



## REVIEW ARTICLE

# Unripe Jackfruit (*Artocarpus heterophyllus* Lam) as a Promising Meat Alternative Ingredient: A Review

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### Abstract

The demand for meat consumption is skyrocketing, hence, the adaption of plant-based meat to fulfil this global demand that requires sustainable and healthier diet is a must. An increase in awareness of the possible link between diet, health and environment among consumers has shifted the dietary pattern in recent times. As such, jackfruit mainly the young and unripe one is considered a promising meat alternative ingredient owing to their texture that mimics meat. In addition, unripe jackfruit possesses high nutritional values, especially protein and fibre content and packed with important vitamins and minerals such as vitamin C, potassium and calcium. High fibre content in unripe jackfruit is beneficial in preventing constipation and helping smooth bowel movement. Moreover, it exhibits antimicrobial, antioxidant, antidiabetic and anti-inflammatory properties. The use of unripe jackfruit is also beneficial from an environmental and sustainability standpoint, aligned with the United Nation's Sustainable Development Goal to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture by 2030. However, jackfruit is still considered an underutilised fruit. This review will focus on young and unripe jackfruit in meat products and meat analogues primarily in term of physicochemical, nutritional and sensorial properties, aligned with recent trends and preferences as well as health benefits.

**Keywords:** Meat alternative; meat analogue; plant-based ingredient; unripe jackfruit

### Introduction

Plant-based meat analogue has caught special attention and become a current food trend in the market sector primarily due to dietary changes and rising awareness on environment and sustainability among the consumers (Ismail, 2023). In fact, the acceptance of the plant-based diet has expanded substantially due to health consciousness, mainly high saturated fat content in traditional meat (Das *et al.*, 2021; Ghangale *et al.*, 2022). From ages ago, meat products are often consumed more than plant products due to its sensory properties and high nutritional values, primarily protein content (Sayeed Ibrahim & Huda-Faujan, 2023). However, many chronic diseases such as diabetes and obesity are associated with a higher intake of processed meat (Das *et al.*, 2021).

Additionally, a higher risk of cardiovascular disease (CVD) is linked to overconsumption of red meat, processed and unprocessed meat, thus, replacing red meat with plant-source is suggested as a preventive measure (Wang *et al.*, 2024). Moreover, meat and meat products have become sources of many foodborne illness and outbreaks in several nations, mainly caused by *Salmonella* and *Escherichia coli*, which negatively impact the overall consumers, food businesses and society (Warmate & Onarinde, 2023). In fact, raising of animals to produce meat products is undesirable from an environmental standpoint, hence, development of healthier and more sustainable products is a must (Das *et al.*, 2021).

Minimising meat consumption are indeed, beneficial in environment and sustainability standpoint. To date, alternative meat market is anticipated to reach \$85 billion in 2030, aligned with high innovation and development, driven mainly by youngsters and health-conscious people in recent times (Samutsri *et al.*, 2023). In fact, consumers are becoming more aware of a possible relationship between dietary intake and overall health, resulting in a change of their dietary pattern to a healthier food option (Das *et al.*, 2021). As such, jackfruit is one of the promising plant-based ingredients.

Jackfruit or scientifically known as *Artocarpus heterophyllus* is one of the most popular tropical fruits in Asia and widely grown in Southeast Asia, and tropical areas including India, Malaysia, Thailand, Bangladesh (Samutsri *et al.*, 2023) and the Philippines (Ye *et al.*, 2025). The market demand for jackfruit is rising, with Malaysia, Thailand and the Philippines among the important jackfruits' cultivators and producers (Ye *et al.*, 2025). In fact, jackfruit is classified as one of 21 tropical fruits commercially grown in Malaysia, with production over 30,000 tonnes per year (Idris *et al.*, 2023). By 2026, the worldwide jackfruits' market size is anticipated to reach US\$359.1 million and expected to continuously increasing at a Compound Annual Growth Rate (CAGR) of 3.3 % (Ali *et al.*, 2024).

Jackfruit is generally consumed as a fresh fruit and used in Asian culinary preparations (Samutsri *et al.*, 2023). In fact, the fruit including the seeds are used in preparation of many food products such as sauce, jams, ice creams, jellies, marmalades (Gupta *et al.*, 2022), instant soups, bakery products and candy (Karigar & Murthy, 2020). Nutritionally, jackfruit is rich in carbohydrates, protein and dietary fibres and a notable source of vitamins and minerals (Ye *et al.*, 2025). It also contains high amounts of bioactive compounds (polyphenols such as flavonoids, tannins, phenolic acids), volatile acids, amino acids and carotenoids, which possess high antioxidant, antimicrobial and anti-inflammatory properties (Ye *et al.*, 2025). In fact, the fruit together with its leaves, bark and roots are endowed with therapeutic attributes (Gupta *et al.*, 2022). Jackfruit is also beneficial in preventing the onset of CVD (Xin *et al.*, 2024), reduce obesity-induced metabolic, type-2 diabetes and aid in weight loss (Samutsri *et al.*, 2023). In addition, it has an anti-aging property, due to the lignins, flavones and saponins present (Ahlawat, 2023).

Generally, ripe jackfruit has a very chewy, stringy texture and unique tropical flavour (Samutsri *et al.*, 2023) and mainly consumed as fresh, whereas the unripe or young green jackfruit is off-white in colour and almost neutral in flavour (Xin *et al.*, 2024). Owing to their nutritional profiles and unique texture that mimic meat, jackfruit has become a popular meat alternative, aligned with the recent trend towards plant-based diets and the growing needs in sustainable food sources (Ye *et al.*, 2025). For instance, unripe jackfruit has been used as meat alternative in many meat products and meat analogues including patties (Abdullah, 2017; Sayeed Ibrahim & Huda-Faujan, 2024), sausages (Huda-Faujan & Arifin, 2022; Konsue *et al.*, 2023), meatballs (Ismail, 2023) and cutlets (Yenrina *et al.*, 2013). Meat analogue is defined as food that is structurally similar to meat, but differ in composition which also commonly recognised as meat substitute, faux meat, mock meat or imitation meat (Huda-Faujan & Arifin, 2022).

Development of unripe jackfruit-based product in recent times is indeed, a healthier alternative for the vegetarian consumer (Xin *et al.*, 2024). To date, there is an excessive production of jackfruit per year, however, only the perfect jackfruit is chosen by the farmers. As a result, unripe jackfruit is omitted as a waste (Ye *et al.*, 2025). Besides, due to limited processing facilities and

short shelf life, jackfruit is considered underutilised (Huda-Faujan & Arifin, 2022). This review will focus on utilisation of unripe jackfruit as meat substitute or meat alternative in meat products and meat analogues, aligned with recent trends and preferences towards more sustainable and healthier food products aligned with Sustainable Development Goals (SDG).

### Botanical Description

Jackfruit (also known as *Nangka* in Malay) (Figure 1) is a well-known Asian tropical fruit notable for its unique shape and size (Ismail & Kaur, 2013; Hamid *et al.*, 2020). In Hindi, jackfruit is called as Kathal; Malayalam Chakka; Portuguese Jaca and French Jacquier (Saha *et al.*, 2022). It is widely cultivated in the tropical regions of the Indian subcontinent, Malaysia, Thailand and Indonesia (Hamid *et al.*, 2020). To date, India is the largest producer of jackfruit in the world, driven by the growing global interest in plant-based diets and sustainable food sources (Ye *et al.*, 2025). In Malaysia, jackfruit is classified as one of the high value tropical fruits (Ali *et al.*, 2024). Jackfruit is also known as the “poor man’s food” as it gives significant role in the food supply, especially for rural areas’ people.

In fact, it is known as the zero-waste fruit as the most parts of the fruits are edible and the remaining part may be utilised for other applications, like animal feed (Ye *et al.*, 2025). There are at least 30 jackfruit strains in Indian subcontinent and another 30 in Malaysia (Ranasinghe *et al.*, 2019).



Figure 1. Jackfruit (As syura, 2025)

Jackfruit is made of three parts, namely pulp (30 to 32 %), seeds (18 %) and rind (5 to 55 %) (Hamid *et al.*, 2020). The length and breadth of jackfruit differs significantly by the stage. It is reported that the length and breadth of the immature jackfruit, mature and ripening stage are 11.7 cm x 13.35 cm, 47.18 cm x 26.12 cm and 44.20 cm x 25.51 cm, respectively. Meanwhile, the weight of jackfruits’ seeds in mature and ripe stages on average was 0.84 kg and 0.92 kg, respectively, however, it is not significantly different. The weight of edible portion is the highest in mature stage (4.66 kg) and the weight of inedible portion was the highest in ripe stage (4.47 kg). Indeed, the maturity of jackfruit (immature, mature and ripe) resulted in difference in shape, size, weight and circumference (Chandra & Bharati, 2020).

Jackfruit tree may reach a height of 8 to 25 m and a canopy diameter of 3.5 to 6.7 m at five years of age. It has a straight stem and a dense canopy that is usually dome-shaped, and the tree’s trunk is rarely buttressed with the greyish-brown, scaly bark (Hamid *et al.*, 2020). Meanwhile, the flowers are tiny and pale green when young and become reddish with age. Male flowers are dense, fleshy and cylindrical in shape (up to 10 cm), whereas female flowers are comparatively larger and elliptic or rounded in shape with a tubular calyx. They are grown discretely and sprouted from branches and the trunk.

The fruits are oblong and cylindrical in shape with length about 30 to 40 cm and grown on the trunk or the main branch. On the other hand, the seeds are rounded, light brown in colour, with a length of 2 to 3 cm or 1 to 1.5 cm in diameter, and covered in a thin, whitish membrane (Gupta *et al.*, 2022).

Jackfruit tree grows in warm and humid conditions and known to be the largest edible fruit globally (Ranasinghe *et al.*, 2019). It weighs between 4.5 to 30 kg, with a recorded weight of 50 kg (Hamid *et al.*, 2020). Jackfruit is a popular fruit among farmers as it is easy to grow, and does not require huge land or water for cultivation (Taikerda & Leelawata, 2023). It also survives high temperature, pest and diseases and is a drought resistant (Weintraub *et al.*, 2022). To date, Malaysia, Thailand, Indonesia, Australia and China have reported year-round availability of jackfruit because of their climatic diversity (Saha *et al.*, 2022).

Every part of jackfruit tree; fruit, pulp, skin, seeds, leaves, flowers, latex and wood are beneficial as they have their own uses and advantages (Ismail & Kaur, 2013). For example, jackfruit seeds are used in many bakery products including biscuits, cakes and cookies (Ahlawat, 2023). Jackfruit seed flour possesses strong antioxidant properties and act as a thickening and binding agent (Fabil *et al.*, 2024). The jackfruit seeds' oil was rich in an important fatty acid, primarily linoleic and alpha-linolenic acids, and are beneficial to human health (Ahlawat, 2023). Previous study revealed that boiled jackfruit seed possess significantly higher oil absorption capacity, water solubility capacity and the water absorption capacity as compared to the raw jackfruit seed (Juárez-Barrientos *et al.*, 2017). The water absorption capacity, fat absorption capacity and bulk density of jackfruit were reported to be 25 %, 17 % and 0.8 %, respectively (Karigar & Murthy, 2020).

### **Nutritional Composition of Jackfruit**

Jackfruit is a member of the Moraceae family and considered a native to tropical climates. It is considered a functional fruit as it contains useful chemicals with functional and therapeutic values, thus, actively used in many food product developments (Ahlawat, 2023). Jackfruit is one of the largest edible fruits in the world, comprises wide ranges of nutrients beneficial for human well-being (Gupta *et al.*, 2022). Nutritionally, jackfruit is rich in carbohydrate, protein (Ye *et al.*, 2025) and fibre (Juárez-Barrientos *et al.*, 2017). Previous study revealed that raw jackfruit exhibited higher carbohydrate and fibre content, while boiled jackfruit possesses higher protein value, however, no significant difference in the protein and fibre content of raw and boiled jackfruit seed was observed (Juárez-Barrientos *et al.*, 2017).

The amino acids found in jackfruit including cystine, arginine, leucine, histidine, lysine, threonine, methionine and tryptophan (Saha *et al.*, 2022). The nutritional values differ by the maturity stages, for example, the moisture content of jackfruit in immature, mature and ripe stage was 70.61 %, 68.43 % and 76.20 %, respectively (Chandra & Bharati, 2020). It is reported that the moisture content, protein, fat, ash and fibre value (crude, soluble, insoluble and total fibre) of jackfruit decreased with an increasing ripening stage, except for the carbohydrate content (Konsue *et al.*, 2023). This supported by a study by Chandra and Bharati (2020) who found a higher amount of protein, fat and ash in the immature jackfruit as compared to ripe jackfruit. Indeed, unripe jackfruit (Figure 2) possesses more advantageous chemical properties than that of ripe jackfruit (Konsue *et al.*, 2023).

Jackfruit is also a source of vitamin A (110 IU), vitamin C (13.7 mg), vitamin E (0.34 mg) and vitamin B. The amount of folate in jackfruit was reported to be 24 µg, while the niacin, pyridoxine, riboflavin and thiamine amount were reported to be 0.92 mg, 0.33 mg, 0.06 mg and 0.11 mg, respectively (Karigar & Murthy, 2020). The level of vitamins in jackfruit flesh changes according to the ages of fruit, for example, the vitamin C content was reported to be 18.5 mg/100g at the age of 45, and increased to 19.67 mg/100g and 23.1 mg/100g at the age of 55 and 65.

Meanwhile, the value of vitamin B<sub>1</sub> at the age of 45, 55 and 65 was 3.9 mg/100g, 14.2 mg/100g and 12.6 mg/100g, respectively (Ranasinghe *et al.*, 2019).

Furthermore, jackfruit is packed with minerals such as iron (0.6 mg), calcium (34 mg), sodium (3.3 mg), magnesium (37 mg), potassium (303 mg), phosphorus (36 mg), zinc (0.42 mg) and manganese (0.2 mg) (Karigar & Murthy, 2020). The amount of minerals is affected by the maturity stage in which the value of calcium, iron, zinc, copper and manganese were observed to be higher in immature jackfruit followed by mature and ripe jackfruit. Contradictory, amount of mineral decreased with an increase in maturity and ripening stage, which might be due to the utilisation of minerals during the growth (Chandra & Bharati, 2020). Indeed, jackfruit is reported to be more superior in nutritional content as compared to other topical fruits like papaya, orange and banana (Gupta *et al.*, 2022).

Jackfruit also possesses phytochemicals like lignans, isoflavones and saponins as well as bioactive compounds, primarily carotenoids and phenolics compounds (Ahlawat, 2023). The highest concentration of carotenoids in jackfruit was all-trans-lutein (37.02 µg/100 g), followed by all-trans-β-carotene (29.55 µg/100) and all-trans-neoxanthin (8.85 µg/100) (Saha *et al.*, 2022). However, the nutritional composition of jackfruit is greatly affected by its maturity stage, as well as the variety, environment and harvesting time (Konsue *et al.*, 2023, Ye *et al.*, 2025).

Moreover, jackfruit sugars' concentration increases during the ripening stage, which might be due to the released of glucose by starch hydrolysis as well as released of glucose and fructose by sucrose hydrolysis (Ye *et al.*, 2025). Notably, jackfruit contains no saturated fats, or cholesterol, and can be used when mature and immature (Nair *et al.*, 2017). The range of nutritional composition of young and ripe jackfruit is shown in Table 1 (Yudhistira, 2022; Saha *et al.*, 2022). Due to its nutritional values, jackfruit is considered as a good option to fulfil the nutritive insufficiency in developing countries to support food security (Gupta *et al.*, 2022). However, jackfruit is yet to be fully exploited and considered as underutilised due to its low shelf life, and high flavour intensity, thus making it less appealing to some consumers (Xin *et al.*, 2024).

Table 1. Comparison of nutritional composition range for unripe and ripe jackfruit

| Nutritional composition | Unripe jackfruit | Ripe jackfruit |
|-------------------------|------------------|----------------|
| Carbohydrate (g)        | 9.4 – 11.5       | 16 – 25.4      |
| Total sugars (g)        | -                | 20.6           |
| Fibres (g)              | 2.6 – 3.6        | 1.0 – 1.5      |
| Protein (g)             | 2.0 – 2.6        | 1.2 – 1.9      |
| Fat (g)                 | 0.1 – 0.6        | 0.1 – 0.4      |
| Calcium (mg)            | 30.0 – 73.2      | 20.0 – 37.0    |
| Phosphorus (mg)         | 20.0 – 57.2      | 38.0 – 41.0    |
| Potassium (mg)          | 287 – 323        | 191 – 407      |
| Sodium (mg)             | 3.0 – 35.0       | 2.0 – 41.0     |
| Vitamin A (IU)          | 30               | 175 – 540      |
| Vitamin C (mg)          | 12.0 – 14.0      | 7.0 – 10.0     |

## Health Benefits of Jackfruit

The popularity of jackfruit is on the rise due to its high nutritional composition and appreciable therapeutic activities (Gupta *et al.*, 2022). The medicinal properties are primarily associated with the presence of alkaloids, flavonoids, saponins, tannins, terpenoids, glycosides and phenols. Traditionally, jackfruits' extracts have been used to treat many diseases including anaemia, diabetes, diarrhea, dermatitis, asthma, malarial fever, tapeworm infection and to induce lactation in women (Karigar & Murthy, 2020). In addition, jackfruit exhibits antimicrobial, antioxidant, antidiabetic, anti-inflammatory, immunomodulatory, antiviral, wound-healing and antineoplastic activities (Gupta *et al.*, 2022). Besides, the phytochemicals (isoflavones, lignans and saponin) present in jackfruit exhibit anti-cancer, anti-hypertensive, anti-ulcer and anti-aging activities (Saha *et al.*, 2022). Indeed, the phytoconstituents in jackfruit possess many health benefits for human health (Karigar & Murthy, 2020) (Table 2).

Table 2. Health benefits of jackfruit

| Phytochemicals        | Health benefits  |
|-----------------------|--|
| Flavonoids            | Anti-inflammatory, anti-atherosclerosis, anti carcinogenic, anti-arthritis |
| Lectin                | Wound healing  |
| Prenylated flavones   | Anti-malarial, anti-diarrhoeal   |
| Isoprenyl flavones    | Anti-fungal  |
| Isoprenoid flavonoids | Anti-cancer  |
| Oxyresveratrol        | Anti-viral   |

Jackfruit is also effective in managing diabetes by regulating blood sugar levels (Ye *et al.*, 2025). It was documented that 30 grams of dehydrated unripe jackfruit may replace two wheat chapattis or a cup of cooked rice and offered a higher level of satiety. In addition, the glucose level in unripe jackfruit is almost half that of rice or wheat, thus helping reverse the diabetic condition (Nair *et al.*, 2017). In fact, routine intake of jackfruit may protect against stomach ulcers, cardiovascular disease, certain cancers and prevent skin and mouth diseases (Gupta *et al.*, 2022).

Furthermore, the high fibre content in jackfruit, especially in unripe jackfruit, promotes smooth bowel movement and helps prevent constipation (Ahlawat, 2023). The antifungal properties of jackfruit may inhibit the growth of *Fusarium moniliforme* and *Saccharomyces cerevisiae* fungus (Saha *et al.*, 2022). In fact, jackfruit seeds (rich source of proteins and carbohydrate) may aid digestion, beneficial in bone health and possess anti-carcinogenic and anti-aging properties (Gupta *et al.*, 2022; Fabil *et al.*, 2024). Furthermore, jackfruits' leave extract are used as traditional medicine in the treatment of foodborne diseases. All parts of jackfruit tree are used as a traditional medicine, mainly to treat malarial fever, kidney stones, infected wounds and asthma. Indeed, the consumption of jackfruit has increased in recent times due to its health advantages (Saha *et al.*, 2022).

## Unripe Jackfruit as a Meat Alternative

The development of a meat analogue to provide alternatives for meat has become a trend, driven health consciousness, changes in dietary pattern, vegetarianism and rising in meat prices (Hamid *et al.*, 2020). In fact, veganism has become one of the rising trends in recent times and the

worldwide vegan market is anticipated to grow to \$24 billion in 2025 (Xin *et al.*, 2024). The vegan meat industry is rapidly growing, especially among the youngsters and health-conscious people (Ghangale *et al.*, 2022). In addition, the emergence of flexitarians (those who occasionally consume meat, but in reduced level) has grown the plant-based sector (Xin *et al.*, 2024). Plant-based diets provide a route while addressing ethical and environmental concerns related to traditional meat (Samutsri *et al.*, 2023).

Unripe jackfruit (Figure 2) is one of the meat alternatives that has become popular in recent times, owing to their high nutritional values and the fibre-like texture that similar to that of meat (Samutsri *et al.*, 2023; Taikerda & Leelawata, 2023; Sayeed Ibrahim & Huda-Faujan, 2024). Unripe jackfruit has been used in the development of many value-added meat products such as sausages (Huda-Faujan & Arifin, 2022), nuggets (Xin *et al.*, 2024), meatball (Samutsri *et al.*, 2023) and patties (Abdullah, 2017; Sayeed Ibrahim & Huda-Faujan, 2024) at different levels.

For example, addition of unripe jackfruit (55%) improved the carbohydrate and ash content of meat analogues (Ismail, 2023). Jackfruit by-product (rind, rags and seed) also is a potential meat analogue, with high nutritional composition, especially protein and dietary fibre content (Hamid *et al.*, 2020). It suits vegetarian and health-conscious people, without jeopardizing protein and micronutrients. Even though, the level of protein in unripe jackfruit (1.45 %) is lower than the protein content in beef meat (animal protein) (20.97 to 21.17 %), jackfruit is rich is nutritious and able to imitate the meaty flavour, making it a good meat alternative (Huda-Faujan & Arifin, 2022). This also aligned with a study by Abdullah (2017) who observed the highest score for taste and aroma (retain meaty flavour) in beef patties with 25 % of unripe jackfruit as compared to commercial meat patty.



Figure 2. Unripe Jackfruit (Misfud, 2021)

Unripe jackfruit also contains no cholesterol which make it as a good alternative to meat (Nair *et al.*, 2017). In contrast, the cholesterol level in traditional meat source for mutton, pork and beef were reported to be 81 mg/100mg, 71 mg/100mg and 62 mg/100mg, respectively (Ahmad *et al.*, 2018). The value differs by the breed, type of feed being ingested, climatic conditions and the meat cut, which possess difference on its nutritional and sensorial properties. In addition, the fatty acid composition and meat fat content is affected by the cooking method (Ahmad *et al.*, 2018).

In sensorial aspects, addition of jackfruit (55 %) in meat analogues recorded highest mean value for appearance and aroma attributes, however, the result is not statistically different ( $p > 0.05$ ) (Ismail, 2023). Indeed, ingredients' ratios plays a vital role in determining the texture and sensory characteristics of vegan meat (Singh *et al.*, 2024) and to achieve a similar flavour and texture to that of meat are among the biggest challenges in the meat analogues' production (Taikerda & Leelawata, 2023). Previously, the sandwich with jackfruit recorded higher mean score for the tested attributes (texture, aroma, flavour) than the pork sandwich. Furthermore, addition of jackfruit (jackfruit in brine and jackfruit in water) recorded higher water retention properties, with the value

of 61 % and 63 %, respectively, higher than the pulled pork meat (49 %) (Uruakpa *et al.*, 2021). Furthermore, the use of young jackfruit was able to improve the microstructure and texture of chicken meat analogues (Taikerda & Leelawata, 2023). Table 3 shows the effects of incorporation of young and unripe jackfruit at different percentages in meat products and meat analogues in terms of its physicochemical, nutritional and sensorial.

Apart from that, ripe jackfruit also has been used in the development of vegan meat product (30 % jackfruit powder), with a comparable acceptability to the control (100 % meat) in terms of taste, texture and overall acceptability in sensory evaluation (Singh *et al.*, 2024). In fact, Malaysians mostly used to eating ripe jackfruit, with an estimated consumption of 2 kg of ripe jackfruit in a year (Durai, 2025). However, the emerging plant-based sector has increased the demand for unripe jackfruit, which is used to produce plant-based meat in recent times (Durai, 2025), and is favourable for consumers who are looking for non-soy-based meat alternative (Uruakpa *et al.*, 2021).

Indeed, there are continuous research on alternative plant-based ingredient that provide meat-like texture and high nutritional values. Plant-based foods are nutritious, can benefit people from all ages and are equally delicious as meat-based diets. Researchers are also actively finding alternative food ingredients from plant sources that could give the same mouth feel and nutritional values by modifying several functional components (Samutsri *et al.*, 2023). Hence, young and unripe jackfruit is a potential meat alternative ingredient, aligned with recent trend and preferences.

Table 3. Effects of incorporation of young and unripe jackfruit at different percentage in meat products and meat analogues

| Type of meat       | Effects  | Reference                  |
|--------------------|--|----------------------------|
| Meat analogues     | <ul style="list-style-type: none"> <li>• Significantly higher in protein and fat content, but lower in carbohydrate and ash value with addition of 35 % of unripe jackfruit as compared to 55 %.</li> <li>• Significantly higher in textural properties (hardness, chewiness and springiness) with 35 % of unripe jackfruit.</li> <li>• No significant difference in appearance, aroma and colour among the meat analogues.</li> <li>• Better sensory acceptance with 35 % of unripe jackfruit.</li> </ul> | (Ismail, 2023)             |
| Vegetarian nuggets | <ul style="list-style-type: none"> <li>• Significantly different in the appearance, taste, texture and overall acceptance except the aroma attributes.</li> <li>• Most preferred nugget with 25 % of unripe jackfruit.</li> <li>• Significantly higher in moisture, ash, crude fibre and carbohydrate value with 25 % of unripe jackfruit (comparison with control (0 % of unripe jackfruit)).</li> </ul>  | (Xin <i>et al.</i> , 2024) |

| Type of meat     | Effects  | Reference                       |
|------------------|--|---------------------------------|
| Chicken meatball | <ul style="list-style-type: none"> <li>• No significant difference in pH value.</li> <li>• Substitution of 150 g/kg of boneless breast with unripe jackfruit resulted in darker colour of meatballs.</li> <li>• Significantly different in hardness and springiness attributes.</li> <li>• Use of unripe jackfruit significantly affected the sensory quality of the meatballs in terms of flavour, taste, texture and overall preference, except the appearance attributes.</li> <li>• Highest liking score for control (0 % of unripe jackfruit), however, higher liking score was observed in appearance, texture and overall acceptability for meatballs with 5 % and 10 % of unripe jackfruit than 15 %.</li> </ul> | (Samutsri <i>et al.</i> , 2023) |
| Meatballs        | <ul style="list-style-type: none"> <li>• Higher ash level and lower in fat value.</li> <li>• Lowest hardness value in meatball with 60 % of young jackfruit.</li> <li>• No significant difference in aroma attributes among all the meatballs.</li> <li>• Highest score for taste attributes was with 90 % of young jackfruit.</li> </ul>  | (Yenrina <i>et al.</i> , 2013)  |
| Beef patties     | <ul style="list-style-type: none"> <li>• Lowest fat and energy content in patties with highest level of unripe jackfruit (75 %).</li> <li>• Significantly highest amount of crude fibre, ash and moisture content in patties with 75 % of unripe jackfruit.</li> <li>• Highest juiciness level in patties with 75 % of unripe jackfruit.</li> <li>• Most preferred patties with 25 % of unripe jackfruit.</li> </ul>   | (Abdullah, 2017)                |
| Beef sausages    | <ul style="list-style-type: none"> <li>• Higher moisture and ash level, but decreased in protein and fat content with 100 % of unripe jackfruit.</li> <li>• No significant difference in hardness and springiness attributes.</li> <li>• Affected the redness (<math>P &lt; 0.05</math>) but not the lightness and yellowish colour of sausages.</li> <li>• Highest overall acceptance in control (100 % beef), however, it was comparable up to 50 % incorporation of unripe jackfruit.</li> </ul>  | (Huda-Faujan & Arifin, 2022)    |

## Conclusion

Consumers are shifting toward a healthier diet and becoming more concern about the environment which has led to the development of products based on plant-based alternatives. Due to its meat-like texture and high nutritional and therapeutic properties, unripe jackfruit has been widely used as a meat alternative ingredient in recent times. It could be a promising ingredient to produce a value-added meat product in the current sector that is aligned with consumers' preferences, recent

trends and the Sustainable Development Goals to end hunger, achieve food security and improved nutrition and promote sustainable agriculture by 2030.

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