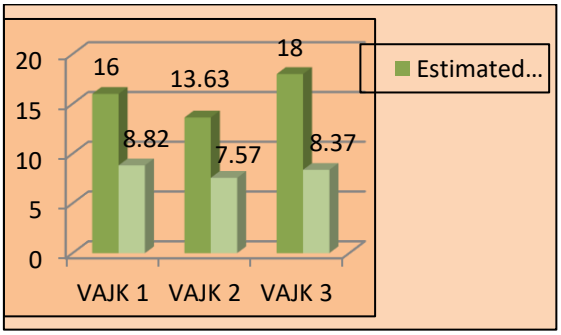


Figure4.2: Comparative Analysis of Estimated and Lab Protein values (VAJK), Stage 1

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Such a result indicates a significant improvement in the protein quality and content of the VAJK- 1 sample in Phase 2, making it a potentially more nutritious product after modification. Phase 1, all three samples showed a reduction in protein content after processing, with VAJK-1 showing the best retention. In Phase 2, **VAJK-1** exhibited a **notable increase in lab-tested protein content**, suggesting successful enhancement or improved processing methods. Overall, VAJK-1 shows promising potential as a protein-rich formulation, particularly after the improvements reflected in Phase II.

IV. Summary and Conclusion:

The product was developed exclusively using natural food sources. To ensure that the protein content exceeded 10%, formulations were created based on nutrient data from the *Nutritive Value of Indian Foods* (ICMR, NIN, 2021). These variations were thoughtfully designed to enhance protein intake through elements such as wraps, fillings, and gravies. For accurate protein measurement, the Kjeldahl method was employed in the second phase of the study, providing precise and reliable results. The experiment was deemed successful as it not only achieved the desired protein levels but also met the standards for sensory evaluation. All three samples received high acceptability ratings across all sensory attributes. VAJK-2 achieved the highest scores for Colour, Appearance, and Taste, reflecting a strong consumer preference. Although VAJK-3 scored slightly lower in individual sensory aspects, it received the highest Overall Acceptance score, making it the most favored formulation. VAJK-1, while marginally lower than the others, still demonstrated good sensory quality, indicating overall acceptability. During the initial stage, the estimated protein values for all three samples were significantly higher than the values obtained through laboratory analysis. For example, Sample 1 had an estimated protein content of 16%, while the lab analysis showed 8.82%. In the second stage, with the addition of soya chunks and use of the Kjeldahl method, the estimated protein content of Sample 1 increased to 26.61%, and the lab value rose to 22.27%, indicating a notable improvement in estimation accuracy. Considering the increasing market presence of jackfruit-based products, there is considerable scope for further research, particularly in the areas of value addition and potential clinical applications.

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