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Anshul Singh
Department of Food Chemistry and Nutrition, College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

KS Gadhe
Department of Food Chemistry and Nutrition, College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Corresponding Author:
Anshul Singh
Department of Food Chemistry and Nutrition, College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Development and physicochemical evaluation of vegan meat balls using composite flours of defatted soya, Amaranth, and jackfruit

Anshul Singh and KS Gadhe

Abstract
The study examines the physical, chemical, and mineral properties of jackfruit, amaranth, and soybean, aiming to optimize agricultural machinery and processes. It reveals differences in color, weight, density, and cohesiveness. Chemical composition analysis reveals variations in moisture, protein, fat, carbohydrates, fiber, and ash content. The study also examines the chemical composition of jackfruit flour and vegan meatballs, finding higher protein content, lower fat, increased carbohydrates, and additional nutrients.

Keywords: Physicochemical evaluation, physical, chemical, and mineral properties, additional nutrients

Introduction
In recent years, there has been a notable surge in research focusing on plant-based proteins as a viable alternative to conventional animal-derived food sources. This trend is driven by the escalating challenges posed by the world's population growth, coupled with constraints on finite natural resources, leading to concerns about the sustainability of animal protein production. Environmental and ethical issues associated with animal husbandry practices, along with health-related concerns linked to red meat consumption, further contribute to the momentum towards plant-based alternatives (Yuliarti *et al.*, 2021) [106]. The food processing industry has undergone a transformative evolution, characterized by the intricate interplay of material streams to create resilient and uniform food products. Increasing pressures on animal meat production have led consumers to seek alternatives, driven by concerns about efficiency, health consequences, environmental impact, and animal welfare (Kumar *et al.*, 2017) [45]. However, changing consumer behavior is a complex task, requiring a shift in attitudes grounded in rationale and motivation. Environmental considerations are explored as potential catalysts for encouraging individuals to reduce or abstain from meat consumption (Sanchez-Sabate & Sabate, 2019) [108].
Plant-based meat analogues, produced from proteins extracted from sources like wheat, soybeans, legumes, and oilseeds, aim to replicate the visual, gustatory, and textural characteristics of animal meat (Lee *et al.*, 2020) [49]. The challenge lies in achieving the desired texture, particularly emulating a fibrous structure, which can be addressed through adjustments in processing conditions (Palanisamy *et al.*, 2018) [62]. Wheat protein, especially gluten, is a widely employed plant-based protein due to its rheological and viscoelastic attributes, contributing to the cohesiveness and fibrous texture in meat analogues (Xiong *et al.*, 2008) [104].
Texturized vegetable proteins, predominantly derived from soy and pea protein isolates, are commonly used to mimic animal proteins. However, there is growing interest in exploring alternative sources such as lupin, hemp, mung bean, and wheat gluten (Samard *et al.*, 2019) [87]. Soy proteins, in combination with wheat gluten or pectin, offer the potential to create diverse fibrous structures, influenced by moisture content, biopolymer proportions, and processing conditions (Floor *et al.*, 2019) [109].
Jackfruit, an underutilized tropical fruit, has gained attention for its nutritional value, including protein, dietary fiber, and various phytonutrients. Jackfruit by-products, combined with vital wheat gluten, emerged as a favored meat analogue in sensory evaluations, displaying favorable characteristics and elevated nutritional content (MA, *et al.*, 2020) [32]. Similarly, amaranth, recognized as a pseudo cereal, serves as a gluten-free alternative with substantial nutritional value, making it suitable for individuals with celiac disease (Arti *et al.*, 2015) [110].

The functional attributes of plant proteins depend on factors like amino acid profile, protein structure, hydrophobicity-to-hydrophilicity ratio, pH, temperature conditions, and interactions with non-protein constituents (Anzani *et al.*, 2020) [3]. Pulse protein concentrates (PPCs) show promise in replacing animal proteins in various food applications, offering benefits such as allergen reduction and improved organoleptic attributes.

To meet the global demand for plant-based food, there is growing interest in exploring new, inexpensive, reliable, and sustainable protein sources. Dry-fractionated proteins, including blends of soybean, amaranth, and jackfruit protein concentrates, are being considered for meat analogue production to achieve essential amino acids, flavor, texture, and a nutritionally valuable composition (Penchalaraju *et al.*, 2022) [6].

The exploration of various plant-based protein sources and the development of meat analogues with desirable characteristics present a promising avenue for addressing these concerns and catering to the growing global demand for sustainable and nutritious food alternatives. In this study physicochemical properties of jackfruit, soybean, and amaranth and the development of vegan meat balls was carried out.

Materials and Methods

Raw materials

Jackfruit and local variety of amaranth grains were procured from the Parbhani city market in Maharashtra, while defatted soybean cake was sourced from Mathura Oil Refinery in the Parbhani Industrial Area, Maharashtra. Essential raw materials for vegan meat production, such as corn flour, spice mix, garam masala, ginger garlic paste, refined wheat flour (Maida), and salt, were obtained from the local Parbhani market. All the chemicals used in this study are analytical grade.

Analysis of physical properties of jackfruit, soybean and amaranth

Jackfruit, soybean and amaranth were cleaned and analysed for various physical properties such as colour, weight of 1000grains, bulk density, true density, porosity and functional properties such as angle of repose as per according to respective standards procedure given by Poshadri *et al.* (2023) [76]

Thousand seeds weight

Thousand seeds weight was measured by 1000 randomly selected seeds and weighing them using an electronic balance having an accuracy measure of 0.001g and then multiplied by 10 to give mass of 1000 seeds.

Bulk Density

Bulk density was calculated by using a container of known volume, the sample was taken into the container for the known volume and weighed. The bulk density was calculated with the help of following formula Poshadri *et al.* (2023) [76]

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of grains (g)}}{\text{Volume of grains including pore space (ml)}}$$

True Density: 50 ml of toluene was taken in a measuring jar. A known weight of grains sample was poured to the measuring jar and rise in the toluene level was recorded. The true density of grain was calculated by using the following formula Poshadri *et al.* (2023) [76]

$$\text{True density (g/ml)} = \frac{\text{Weight of grains (g)}}{\text{Volume of grains excluding void space (ml)}}$$

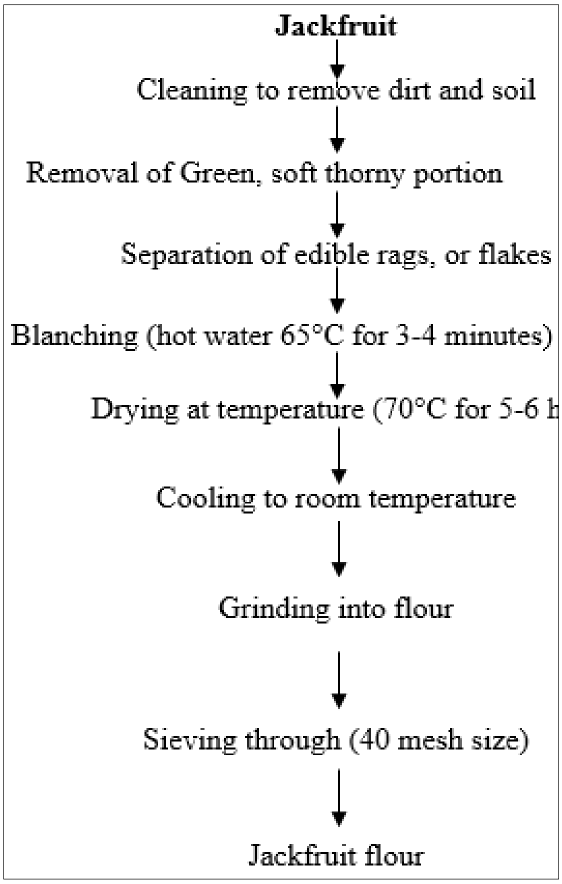
Methods of preparation of jackfruit, defatted soybean and amaranth flour along with their composite blended flour

Experimental design

Based on review of literature and preliminary trials, the experimental work plan was prepared and experimental parameters were identified. The detailed work plan, treatment variables and experimental designs are given below:

Jackfruit powder preparation

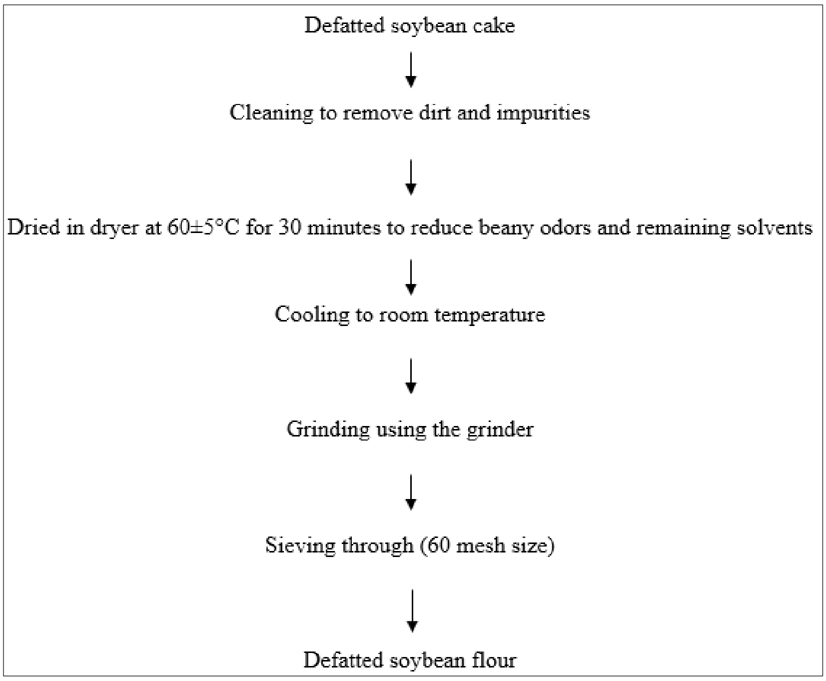
The freshly harvested jackfruit (*Artocarpus heterophyllus*) were sourced from local market and processed according to the method previously described by MA, Hamid *et al* (2020) [32]. A ripe jackfruit was chosen, and the green, soft thorny portion on the skin's outer layer was taken out, keeping only the white portion. The rags, or flakes, which were white bands encircling the yellow jackfruit, were attached to the rinds. The rags and rinses were divided into smaller pieces. Then blanched for two minutes in boiling water after washing. Following blanching, they were submerged in running cold water stop the continuous cooking process. Squeezed water was extracted from the blanched and used their hands to cool down the rigs and cloths before settling down. Then dried those rags and rinds in a dryer at 70 °C for 5-6 hours. After cooling grounded in a micro pulveriser. The Jackfruit flour was packed in LDPE pouches until it was processed into wet, extruded vegan meat balls.



Preparation of Jackfruit flour

Defatted soybean cake flour preparation

Defatted soybean cake was processed into defatted soybean flour. The defatted cake was dried in a dryer to reduce beany odors and evaporated leftover solvents in the cake at a temperature of 60 °C for 30 minutes. Then it was cooled to room temperature and ground in the laboratory micro-pulverizer into fine flour. The defatted soy cake flour was packed in LDPE pouches until it was processed into wet, extruded vegan meat balls.



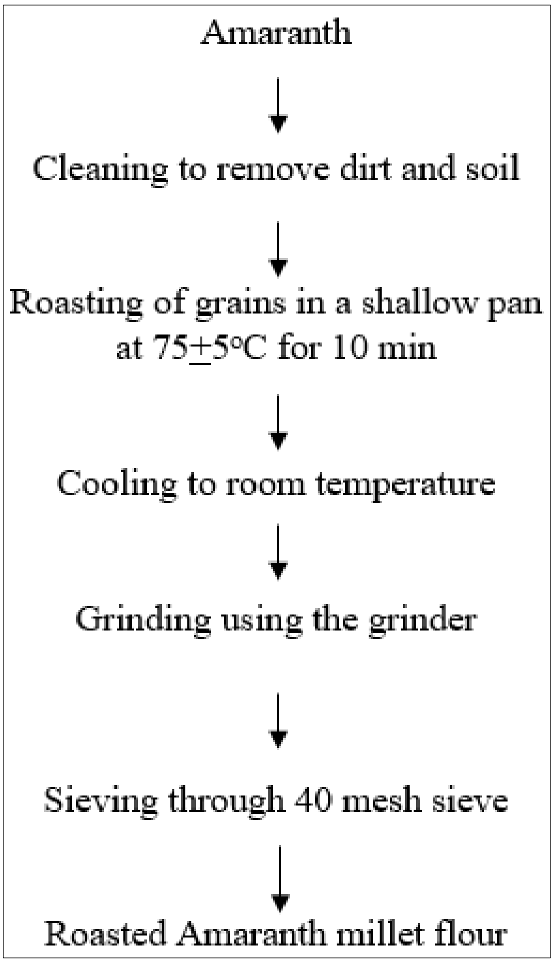
Preparation of soybean flour

Amaranth Flour preparation

The roasting of Amaranth grains was carried out by using the method suggested by Poshadri *et al.* (2023) [76] to reduce anti nutritional factors and improving of sensory attributes of end product. The best quality Amaranth was purchased from local store. Grains were cleaned to remove dirt. Amaranth grains were roasted in a shallow pan at 75±5ºC temperature for 10 min.

The pan was maintained at that temperature (by using laboratory scale digital thermometer) and vigorously stirred for the purpose of uniform roasting. After roasting the samples were brought to room temperature and ground to fine flour using laboratory grinder and the flour was passed through a sieve of mesh size 40. The resultant flour was packed in air tight plastic containers until used for analysis and preparation of product.

Roasted amaranth flour was prepared meat analogues by using following flow chart (Flow sheet 1)



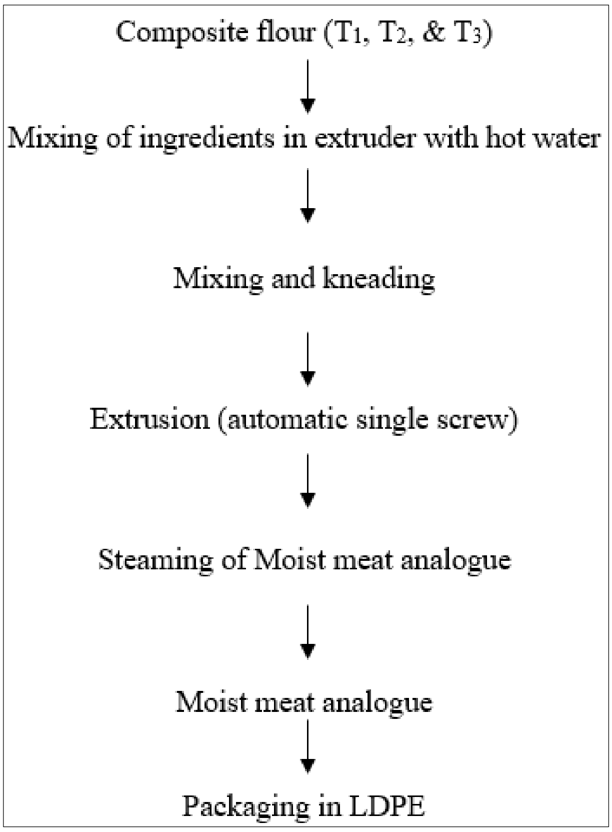
Preparation of roasted amaranth flour

Preparation of composite flour for vegan meat balls production

Meat balls was prepared in the laboratory as previously described by Malleboina Penchalaraju & Sowriappan (2022) and Leelawat *et al.*, (2023) [96]. The composite flour blend comprises different proportions of defatted soy flour, roasted amaranth flour, and Jackfruit flour chosen for the wet extrusion process to produce high-moisture meat analogue shreds as presented in Table 3.1. The moisture of composite flour was adjusted to 50% with hot water (70°C) to give pre-gelatinization effect on the feed mixture. Then the different formulations were processed into meat analogue using extruder (Model No. 16009, Kent Noodle and Meat analogue Maker).

Table 1: Standardization of recipe used for preparation of vegan meat balls.

Ingredients	Control	T_1	T_2	T_3
Minced chicken (g)	100%	-	-	-
Defatted soy flour (g)	0	50	50	50
Amaranth flour (g)	0	30	20	40
Jackfruit powder (g)	0	20	30	10
Hot water (70°C) (ml)	-	100	100	100



Flow sheet 3.4: Preparation of vegan meat balls from composite flours

Formulation of final vegan meat balls

Table 2: Formulation of final vegan meat balls

Ingredients	Control	T_1	T_2	T_3
Minced chicken	250	0	0	0
Defatted soy flour	0	50	50	50
Amaranth flour	0	30	20	40
Jack fruit powder	0	20	30	10
spice mix	4	4	4	4
Garam masala	6	6	6	6
Salt	2	2	2	2
Corn flour	20	5	5	5
Black pepper	1	1	1	1
Ginger garlic paste	2	2	2	2
Chopped onions	2.8	2.8	2.8	2.8
Green coriander leaves	2	2	2	2
Baking soda	0.2	0.2	0.2	0.2
Maida	0	10	10	10
Beet root	0	5	5	5

Preparation of moist vegan meat balls

T_1, T_2 and T_3 samples of moist vegan meat balls samples were mixed with spices and other ingredients as presented in the Table 3.2. to make vegan meat balls. The vegan meat balls were fried in hot edible oil at temperature 180 °C till they turn into golden brown colour. Similarly, the control meat balls were prepared using minced chicken with spice and other ingredients as given in the Table 3.2. Then fried in hot edible oil at temperature 180 °C till they turn into golden brown colour.

Results and Discussion

Physical properties of jackfruit, soybean and amaranth

The methodical assessment of the physical properties of legumes and pseudo cereals is crucial for optimizing parameters that are crucial for the creation of agricultural machinery utilized in the operations of handling, storing, and producing these crops. It is essential to build and acknowledge a comprehensive database that includes the physical attributes of various agricultural goods. These characteristics have a significant impact on the creation and design of specialized gear, which in turn affects operational tasks like cleaning, sorting, and separation.

A thorough examination of the physical attributes of the chosen jackfruit, amaranth, and soybean was carried out in this regard. For soybean, amaranth, and jackfruit, these features were colour, thousand-grain weight, bulk density, actual density, porosity, and the angle of repose. Table 4.1 provides an explanation of the findings regarding the physical characteristics of jackfruit, soybean, and amaranth.

Table 3: Physical properties of soybean, amaranth and jackfruit

Physical Parameter	Soybean	Amaranth	Jackfruit
Colour	Pale Yellow	Dull whitish	Greenish Yellow
Thousand grain weight (g)	210	4.6	-
Bulk Density (g/ml)	0.74	0.80	0.81
True density (g/ml)	1.33	2.73	2.16
Porosity (%)	41.6	67.41	66.32
Angle of repose (^{0})	26° 40′	24° 2′	-

A considerable fluctuation in the pale-yellow hue of soybeans, which is attributed to the presence of pigments such as carotenoids, specifically beta-carotene, was found by empirical analysis of the data shown in Table 4.1. One naturally occurring pigment known as beta-carotene is the source of the yellow to orange hue found in a variety of foods that come from plants. According to Yuan *et al.* (2009) [105], beta-carotene is the predominant carotenoid in soybeans, which contributes to their unique light-yellow colour.

Research has been done on the carotenoid profile of many legumes, including amaranth. Carotenoids are essential forgiving many plant tissues their colour. Moreover, the pale-yellow hue that may be seen in amaranth grains is owing to carotenoids Pinheiro *et al.* (2016) [72].

Understanding how jackfruit ripens involves understanding how the green pigment chlorophyll changes into the yellow and orange pigments called carotenoids as the fruit ages.

The significant difference in the weight of the thousand grains between the soybean (Around 210g) and amaranth (4.6g) can be attributed to natural differences in the traits of the seeds and the different plant species. Similar results were also seen by Poshadri *et al.* (2023) [76] for the physical properties of amaranth.

Studies concerning amaranth and soybean grains often highlight the diversity of traits present in their seed sizes. For soybeans, the higher thousand-grain weight corresponds to their typical seed weight, which can range from 100 to 400g per thousand seeds, depending on the type of soybean and the surrounding conditions.

On the other hand, amaranth grains are noticeably smaller than soybean grains, which leads to a lower thousand-grain weight. One inherent feature of this specific plant variety is the smaller size of amaranth seeds.

The differences in bulk density between jackfruit (0.81g/ml), amaranth (0.80g/ml), and soybeans (0.74g/ml) can be attributed to differences in the physical properties of these food products.

For soybeans (1.33g/ml), amaranth (2.73g/ml), and jackfruit (2.16g/ml), the real density values illustrate differences in the mass distribution and compactness within these food matrices.

The mass of a solid substance per unit volume is measured by its true density, which depends on a number of variables such as porosity and the effectiveness of particle packing. The observed differences can be attributed to intrinsic differences in the physical characteristics and makeup of amaranth, jackfruit, and soybean.

Regarding soybeans, the lower actual density could be attributed to either a higher interstitial space between particles or a more porous structure. On the other hand, the higher actual density found in jackfruit and amaranth may indicate a denser and more compact particle arrangement.

A substance's bulk density can be affected by factors like porosity, packing arrangement, and particle size. For soybeans, higher seed sizes and possibly a looser packing arrangement could be associated with the lower bulk density. Soybeans are known for their somewhat larger seeds when compared to jackfruit and amaranth.

For amaranth and jackfruit, the slightly higher bulk density may be due to smaller particle sizes and a more compact arrangement of their respective grains or pieces.

Differences in porosity between soybeans (41.6%), amaranth (67.41%), and jackfruit (66.32%) are indicative of differences in the internal composition and packing arrangement of various food items.

The number of empty spaces or voids in a material is known as its porosity, and it depends on a number of variables, such as the size, shape, and arrangement of the particles. The differences found suggest that jackfruit and amaranth have higher porosity than soybeans.

The higher porosity in jackfruit and amaranth can be attributed to smaller particles and a more expansive or porous interior structure. On the other hand, soybeans' internal structure could be more compacted, which would result in a decreased porosity.

The angles of repose of amaranth (24°2′) and soybeans (26°40′) provide information about the cohesiveness and flow characteristics of these particulate materials. The maximum angle at which a pile of material remains stable without further collapsing is known as the angle of repose.

The differences seen in the angle of repose between amaranth and soybeans could indicate variations in the characteristics of the particle's shape, size, and surface. Materials that have a lower angle of repose are usually more soluble.

Chemical composition of jackfruit, soybean and amaranth

The study emphasizes the fundamental role that chemical composition has in defining the nutritional quality when creating a meat substitute with flour and key ingredients including amaranth, jackfruit, and soybeans. The investigation's principal goal is to thoroughly examine and characterize these raw materials' chemical makeup, realizing that this has a direct impact on the final product's quality. Table 4.2 provides a concise summary of the collected data.

Table 4: Chemical composition of jackfruit, soybean and amaranth

Parameter	Jackfruit (%)	Soybean (%)	Amaranth (%)
Moisture	76.40 ± 0.51	7.51 ± 0.55	9.87 ± 0.63
Protein	0.98 ± 0.33	42.8 ± 0.30	13.72 ± 0.96
Fat	2.64 ± 0.21	1.20 ± 0.25	6.79 ± 0.45
Carbohydrate	17.3 ± 0.56	35.6 ± 0.40	73.3 ± 0.39
Fibre	0.53 ± 0.82	7.35 ± 0.92	7.42 ± 0.51
Ash	0.75 ± 0.17	5.60 ± 0.15	2.60 ± 0.36

From table 4.2 it can be revealed that the chemical proximate for soybean, jackfruit and amaranth. The moisture content ranged between 7.51 to 76.40 per cent, protein 0.98 to 42.8 per cent, fat 1.20 to 6.79 per cent, carbohydrate 17.3 to 73.3 per cent, fibre 0.53 to 7.42 per cent, ash 0.75 to 5.60 per cent.

The data depicted in Table 4 exhibited that soybean contained highest protein 42.8 per cent and lowest fat 1.20 per cent. It is also found that soybean contains 7.51 per cent moisture, 35.6 per cent carbohydrate, 7.35 per cent fibre and 5.60 per cent ash. The similar results were observed by Rosset *et al.* (2012).

The observed increase in protein content and simultaneous decrease in fat content in soybeans can be attributed to the defatting procedure, which entails the mechanical or chemical separation of the lipid component from the soybean matrix.

The data depicted in Table 4 exhibited that jackfruit had highest value for moisture 76.40 per cent and lowest fibre 0.53 per cent. It was also found that jackfruit contains 0.98 per cent protein, 2.64 per cent fat, 17.3 per cent carbohydrate and 0.75 per cent ash. The similar results were observed by C. go swami *et al.* (2011) [29].

The juicy tropical fruit known as jackfruit has a high-water content, mostly because it contains cell sap-filled vacuoles. The fruit's flesh is kept generally hydrated by these vacuoles. The plant's systems for absorbing and storing water, as well as external circumstances throughout development and maturation, all affect the moisture content. Because the edible components of jackfruit have a soft, pulpy feel, this may explain why the fruit has a comparatively low fibre level. Fruit structural elements like cell walls are frequently where Crude Fibre is found in fruits; however, in the case of jackfruit, the lower fibre content indicates a lower concentration of these structural elements.

The data depicted in Table 4 exhibited that amaranth had highest value for carbohydrate 73.3 per cent and fat 6.79 per cent respectively. It is also found that amaranth also contained 9.87 per cent moisture, 13.72 per cent protein, 7.42 per cent fibre and 2.60 per cent ash. The similar results were observed by Bressani *et al.* (1992) [9].

The process of roasting grains can have complex effects on their nutritional makeup, affecting both macro and micronutrients. Variations in the final nutritional profile can result from contributing factors like temperature, roasting time, and particular procedural conditions.

Notably, these findings are consistent with previous research, particularly in alignment with the results of Poshadri *et al.* (2023) [76]. This concurrence in results substantiates the reliability and consistency of the chemical composition of amaranth flour were observed in Deshpande and Poshadri (2011) [19] thereby providing valuable insights into its nutritional characteristics and quality.

Mineral composition of soybean, jackfruit and amaranth

The examination of mineral composition in jackfruit, soybean and amaranth is crucial for establishing their nutritional significance. The minerals scrutinized in the current study include calcium, zinc, iron, magnesium, phosphorus potassium. Minerals play a pivotal role in numerous physiological functions within the human body, specifically in processes associated with growth, structural development, and regulatory mechanisms. The detailed data on specific mineral content is presented in Table 5. for reference and analysis.

Table 5: Minerals composition of soybean, jackfruit and amaranth

Parameter	Soybean (mg/100gm)	Jackfruit (mg/100gm)	Amaranth (mg/100gm)
Calcium	65.16 ± 0.7	44.70 ± 0.2	68.5 ± 0.6
Zinc	2.83 ± 0.3	1.67 ± 0.4	3.21 ± 0.3
Iron	8.75 ± 0.5	1.21 ± 0.6	13.80 ± 0.2
Magnesium	690.5 ± 02	130.3 ± 0.2	236.8 ± 0.5
Phosphorous	924.5 ± 0.1	134.2 ± 0.5	529.4 ± 0.4
Potassium	379.4 ± 0.4	296.8 ± 0.8	508.6 ± 0.6

The data presented in Table 5. disclosed the mineral composition of soybean, encompassing calcium (265.16 mg/100g), zinc (2.73mg/100g), iron (18.75mg/100g), magnesium (258.24mg/100g), phosphorus (624.5mg/100g), and potassium (579.4mg/100g). These outcomes closely correspond to the observations documented by Rani Varsha *et al.* (2008). Particularly noteworthy is the discernible indication that soybean manifested a substantial content of both calcium and phosphorus.

The data presented in Table 4.3 disclosed the mineral composition of jackfruit, encompassing calcium (44.70 mg/100g), zinc (1.67mg/100g), iron (1.21mg/100g), magnesium (130.3mg/100g), phosphorus (134.2mg/100g), and potassium (296.8mg/100g). These outcomes closely correspond to the findings documented by MS Abedin *et al.* (2012) and Goswami C. *et al.* (2016). Particularly noteworthy is the discernible indication that jackfruit was reported to demonstrate a substantial content of calcium, phosphorus, magnesium, phosphorus, and potassium.

The data presented in Table 4.3 indicated the mineral composition of amaranth, including calcium (22.5mg/100g), zinc (2.10mg/100g), iron (13.80mg/100g), magnesium (536.8 mg/100g), phosphorus (529mg/100g), and potassium (523.1mg/100g). These results are in good agreement with those that Shimelis Admassu Emire *et al.* (2012) published. Of particular significance is the apparent suggestion that amaranth had a significant iron and potassium content.

Chemical composition of jack fruit flour

The chemical composition of jack fruit flour is presented in Table 6

Table 6: Chemical composition of jack fruit flour

Parameter	Jack Fruit Flour (Amount/100g)
Moisture	6.53 ± 0.3
Protein	4.19 ± 0.4
Fat	1.91 ± 0.2
Carbohydrate	77.52 ± 0.8
Fibre	8.02 ± 0.3
Ash	1.70 ± 0.1

The data presented in Table 6 provides the chemical composition of jack fruit flour. The analysis revealed that the moisture content of jack fruit flour was measured at 6.53 per cent. Additionally, the protein content in jack fruit flour was determined to be 4.19 per cent. The ash content was found to be 1.70 per cent, while the fat content was 1.91 per cent. The carbohydrate content was noted at 77.52 per cent, and the fibre content was measured at 8.02 per cent. These numbers represent the exact chemical makeup of jackfruit flour. These findings closely match the information provided by Christy Paul and Colleagues (2017).

Table 4.5 presents a comprehensive dataset that pertains to the impact of the roasting process on the functional attributes of the composite flour. The data within this table provides a detailed account of the precise modifications in functional characteristics that arise as a direct consequence of subjecting the composite flour to the roasting treatment.

Nutritional Composition of jackfruit, soybean and amaranth based vegan meat

The chemical composition of meat is a pivotal determinant of the nutritional quality of a plant meat balls product. The overall quality of the final product is intimately associated with the quality of the raw materials utilized. In the specific context of vegan meat production, the foundational ingredients encompass jackfruit powder, amaranth flour, and soybean flour. The nutritional composition of vegan meat balls and control chicken meat balls are presented in the Table 7

Table 7: Nutritional composition of vegan meat balls v/s control per 100g.

Nutrients	C	T_1	T_2	T_3
Energy (Kcal)	199.1	340.4	341.1	339.6
Moisture (g)	8.3	8.4	8.2	8.3
Protein (g)	19.3	26.0	25.5	26.5
Total Carbohydrates (g)	20.8	52.3	53.6	51.1
Sugar (g)	0.1	0.1	0.1	0.1
Total Fat (g)	4.3	3.0	2.8	3.2
Crude Fibre	4.1	9.0	9.4	8.7
Total Ash (g)	1.2	3.4	3.3	3.5
Calcium (mg)	73.8	154.3	161.4	147.1
Iron (mg)	3.3	4.3	4.1	4.5

The protein content in the composite flour samples, as presented in Table 7, reveals that Vegan meat balls T_3 exhibited the highest protein content at 26.5g, surpassing T_1 (26.0g) and T_2 (25.5g). This increase is attributed to the 40 percent inclusion of amaranth flour in T3. Notably, chicken meat balls had significantly lower protein content than plant-based vegan balls.

Vegan meat analogue sample - T_2 exhibited the lowest at 2.82g, followed by T_1 (3.0g) and T_3 (3.2g). Increased jackfruit flour in T_2 correlated with decreased fat content. Control chicken balls had significantly higher fat content, consistent, attributing it to the inherently lower fat in plant protein sources compared to chicken.

Total carbohydrates content in vegan meat balls was significantly higher than the control, with T_2 (53.6g) having more than T_1 (52.3g) and T_3 (51.1g). This difference may be linked to the greater proportion of roasted amaranth flour in T_2. Crude fibre content was absent in raw chicken but present in chicken meat balls due to added ingredients. Vegan meat balls exhibited the highest crude fibre in T_2 (9.4g), potentially attributed to 30 percent jackfruit powder.

Ash content showed no significant difference among vegan meat balls, though T_3 (3.5g) contained more ash than the other two samples. Energy content in vegan meat balls was higher in T_3 (341.1 Kcal) than T_1 (340.4 Kcal) and T_2 (339.6 Kcal) due to higher fat and protein. Chicken energy was 44% lower than vegan meat balls. Calcium content in vegan meat balls was double that of the control, with higher quantities in T_1 and T_2. Increasing jackfruit powder correlated with higher calcium. Iron content in vegan meat balls was higher than chicken, with no significant difference among vegan samples. The results suggest the potential nutritional superiority of plant-based vegan meat alternatives.

Conclusion

The study meticulously assessed the physical properties of jackfruit, amaranth, and soybean, crucial for optimizing agricultural machinery. Further analysis delved into the chemical composition of jackfruit, soybean, and amaranth, including moisture, protein, fat, carbohydrates, fiber, and ash. Soybean exhibited the highest protein, while amaranth showed high carbohydrate and fat content. Jackfruit's high moisture and low fiber indicated its juicy nature. The mineral composition, encompassing calcium, zinc, iron, magnesium, phosphorus, and potassium, highlighted significant variations among the three. Additionally, the chemical composition of jackfruit flour and its impact after roasting were examined. The study also investigated the nutritional composition of vegan meatballs made from jackfruit powder, amaranth flour, and soybean flour, comparing them to control chicken meatballs. Vegan meatballs, particularly T3 with increased amaranth flour, exhibited higher protein content, lower fat, increased carbohydrates, and additional nutrients, indicating their potential nutritional superiority over traditional meat-based counterparts.

References

1. Alves AC, TavaresgM. Mixing animal and plant proteins: Is this a way to improve protein techno-functionalities? Food Hydrocolloids. 2019;97:105-171.
2. Amin T, Thakur M. A comparative study on proximate composition, phytochemical screening, antioxidant and antimicrobial activities of *Linum usitatissimum* L. (Flaxseeds). International Journal of Current Microbiology and Applied Sciences. 2014;3(4):465-481.
3. Anzani C, Boukid F, Drummond L, Mullen AM, Álvarez C. Optimizing the use of proteins from rich meat co-products and non-meat alternatives: Nutritional, technological and allergenicity challenges. Food Research International. 2020;137:109-575.
4. Aussanasuwannakul A, Teangpook C, Treesuwan W, Puntaburt K, Butsuwan P. Effect of the Addition of Soybean Residue (Okara) on the Physico-chemical, Tribological, Instrumental and sensory texture properties of extruded snacks. Foods. 2021;11(19):29-67.
5. Balamaze J, Muyonga J, Byaruhanga Y. Production and utilization of jackfruit (*Artocarpus heterophyllus*) in Uganda. African Journal of Food, Agriculture, Nutrition and Development. 2019;19(2):14289-14302.
6. Balamaze J, Muyonga JH, Byaruhanga YB. Physicochemical Characteristics of Selected Jackfruit (*Artocarpus heterophyllus* Lam) Varieties. Journal of Food Research. 2019;8(4):11-22.
7. Banerjee S, Bhattacharya S. Food gels: Gelling process and new applications. Critical Reviews in Food Science and Nutrition. 2012;52(4):334-346.
8. Bohrer BM. An investigation of the formulation and nutritional composition of modern meat analogue products. Food Science and Human Wellness. 2019;8(4):320-329.
9. Bressani R, Sánchez-Marroquín A, Morales E. Chemical composition ofgrain amaranth cultivars and effects of processing on their nutritional quality. Food Reviews International. 1992;8(1):23-49.
10. Caporgno MP, Böcker L, Müssner C, Stirnemann E, Haberkorn I, Adelmann H, *et al.* Extruded meat analogues based on yellow, heterotrophically cultivated *Auxenochlorella protothecoides* microalgae. Innovative Food Science & Emerging Technologies. 2019;59:102-275.
11. Carmo CS Do, Knutsen SH, Maliziag, Dessev T, Geny A, Myhrer KS, *et al.* Meat analogues from a faba bean concentrate can be generated by high moisture extrusion. Future Foods. 2021;3:100014.
12. Cha MH, Heo JY, Lee C, Lo YM, Moon B. Quality and Sensory Characterization of White Jelly Mushroom (*Tremella fuciformis*) as a Meat Substitute in Pork Patty Formulation. Journal of Food Processing and Preservation. 2013;38(4):2014-2019.
13. Chandra S, Singh S, Kumari D. Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. Journal of Food Science Technology. 2015;52(6):3681-3688.
14. Chaudhary A, Tremorin D. Nutritional and Environmental Sustainability of Lentil Reformulated Beef Burger. Sustainability. 2019;12(17):67-12.
15. Culetu A, Duta DE, Papageorgiou M, Varzakas T. The Role of Hydrocolloids in gluten-free bread and pasta, Rheology, Characteristics, Staling and glycemic Index. Foods. 2021;10(12):31-21.
16. Culetu A, Susman IE, Duta DE, Belc N. Nutritional and functional properties of gluten-free flours. Applied Sciences. 2021;11(14):62-83.
17. Angelis DD, Kaleda A, Pasqualone A, Vaikma H, Tamm M, Tammik ML, *et al.* Physicochemical and Sensorial Evaluation of Meat Analogues Produced from Dry-Fractionated Pea and Oat Proteins. Foods. 2020;9(12):1754.
18. Dekkers BL, De Kort DW, Grabowska KJ, Tian B, As VH, Dergoot VAJ. A combined rheology and time domain NMR approach for determining water distributions in protein blends. Food Hydrocolloids. 2016;60:525-532.
19. Deshpande HW, Poshadri A. Physical and sensory characteristics of extruded snacks prepared from Foxtail millet based composite flours. International Food Research Journal. 2011;18:751-756.
20. Deshpande HW, Katke SD, Poshadri A. Influence of probiotics on physico-chemical and organoleptic characteristics of sweet orange juice. Journal of Environmental Biology. 2022;43:170-176.
21. Estell M, Hughes J, Grafenauer S. Plant protein and plant-based meat alternatives: Consumer and nutrition professional attitudes and perceptions. Sustainability. 2021;13(3):1478.
22. Feldsine P, Abeyta C, Andrews WH. AOAC international

methods committee guidelines for validation of qualitative and quantitative food microbiological official methods of analysis. Journal of AOAC International. 2002;85(5):1187-1200.
23. Ferawati F, Zahari I, Barman M, Hefni M, Ahlström C, Witthöft C, *et al.* High-Moisture meat analogues produced from yellow pea and faba bean protein isolates/concentrate: Effect of raw material composition and extrusion parameters on texture properties. Foods. 2021;10:843.
24. Fiorentini M, Kinchla AJ, Nolden AA. Role of Sensory Evaluation in Consumer Acceptance of Plant-Based Meat Analogs and Meat Extenders: A Scoping Review. Foods MDPI. 2020;9(9):1334.
25. Gandhi AP. Quality of soybean and its food products. International Food Research Journal. 2009;(16):11-19.
26. Gao Z, Shen P, Lan Y, Cui L, Ohm J, Chen B, *et al.* Effect of alkaline extraction pH on structure properties, solubility, and beany flavor of yellow pea protein isolate. Food Research International. 2020;131:109045.
27. Ghangale D, Veerapandian C, Rawson A, Rangarajan J. Development of plant-based meat analogue using jackfruit: A healthy substitute for meat. The Pharma Innovation Journal. 2022;11(8):85-89.
28. Gomes Martins VM, Milano P, Rodrigues Pollonio MA, Ferreira Ignácio Câmara AK, Paglarini S. Adding cricket (*Gryllus assimilis*) flour in hybrid beef patties: Physicochemical, technological and sensory challenges. International Journal of Food Science & Technology. 2023, 16826.
29. Goswami C, Hossain MA, Kader HA, Islam R. Assessment of physicochemical properties of jackfruits (*Artocarpus heterophyllus* Lam) pulps. Journal of Horticulture, Forestry and Biotechnology. 2011;15(3):26-31.
30. Guan X, Zhong X, Lu Y, Du X, Jia R, Li H, *et al.* Changes of Soybean Protein during Tofu Processing. Foods. 2021;10(7):1594.
31. Gupta R. Nutrient Analysis of Raw and Processed Soybean and Development of Value-Added Soybean Noodles. Inventi Rapid: Life Style. 2013;1:1-10.
32. Hamid MA, Tsia FLC, Okit AAB, Xin CW, Cien HH, Harn LS, *et al.* The application of Jackfruit by-product on the development of healthy meat analogue. IOP Conf. Series: Earth and Environmental Science. 2020;575:1-7.
33. Hertzler SR, Lieblein-Bo JC, Weiler M, Allgeier C. Plant Proteins: Assessing Their Nutritional Quality and Effects on Health and Physical Function. Nutrients. 2020;12:3704.
34. Hossain MA, Evan MSS, Moazzem MS, Roy M, Zzaman W. Response Surface Optimization for Antioxidant Extraction from Jackfruit (*Artocarpus heterophyllus* Lam.) Seed and Pulp. Journal of Scientific Research. 2020;12(3):397-409.
35. Ihekoronye AI, Ngoddy PO. Physico-Chemical and Sensory Evaluation of Wheat Bread Supplemented with Stabilized Undefatted Rice Bran. Food and Nutrition Sciences. 1985;4(9B):296-301.
36. Ishaq A, Irfan S, Sameen A, Khalid N. Plant-based meat analogues: A review with reference to formulation and gastrointestinal fate. Current Research in Food Science. 2022;5:973-983.
37. Joshi VK, Kumar S. Meat Analogues: Plant based alternatives to meat products- A review. International Journal of Food and Fermentation Technology. 2015;5(2):107-119.
38. Kachiguma NA, Mwase W, Maliro M, Alex malawi lilongwe. chemical and mineral composition of amaranth (*Amaranthus* L.) Species Collected from Central Malawi. Journal of Food Research. 2015;4(4):92-102.
39. Bemmo KUL, Bindzi JM, Kam-Seu TPR, Ndomou HSC, Tambo TS, Zambou NF. Physicochemical properties, nutritional value, and antioxidant potential of jackfruit (*Artocarpus heterophyllus*) pulp and seeds from Cameroon eastern forests. Food Sci Nutr. 2023;(11):4722-4734.
40. Kaur S, Singh N, Rana JC. *Amaranthus* hypochondriacus and *Amaranthus* caudatus germplasm: Characteristics of plants, grain and flours. Food Chemistry. 2010;123(4):1227-1234.
41. Kong X, Bao J, Corke H. Physical properties of *Amaranthus* starch. Food Chemistry. 2009;113(2):371-376.
42. Krintirasg A, Diaz GJ, Dergoot VAJ, Stankiewicz AI, Stefanidisg D. On the use of the couette cell technology for large scale production of textured soy-based meat replacers. Journal of Food Engineering. 2015;169:205-213.
43. Krintirasg A, Göbel J, Dergoot VAJ, Stefanidisg D. Production of structured soy-based meat analogues using simple shear and heat in a Couette Cell. Journal of Food Engineering. 2015;160:34-41.
44. Kulthe A. Microencapsulation of beta-carotene and its incorporation in Pearl millet-based cookie. (Doctoral dissertation). Mahatma Phule Krishi Vidyapeeth, Rahuri; c2016.
45. Kumar P, Chatli MK, Verma AK, Mehta N, Malav OP, Kumar D, *et al.* Quality, functionality, and shelf life of fermented meat and meat products. A review, Critical Reviews in Food Science and Nutrition. 2017;57(13):2844-2856.
46. Kurek MA, Onopiuk A, Nowicka PE, Szpicer A, Zalewska M, Półtorak A. Novel protein sources for applications in meat-alternative products-insight and Challenges. Foods. 2022;11(11):957.
47. Kuzniar P, Krok SE, Findura P, Jamro BD. Physical and chemical properties of soybean seeds determine their susceptibility to mechanical damage. Zemdirbyste-Agriculture. 2016;103(2):183-192.
48. Kyriakopoulou K, Dekkers B, Dergoot VAJ. Plant-Based Meat Analogues. In Sustainable Meat Production and Processing; c2018. p. 103-126.
49. Lee HJ, Yong HI, Kim M, Choi S, Jo C. Status of meat alternatives and their potential role in the future meat market: A review. Asian-Australasian Journal of Animal Sciences. 2020;33(10):1533-1543.
50. Leelawat B, Taikerd T. Development of gluten-free and soy-free plant-based chicken meat from young jackfruit. Agriculture and Natural Resources. 2023;19(3):1041-1054.
51. Luo J, Xu Q, Lin S, Luo R, Yang B, Wang W, *et al.* Physico-chemical properties of soybean-based diacylglycerol before and after dry fractionation. Food Chemistry. 2020;27(3):497-504.
52. Malav OP, Talukder S, Gokulakrishnan P, Chand S. Meat Analog: A Review. Critical Reviews in Food Science and

Nutrition. 2015;(55):1241-1245.
53. Mashayekh M, Mahmoodi MR, Entezari MH. Effect of fortification of defatted soy flour on sensory and rheological properties of wheat bread. International Journal of Food Science & Technology. 2008;43(9):1693-1698.
54. Maurya NK, Arya P. *Amaranthus* grain nutritional benefits: A review. Journal of Pharmacognosy and Phytochemistry. 2018;7(2):2258-2262.
55. Mishal S, Kanchan S, Bhushette PR, Sonawane SK. Development of plant-based meat analogue. International Journal of Food Science and Applied Biotechnology. 2022;5(1):45-53.
56. Nehete JY, Bhambar RS, Narkhede MR, Gawali SR. Natural proteins: Sources, isolation, characterization and applications. Pharmacogn Rev. 2013;7(14):107-116.
57. Nisar AM, Charanjit SR, Sukhcharn S. Nutritional constituents of pseudo cereals and their potential use in food systems: A review. Trends in Food Science & Technology. 2018;75:170-180.
58. Nova HJK, Lakshmy PS, Panjikkaran ST, Sharon CL, Ayyoob KC. Standardization of meat analogues incorporated with tender jackfruit. The Journal of Research ANGRAU. 2023;51(2):59-67.
59. Omohimi CI, Sobukola OP, Sarafadeen KO, Sanni LO. Effect of thermo-extrusion process parameters on selected quality attributes of meat analogue from mucuna bean seed flour. Nigerian Food Journal. 2013;32(1):21-30.
60. Omohimi C, Sobukola O, Sarafadeen K, Sanni L. Effect of thermo-extrusion process parameters on selected quality attributes of meat analogue from Mucuna bean seed flour. Nigerian Food Journal. 2013;32(1):21-30.
61. Onwezen MC, Bouwman EP, Reinders MJ, Dagevos H. A systematic review on consumer acceptance of alternative proteins: Pulses, algae, insects, plant-based meat alternatives, and cultured meat. Food Quality and Preference. 2021;159:105058.
62. Palanisamy M, Töpfl S, Aganovic K, Berger RG. Influence of iota carrageenan addition on the properties of soya protein meat analogues. LWT. 2018;87:546-552.
63. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers, 2nd Edition, Indian Council of Agricultural Research, New Delhi; c1967.
64. Parveen A, Mohd AA, Dubey RP. Preparation and standardization of food product by soya chunks and oats as a substitute of meat products and nutraceuticals potential of soybean. Journal of Pharmacognosy and Phytochemistry. 2018;7(4):1003-1008.
65. Patel M, Zhang X, Kumar A. Techno-economic and life cycle assessment on lignocellulosic biomass thermos-chemical conversion technologies: A review. Renewable and Sustainable Energy Reviews. 2015;53:1486-1499.
66. Penchalaraju M, Don Bosco SJ. Leveraging Indian pulses for plant-based meat: Functional properties and development of meatball analogues. International Journal of Food Science and Technology. 2022;57(9):5869-5877.
67. Penchalaraju M, Poshadri A, Swaroopag, Nikkam IT, Don Bosco SJ. Leveraging Indian pulse proteins for plant-based mock meat III: Physicochemical characterisation, FTIR spectra and texture profile analysis of meat analogues. International Journal of Food Science and Technology; c2023.
68. Philipp C, Buckow R, Silcock P, Oey I. Instrumental and sensory properties of pea protein-fortified extruded rice snacks. Food Research International. 2017;102:658-665.
69. Pietsch VL, Bühler JM, Karbstein HP, Emin MA. High moisture extrusion of soy protein concentrate: Influence of thermomechanical treatment on protein-protein interactions and rheological properties. Journal of Food Engineering. 2019;251:11-18.
70. Pietsch VL, Emin MA, Schuchmann HP. Process conditions influencing wheat gluten polymerization during high moisture extrusion of meat analog products. Journal of Food Engineering. 2017;198:28-35.
71. Pietsch VL, Karbstein HP, Emin MA. Kinetics of wheat gluten polymerization at extrusion-like conditions relevant for the production of meat analog products. Food Hydrocolloids. 2018;85:102-109.
72. Pinheiro C, Rivas SC, Gonzalo RJC. Carotenoid composition, antioxidant capacity and nutritional profile of two southern European legumes. Food Research International. 2016;89:1094-1101.
73. Pintado T, Pandog D. Towards more sustainable meat Products: Extenders as a way of reducing meat content. Foods MDPI. 2020;(9):1044.
74. Piotr K, Ewa S, Pavol F, Jan B, Dorota BJ. Physical and chemical properties of soybean seeds determine their susceptibility to mechanical damage. Zemdirbyste-Agriculture. 2016;2(103):183-192.
75. Poshadri A, Pawar VS. The Potential of Production of Meat Analogue by using Indian Legumes: A Review. Biological Forum - An International Journal. 2021;13(2):557-564.
76. Poshadri A, Deshpande HW, Machewadg M, Kshirsagar RB, Gadheg S, Kadam SD. Functional properties of selected composite gluten-free pseudo cereals flour. Food and Humanity. 2023;(1):1200-1205.
77. Poshadri A, Deshpande H, Machewadg, Kshirsagar R, Gadhe K, Kadam S. Functional properties of selected composite gluten-free pseudo cereals flour. Food and Humanity. 2023;1:1200-1205.
78. Prajyoti K, Mishra A, Annapure US. Development of vegan meat flavour: A review on sources and techniques. Elsevier B.V. 2022;(5):100149.
79. Ranasinghe RASN, Maduwanthi SDT, Marapana RAUJ. Nutritional and Health Benefits of Jackfruit (*Artocarpus heterophyllus* Lam.): A Review; c2019. p. 1-12.
80. Riaz MN. Texturized vegetable proteins. Handbook of Food Proteins; c2010. p. 395-418.
81. Rizzog, Baroni L. Soy, Soy Foods and Their Role in Vegetarian Diets. Foods. Nutrients. 2018;10(1):43.
82. Rupanawar HD, Sawant AA, Thakor NJ, Swami SB, Patil AP. Physical Properties of Jackfruit (*Artocarpus heterophyllus* Lam.) and its Components. International Journal of Processing and Postharvest Technology. 2016;7(2):171-178.
83. Rupnawar HD, Sawant AA, Thakor N, Swami S, Patil AP. Physical properties of Jackfruit (*Artocarpus heterophyllus* Lam.) and It's Components. International Journal of Processing and Post-Harvest Technology. 2016;7:171-178.
84. Sabaté J, Sanchez Sabate R. Consumer attitudes towards environmental concerns of meat consumption: A Systematic Review. Inter. J of Environmental Research and Public Health. 2018;16(7):1220.

85. Saha A, Mandal S. Nutritional Benefit of Soybean and Its Advancement in Research. Sustainable Food Production. 2019;5:6-16.
86. Sahoo MR, Kuna A, Devi MP, Sowmya M, Dasgupta M. Fortification of ready-to-eat extruded snacks with tree bean powder: Nutritional, antioxidant, essential amino acids, and sensory properties. Journal of Food Science and Technology. 2022;59(6):2351-2360.
87. Samard S, Gu Y, Ryu H. Effects of extrusion types, screw speed and addition of wheat gluten on physicochemical characteristics and cooking stability of meat analogues. Journal of the Science of Food and Agriculture. 2019;99:11.
88. Schreuders FKG, Dekkers BL, Bodnár I, Erni P, Boom RM, Dergoot VAJ. Comparing structuring potential of pea and soy protein with gluten for meat analogue preparation. Journal of Food Engineering. 2019;261:32-39.
89. Sha L, Xiong YL. Plant protein-based alternatives of reconstructed meat: Science, technology, and challenges. Food Chemistry. 2020;102:51-61.
90. Shah F, Sharif MK, Ahmad Z, Amjad A, Javed MS, Suleman R, *et al.* Nutritional characterization of the extrusion-processed micronutrient-fortified corn snacks enriched with protein and dietary fiber. Frontiers in Nutrition. 2022;9:1062616.
91. Silvagrobelnik Mlakar M, Turinek M, Jakop M, Bavec M, Bavec F. Nutrition value and use of grain amaranth potential future application in bread making. Agricultura. 2009;6:43-53.
92. García SM, Olguín AII, Montes CJP, Ramírez RDG, Figueroa MJS, Valverde FE, *et al.* Nutritional functional value and therapeutic utilization of Amaranth. Journal of Analytical & Pharmaceutical Research. 2018;7(5):596-600.
93. García SM, Olguín AI, Montes CJ, Ramírez RD, Figueroa J, Valverde FE, *et al.* Nutritional functional value and therapeutic utilization of Amaranth. Journal of Analytical & Pharmaceutical Research. 2018;7:10.
94. Sumangala S, Kulkarni UN. Physico-chemical properties of black and yellow soybean (*Glycine max* L.) genotype. The Pharma Innovation Journal. 2019;8(7):33-37.
95. Sun C, GE J, He J, Gan R, Fang Y. Processing, Quality, Safety, and Acceptance of Meat Analogue Products. Journal Pre-proofs. 2020;7(5):674-678.
96. Taikerd T, Leelawat B. Effect of young jackfruit, wheat gluten and soy protein isolate on physicochemical properties of chicken meat analogs. Agriculture and Natural Resources. 2023;57(2):201-210.
97. Tanimola AR, Otegbayo B, Akinoso R. Chemical, functional, rheological and sensory properties of amaranth flour and amaranth flour-based paste. African Journal of Food Science. 2016;10(11):313-319.
98. Thiex N. Evaluation of Analytical Methods for the Determination of Moisture, Crude Protein, Crude Fat, and Crude Fiber in Distillers Driedgrains with Solubles. Journal of AOAC International. 2009;92(1):61-73.
99. Trejo Rodríguez IS, Alcántara Quintana LE, Algara Suarez P, Ruiz Cabrera MA, Lagunes GA. Physicochemical Properties, Antioxidant Capacity, Prebiotic Activity and Anticancer Potential in Human Cells of Jackfruit (*Artocarpus heterophyllus*) Seed Flour. Molecules. 2021;26:4854.
100. Tziva M, Negro S, Kalfagianni A, Hekkert M. Understanding the protein transition: The rise of plant-based meat substitutes. Environmental Innovation and Societal Transitions. 2020;35:217-231.
101. Vatansever S, Tulbek MC, Riaz MN. Low- and High-Moisture Extrusion of Pulse Proteins as Plant-Based Meat Ingredients: A Review. Cereal foods world, 2020, 65(4).
102. Venkidasamy B, Selvaraj D, Nile AS, Ramalingam S, Kaig, Nile SH. Indian pulses: A review on nutritional, functional and biochemical properties with future perspectives. Trends in Food Science & Technology. 2019;88:228-242.
103. Wakefield DK, Dransfield E, Down NF, Taylor AA. Influence of post-mortem treatments on turkey and chicken meat texture. International Journal of Food Science & Technology. 1989;24(1):81-92.
104. Xiong YL, Agyare KK, Addo K. Hydrolyzed wheat gluten suppresses transglutaminase-mediated gelation but improves emulsification of pork myofibrillar protein. Meat Science. 2008;80(2):535-544.
105. Yuan Y, Chiu L, Li MH. Carotenoid composition in different developmental stages of *Bixa orellana* seeds. Journal of Agricultural and Food Chemistry. 2009;57(14):6638-6644.
106. Yuliarti O, Kovis KTJ, Yi NJ. Structuring the meat analogue by using plant-based derived composites. Journal of Food Engineering. 2021;(288):110138.
107. Zhang J, Liu L, Jiang Y, Shah F, Xu Y, Wang Q. High-moisture extrusion of peanut protein-/carrageenan/sodium alginate/wheat starch mixtures: Effect of different exogenous polysaccharides on the process forming a fibrous structure. Food Hydrocolloids. 2020;99:105311.
108. Kite ME, Deaux D. Attitudes toward homosexuality: Assessment and behavioral consequences. Basic and Applied Social Psychology. 1986 Jun 1;7(2):137-62.
109. Iwasaki S, Iwasaki W, Takahashi M, Sakamoto A, Watanabe C, Shichino Y, *et al.* The translation inhibitor rocaglamide targets a bimolecular cavity between eIF4A and polypurine RNA. Molecular cell. 2019 Feb 21;73(4):738-48.
110. Arti MK. Channel estimation and detection in hybrid satellite-terrestrial communication systems. IEEE Transactions on Vehicular Technology. 2015 Jul 14;65(7):5764-71.