Development of Protein Rich Plant Based Meat Analogue for Vegan Athletes

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Abstract
The growing demand for plant-based diets among athletes has raised concerns about their protein intake without animal products. To necessitate this, a protein-rich plant-based meat analogue using jackfruit, seitan/gluten, and soy chunks was developed in this study as a suitable alternative for vegan athletes. Three samples (A, B, and C) of vegan sausages were prepared using different ingredient proportions. Sample D served as the control and was a commercial product. To assess the overall acceptability of the samples, sensory evaluation was conducted using a scorecard and hedonic scale. The sample that received the highest overall acceptance in the sensory evaluation was sample A, which was chosen for further proximate and physical analysis, and the nutritional components were compared with the commercial control sample. Sample A exhibited a moisture content of 58.75%, an ash content of 3.77%, a fat content of 5.05%, a protein content of 16.90%, a crude fibre content of 1.1%, a carbohydrate content of 14.42%, and provided 170.7 Kcal of energy. The inclusion of seitan/gluten, and soy chunks contributed to its high protein content. The findings highlight the potential of Sample A as a sustainable and nutritious protein-rich analogue for athletes following a plant-based diet.

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1. Introduction

The number of athletes choosing a vegan diet is increasing, but concerns about protein intake without animal products remain. However, evidence shows that vegans can excel in sports (Wirnitzer, 2020) [11]. It's important to plan a vegan diet carefully to ensure sufficient intake of essential nutrients. Without proper planning, there is a risk of inadequate consumption of important macro- and micronutrients (Shaw, 2022) [7]. A diversified diet of plant foods offer necessary amino acids, and surveys indicate that endurance athletes meet recommended protein intake (Barnard *et al.*, 2019) [1]. Many plant-based meat alternatives, available in the market are not healthy and may contain chemical preservatives, additives, artificial flavours, and high amounts of sodium (Bogueva & McClements, 2022) [2]. Sodium intake, whether too high or too low, can cause health and performance problems for athletes. Consuming too much sodium can result in fluid retention and dehydration, which negatively affects athletic performance and recovery (Veniamakis *et al.*, 2022) [9]. To address this, a study aims to develop a protein-rich plant-based meat analogue for athletes. This product will meet dietary needs, provide a delicious taste and texture, and offer an alternative protein source for vegan athletes. The study focuses on developing a vegan sausage using ingredients like jackfruit, seitan/gluten, and soy chunks.

Seitan/gluten protein, as we know, has an imbalanced amino acid composition, lacking lysine (Reynaud *et al*., 2021) [6] while containing tryptophan. To achieve this, incorporation of soy chunks, which are rich in lysine but lack tryptophan, helps to complete protein (Warwick, 2022) [10]. Additionally, the incorporation of jackfruit further enhanced the quality of the vegan sausage being developed.

2. Methods and Material

Procurement of raw material

In the development of vegan sausage, key ingredients included jackfruit, wheat flour, and soy chunks. Additional ingredients such as mushroom, onion, cumin, garlic, nutritional yeast, chicken masala, chickenless broth powder, salt, gram flour, mustard oil, and parchment paper were sourced locally in Gurgaon, sector 83. Nutritional yeast and chickenless broth powder were obtained from Amazon, while the control sample was a plant-based chicken sausage purchased from Big Basket. The development process took place in the laboratory of the Department of Dietetics and Applied Nutrition at Amity University Haryana.

Processing of jackfruit

The raw jackfruit was washed and pressure cooked with chickenless broth powder for 3 whistles. Then, the excess water was drained, the jackfruit was mashed, and the seeds were removed. Finally, it was left to cool at room temperature.

Processing of wheat flour to obtain seitan/gluten

A dough was prepared from wheat flour, which was immersed in cold water for 2 hours and washed 5 times until the gluten formed. The excess water was squeezed out using a muslin cloth. The dough was then cut into pieces and simmered in a broth for 20 minutes. After that, it was drained, cooled, and ground.

Processing of soy chunks for vegan-sausage

Soy chunks were soaked in water for 1 hour, then squeezed to remove excess water. They were ground and left to dry at room temperature for a few hours.

Preparation of a condiments and spices

A paste was made by stir-frying cumin, garlic, onion, and mushroom in mustard oil, then ground. Spices, including chicken masala, nutritional yeast, gram flour, black pepper, and salt, were mixed. For each sample, 5g of paste and 5g of spice mix were combined in a bowl, totaling 10g of spices and condiments.

Method of vegan sausage preparation

Three different samples were prepared by mixing processed jackfruit, seitan/gluten, and soy chunks in controlled proportions to compare their taste, texture, and overall quality. The blend in each container was combined with measured spices and condiments as shown in Table 1.

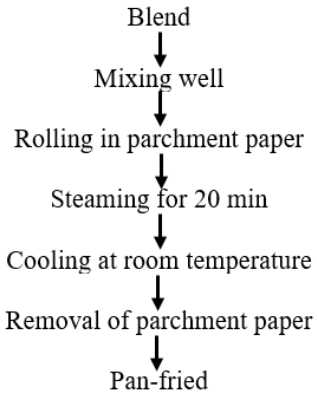


Fig 1: Flowchart for making vegan sausage

Table 1: Proportion of the variation of samples

Sample No.	Jackfruit	Seitan/ gluten	Soy chunks	Seasoning
Sample A	50g	20g	20g	10g
Sample B	20g	20g	50g	10g
Sample C	20g	50g	20g	10g

Sensory Evaluation

The four samples, including three prepared samples and one control sample, were labelled with their respective sample numbers and presented on a serving table under uniform daylight at room temperature. Faculty members and post-graduate students from Amity University, Haryana, India, tasted each sample and evaluated its appearance, colour, flavour, texture, taste, hardness, chewiness, elasticity, and overall acceptability using a scorecard. A nine-point hedonic scale was also used for comparison. Panellists provided their details and were instructed to drink water between samples.

Fig 2: Different samples of sausages ready for sensory evaluation

Nutritional Composition

The most accepted vegan sausage sample underwent proximate analysis at FARELAB Private Limited in M.G. Road, Gurgaon. Moisture content, ash content, protein, fat, and crude fiber were analyzed using specific methods (IS-10770, IS-1155, AOAS 922.06, IS-7219, and IS-10226, respectively). The total carbohydrate content was calculated. The energy content of the selected sample was calculated by multiplying the gram of protein, carbohydrate and fat by their respective calorie values and then added total calories from each macronutrients. The nutritional composition of the selected vegan sausage sample was then compared to a commercial control sample, with the nutritional information obtained from the packet of the control sample.

Physical parameter analysis

The physical parameters (height, weight, diameter, and thickness) of three sausages from the selected sample and the control sample were measured and compared. Tools such as string, scale, weighing scale, and calculator were used for the measurements.

Statistical analysis

Statistical analysis was done using mean and standard deviation to determine the most acceptable sample by looking at sensory parameters and physical parameters.

3. Results and Discussion

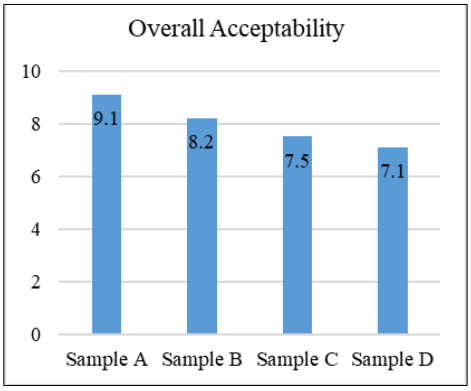
Sensory evaluation

The results displayed in Table 2 demonstrate that Sample A was the most preferred among all the panellists, as indicated by the highest total score. Conversely, Sample D was found to be the least preferred.

Furthermore, based on the hedonic scale ratings given by the panellists, sample A received "Liked extremely" rating with a score of 9, while sample D received "Liked moderately" rating with a score of 7.

Table 2: Result of sensory evaluation (mean± standard deviation)

Sensory Parameters	Sample A	Sample B	Sample C	Sample D
Appearance	8 ±1.3	8.2±0.7	8.1±0.9	8.3±1.1
Colour	8.4±0.8	8±0.7	8.2±1.1	8.5±1.0
Flavour	8.8±0.8	7.8±0.9	7.5±1.0	6.7±1.4
Texture	8.7±0.9	7.9±0.8	8.1±0.9	7.3±1.5
Taste	9±0.8	7.8±0.9	8±1.3	6.5±1.6
Hardness	8.3±0.9	7.8±1.0	8.1±0.8	6.9±1.9
Chewiness	8.8±1.1	8.3±0.8	7.7±0.9	6.7±1.8
Elasticity	8.7±1.0	8.1±0.9	7.8±0.9	6.7±2.2
Overall Acceptability	9.1±0.8	8.2±0.8	7.5±0.9	7.1±1.2



Graph 1: Column chart representing mean score of overall acceptability

In sensory evaluation, overall acceptance is crucial in determining consumer preference for vegan sausage. Sample A, with 50% jackfruit, 20% soy chunks, 20% seitan/gluten, and 10% spices and condiments, received the highest overall acceptance (mean score: 9.1), while Sample D had the lowest overall acceptability (mean score: 7.1).

Nutritional Composition

Sample A, composed of 50% jackfruit, 20% soy chunks, 20% seitan/gluten, and 10% spices, was the most accepted. Its nutritional composition was analyzed and compared with a market-bought control sample. Table 3 displays the nutritional composition of both samples.

Table 3: Nutritional composition of selected sample A and control sample D per 100g

Compositions	Selected Sample A	Control Sample D
Moisture (%)	58.75	-
Ash content (%)	3.77	-
Protein (g)	16.90	10.9
Fat (g)	5.05	14.68
Crude fiber (%)	1.11	-
Carbohydrate (g)	14.42	8.25
Energy (Kcal/g)	170.7	247

Moisture content

Moisture content above 40% is considered as high moisture (Zhang *et al.*, 2022) [12]. The selected sample had a moisture content of 58.75%, which is relatively high. This can be attributed to the cooking and processing method used for jackfruit, seitan/gluten, and soy chunks. While high moisture levels can make sausages more prone to spoilage, they also contribute to a softer texture. In the studies conducted by Stanin *et al.* (2020) **[8]**, Hamid *et al.* (2020) [4], and Paranagama *et al.* (2022) [5], the moisture content found in meat analogues was 56.72%, 42.27% and 64.49%, respectively, which is close to the values of moisture content found in selected sample.

Ash Content

The ash content of the selected sample is 3.77% which shows the quantity of mineral matter in the sample. As compared to the study conducted by Hamid, *et al.* (2020) [4], the ash content found in meat analogues was 3.76% which is close to the values of ash content found in selected sample. Similarly, other studies done by Stanin *et al.* (2020) **[8]**, and Paranagama *et al.* (2022) [5], the ash content found in meat analogues was 2.29%, and 2.62% respectively, which is low comparing to the ash content found under present study.

Protein content

The selected sample, Sample A, has a high protein content of 16.90%. This is due to its composition, which includes 20% seitan/gluten and 20% soy chunks, both of which are rich in protein. In contrast, the control sample, Sample D, contains only 10.9% protein, making it lower in protein content compared to the selected sample. In the study done by Hamid, *et al.* (2020) [4], the protein content found in meat analogue was 20.67% which is higher to the value of protein content. In other studies done by Paranagama *et al.* (2022) [5] and Stanin *et al.* (2020) **[8]**, the protein content was 3.95% and 9.25% respectively, which is significantly lesser than the value of the protein found under present study.

Fat content

Sample A, the selected sample, has a low fat content of 5.05% due to minimal use of fat during preparation. In contrast, the control sample, Sample D, has a high fat content of 14.68%. The high fat content in the control sample is likely due to extensive processing and the presence of additives. During sensory evaluation, the control sample released a significant amount of fat when cooked, leading to an unpleasant taste. This further indicates the presence of additives in the control sample. In the studies conducted by Stanin *et al.* (2020) [8] and Paranagama *et al.* (2022) [5], the fat content found in meat analogues was 2.94% and 5.94% respectively, which is similar to the fat content in the present study. However, in the study conducted by Hamid *et al.* (2020) [4], the fat content was 13%, which is higher compared to the selected sample in the present study.

Crude fiber

The selected sample has a crude fiber content of 1.11%. This value represents the proportion of indigestible plant material present in the sample. In a study conducted by Hamid *et al.* (2020) [4], the crude fiber content found in meat analogues was 3.41 %, which is higher that the value of selected sample. However, the similar value of crude fiber that is 1.125% has been reported by Paranagama *et al.* (2022) [5].

Carbohydrate

The selected sample had a carbohydrate content of 14.42%, while the control sample had a lower content of 8.25%. Carbohydrates are important for athletes as they contribute to protein synthesis (Figueriredo & Smith, 2013), crucial for muscle repair and recovery. The higher carbohydrate content in the selected sample suggests potential benefits for athletes and their performance. The carbohydrate content in the studies done by Satanin *et al.* (2020), Hamid *et al.* (2020) [4], and Paranagama *et al.* (2022) [5], was 28.32%, 16.90% and 21.78% respectively, which is much higher than the value of selected sample.

Energy

Sample A has an energy content of 170.7 Kcal, lower than Sample D with 247 Kcal. This difference could be due to variations in macronutrient composition and quantity. In the study conducted by Hamid *et al.* (2020) [4], the energy content of the samples was determined, and they reported an average energy content of 271.65 Kcal. This value is significantly higher than the energy content observed in our selected sample, Sample A.

Physical Parameters

Physical parameters in sausages are measured to evaluate their quality and quantity. These measurements provide valuable information about the sausage's physical characteristics, influencing its appearance and overall acceptability. Parameters like length, diameter, and weight are crucial for standardization and portion control, ensuring that sausages meet size requirements and maintain consistency in packaging, labelling, and pricing.

Table 4: Result of physical parameters (mean± standard deviation)

Parameters	Selected Sample A	Control Sample D
Height (inch)	3.5±0.4	4.8±0.3
Weight (g)	50±0.0	33±2.0
Circumference (cm)	8.9±0.2	7.2±0.3
Diameter (cm)	2.8±0.1	2.2±0.3
Thickness (inch)	0.9±0.2	0.6 ±0.2

Fig 3: Selected sample and control sample

4. Conclusion

This study aimed to develop a protein-rich, plant-based meat analogue for athletes. Among three formulations, Sample A, consisting of 50% jackfruit, 20% seitan/gluten, 20% soy chunks, and 10% spices and condiments, was the most accepted. While the control sample had better appearance, Sample A excelled in flavor, texture, and overall acceptability. It also had higher protein content (16.90%) and carbohydrate content (14.12%) compared to the control sample, making it beneficial for athletes. This development provides a sustainable and nutritious alternative for athletes on vegan diets, promoting their well-being and supporting their dietary preferences. Further improvements can enhance plant-based meat analogues for athletes.

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