The application of Jackfruit by-product on the development of healthy meat analogue

M A Hamid, F L C Tsia, A A B Okit, C W Xin, H H Cien, L S Harn, P N Patrick, S Samirin, W A A W Azizi, A Irfanian, and C F Yee

Faculty of Food Science and Nutrition, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah

Email: chot@ums.edu.my

Abstract. This study is aimed to introduce the potential of jackfruit by-products to develop a healthy meat analogue. Meat analogue had been produced with different jackfruit by-products to wheat gluten ratio. The textural properties of meat analogs were studied, where the result showed a significant decrease in hardness and chewiness with decreasing wheat gluten content. In sensory properties, meat analogue with 58% jackfruit by-products and 20% vital wheat gluten was the most preferred meat analogue in terms of appearance, aroma, taste, color, hardness, juiciness and overall acceptability. Other than that, the nutritional composition of jackfruit by-products meat analogue showed higher content of protein and dietary fiber. It was concluded that jackfruit by-products were the new main ingredient to develop healthy meat analogue for vegetarians and health-conscious individuals who stick on meat-free or a reduced meat diet without jeopardizing protein and micronutrients intake.

1. Introduction

Jackfruit is a kind of popular Asian tropical fruit likes durian and banana, and it is recognized for its unique size and shape. Its sweet arils have a pretty strong fruity aroma, which can be appreciated from a distance. Jackfruit belongs to the family of Moraceae, which is a congener of the tree of fig, mulberry, and breadfruit, and its botanical name is Artocarpus heterophyllus [1]. Today, it widely cultivated in the tropical regions of the Indian subcontinent, Thailand, Malaysia, Indonesia, and Brazil for its fruit, seeds, and wood. Jackfruit plant is a huge tree that can grow to 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 dense canopy, which is normally dome in shape. The trunk of the tree is rarely buttressed with the greyish-brown, scaly, uneven, and rough bark [2]. The tree grows best in tropical humid and rainy climates but rarely survives cold and frosty conditions. The jackfruit, which is known as the largest of all cultivated fruits, has a weight range from 4.5 to 30 kg with a reported weight of 50 kg [3].

The compound fruit of jackfruit is made of three parts, which are pulp (30-32%), seeds (18%), and the rind (5-55%) [4]. Apart from its pulp, the underutilized parts of jackfruit like jackfruit seed and rind have been reported to possess high nutritional values. Jackfruit seed is reported to have a similar nutritional composition as that of grains [5]. Jackfruit seed is a good source of starch and dietary fiber, which composed 22% and 3.19% of the jackfruit seed, respectively [6]. Besides, jacalin is the major protein in jackfruit seed which possessed immunological properties. Not only that, but jackfruit seed also contains lignans, isoflavones, saponins, all phytoneutrants, and their health benefits are
wide-ranging from anti-cancer to antihypertensive, anti-aging, antioxidant, antiulcer and so on [7]. On the other hand, jackfruit rind is high in pectin content. It was found that inedible portions of jackfruit contain higher pectin content than the edible part (pulp). The yields of pectin from jackfruit rind ranged from 14.8-18.6 % (w/w), while pectin from cempedak rind was from 17.6-20.5% (w/w) [8]. In addition, jackfruit rind also contributes to some antioxidants content of the jackfruit. It was reported that jackfruit rind extracts had a higher polyphenol and flavonoid content compared to its spine and skin. It was also found that the polyphenol content of jackfruit rind was higher than the fruit peels of pineapple, pomegranate, and orange [9].

Nowadays, the development of a meat analogue to provide alternatives for meat has become a trend. The increase in consumers has driven this trending demand healthy diet, the concern about rising meat prices, the increase in the popularity of vegetarianism, and the growing consumer interest in related eating patterns such as the avoidance or reduced consumption of red meat [10]. Meat analogue can be defined as food which structurally similar to meat but differs in composition [11]. A typical meat analogue is composed of a combination of ingredients such as water (50-80%), non-textured proteins (4-20%), textured vegetable proteins (10-25%), fat (0-15%), flavourings (3-10%), binding agents (1-5%) and coloring agents (0-0.5%) [12]. Meat analogues could be deemed as one of the best suitable ways in which non-animal protein can be introduced, and the underlying impetus remains the utilization of a wider range of proteins for human food [13].

Recently, the utilization of by-products with high nutrient values to develop value-added food products have been receiving special attention. About 60% of the whole jackfruit is deemed inedible consisting of the outer prickly rind, inner perigones (no edible perianth), and central core, which are unutilized waste [14]. Thus, with the wide usage of jackfruit in the food industry, there will be a large quantity of jackfruit rind accumulated. Besides, the soaring of the human population has caused the resources which are available to sustain the population getting depleted, and this has brought a direct impact on the food supply. The demand for food is predicted to increase by 70% by 2050 due to the further addition of 2.3 billion populations [15]. The rapid growth of the population has also led to an increase in waste and by-products accumulated. Thus, this research aims to utilize underutilized jackfruit by-products as the main ingredient to produce value-added meat analogue for a healthy diet.

2. Materials and Methods

2.1. Preparation of jackfruit by-products

Jackfruit (*Artocarpus heterophyllus*) was purchased from the market around Kota Kinabalu, Sabah. Ripe jackfruit was chosen, and the green with soft thorn part at the outer layer of the skin was removed by cutting them away, remaining only the white part. Attached to the rinds were the rags or flakes, which were white stripes surrounding the yellow jackfruit. Rinds and rags were cut into smaller pieces, washed, and blanched in boiling water for 2 minutes. After blanching, they were soaked in cold running water to stop the continued cooking activity. Water was squeezed out from the blanched and cooled rags and rags by using hands and settled aside. Finally, those rinds and rags were blended into fine chunks by using a blender.

Seeds of jackfruit were washed and then cooked in boiling water for about 20 minutes until they were softened. After that, the thin brownish shell coats surrounding each seed were removed, leaving the whitish cotyledon to be blended into a fine powder. The blended rinds, rags, and seed powders were stored into the cold storage (6°C) until analysis.

2.2. Preparation of jackfruit by-products meat analogue

Four different jackfruit by-products meat analogue formulations were prepared with the addition of jackfruit by-products at different levels (18%, 38%, 58%, and 78%). Vital wheat gluten was also used at different levels (60%, 40%, 20%, and 0%) for texture modification. 5% of starch was also added for texture modification. For the fat source, 6% of vegetable oil was used. 8% of soy protein was added for the additional protein source. Seasonings and spices used were salt (0.2%), nutritional yeast (0.75%), mushroom seasonings (0.7%), garlic powder (0.4%), onion powder (0.4%), chili powder
(0.3%), turmeric powder (0.15%), black pepper powder (0.05%) and Chinese five-spices powder (0.05%). First, the blended jackfruit by-products and other ingredients were weighed according to the formulation and mixed in a bowl. Seasonings were added first to let them dissolve in the slightly moist jackfruit by-products blend, followed by other ingredients. Kneading was followed by the mixing of all the ingredients. The dough was divided into a suitable size of patty using a cutter and rounded into a ball shape, followed by flattening them shapes that resemble burger patty. After that, they were being placed in an oiled baking tray and rested for a few minutes. Steaming was carried out to precook the patties. The patties were cool down for a while before the patties were packaged inside the plastic film. The patties were placed overlapping with each other, and grease paper was put between each patty to make it easy for separation prior cooking process. The patty was stored under a freezing temperature of -18°C inside the freezer.

2.3. Instrumental textural properties

Hardness and chewiness of jackfruit by-products were determined by using a texture analyzer (TA.XT Plus, Stable Micro Systems, UK), as described by Chiang et al. [16]. The sample was cut into square shape and dimension (15×15×8 mm) and compressed using a P/51 probe to 50% of its original thickness at a speed of 1 mm/s for the first bite, returned to original position over 5 s, and followed by the second bite at 1 mm/s to 50% of the first compressed thickness.

2.4. Sensory evaluation

Four formulations of jackfruit by-products meat analogue were prepared for sensory evaluation by using the seven-point hedonic scale (1= extremely dislike, 7= extremely like). Each meat analogue was cut uniformly and presented in a randomized order. The sensory panelists were comprised of 50 students from the Faculty of Food Science and Nutrition, University Malaysia Sabah, Malaysia. These formulations were evaluated based on attributes of appearance, aroma, taste, color, hardness, juiciness, and overall acceptability.

2.5. Nutritional composition

The methods used for all the analysis of the sample compositions were based on the methods provided by AOAC [17]. The nutritional composition, including carbohydrate, protein, fat, and total dietary fiber of best formulations of meat analogue were used to compare with commercial meat analogue. The moisture content of jackfruit by-products meat analogue was determined using the oven-drying method after drying the sample at 105°C for 12 hours in an air-drying oven. Ash content of jackfruit by-products meat analogue was determined by using the method of dry ashing, which was using a muffle furnace heated at 550°C for 24 hours. Crude fat content was measured by Soxhlet extraction methods using the solvent extraction system (Soxhlet™ 2050, FOSS, Germany). Crude protein content was determined using the Kjeldahl method with the Kjeldahl nitrogen analyzer (Kjeltec™ 2030, FOSS, Germany). The total carbohydrate content of jackfruit by-products meat analogue was calculated using equation 1.

\[
\text{Total carbohydrate (\%) = 100\% - (\%MC + \%F + \%P + \%A + \%CF)}
\]  

Where:

- MC = moisture content,
- F = fat,
- P = protein,
- A = ash and
- CF = crude fibre

2.5.1. Determination of total dietary fiber. Total dietary fiber of jackfruit by-products meat analogue was determined based on the Enzymatic Gravimetric method provided by AOAC [17]. Dried and defatted samples were cooked at 100°C with heat-stable \(\alpha\)-amylase and incubated at 60°C with protease and amyloglucosidase. The residue was filtered, then washed with 95% ethanol and acetone, dried, and weighed. One duplicate sample was analyzed for protein content, whereas another duplicate sample was incubated in a muffle furnace at 525°C to determine ash content. The total dietary fiber was obtained by deducting the weight of ash and protein.
2.5.2. **Statistical analysis.** A One Way Analysis of Variance (ANOVA) was used to determine the effects of the addition of jackfruit by-products on the sensory properties of meat analogue. All the data collected was analyzed using statistical SPSS software version 22.0. The significant differences among the means of different parameters were considered at \( p < 0.05 \).

3. **Results and discussion**

3.1. **Instrumental textural properties**

The instrumental textural properties of jackfruit by-products meat analogue are shown in table 1. Hardness is considered as the maximum force of the first compression, while chewiness applies only to solid products and is calculated as hardness \( \times \) cohesiveness \( \times \) springiness \[18\]. The hardness of meat analogue decreased with decreasing wheat gluten content and increasing jackfruit by-products. The addition of wheat gluten enhanced more dense network formation. The low chewiness of meat analogue was due to low content of wheat gluten and high content of jackfruit by-products. Might due to the addition of wheat gluten that formed in the better dissolution of proteins within the melt and a more dense, cohesive structure on cooling \[18\].

**Table 1.** Instrumental textural properties of meat analogue with different percentages of jackfruit by-products to wheat gluten ratio.

| Instrumental textural properties | Score (Mean ± SD) | F1     | F2     | F3     | F4     |
|----------------------------------|-------------------|--------|--------|--------|--------|
| Hardness                         | 77.60 ± 4.25 \(^a\) | 60.80 ± 9.55 \(^b\) | 43.70 ± 7.54 \(^c\) | 45.40 ± 4.69 \(^d\) |
| Chewiness                        | 44.31 ± 5.16 \(^a\) | 41.77 ± 7.77 \(^ab\) | 34.01 ± 7.24 \(^b\) | 35.28 ± 4.11 \(^ab\) |

\(^1\) Samples F1, control = 18% jackfruit by-products + 60% vital wheat gluten; F2 = 38% jackfruit by-products + 40% vital wheat gluten; F3 = 58% jackfruit by-products + 20% vital wheat gluten; F4 = 78% jackfruit by-products + 0% vital wheat gluten. Different superscript alphabets indicates that there is significant different (\( p < 0.05 \)) within same row.

3.2. **Sensory evaluation**

Sensory characteristics were evaluated, and the results are presented in Table 2. The results showed that the addition of different percentages of jackfruit by-products had a significant effect (\( p < 0.05 \)) on appearance, aroma, taste, color, hardness, juiciness and overall acceptability of the prepared meat analogue samples. The sample F3, with the addition of 58% jackfruit by-products and 20% vital wheat gluten, had the highest overall acceptability compared to other samples. In terms of appearance, there were no significant differences between all the samples. There were also no significant differences between the color of sample F1 and F3. However, the aroma of sample F2 and F3 showed significant differences with other samples. This indicates that a high amount of jackfruit by-product will affect the aroma of patties as jackfruits have a very strong fruity aroma. The odor-active compounds that give jackfruit its strong and distinctive aroma are 3-methyl butanoate, ethyl butanoate, 3-methylbutanal, and 2-methyl propanal \[19\].

Taste is an important attribute for consumers to choose a food product. The sample F3 had the highest level of taste acceptance. The sample F4 showed the lowest value of hardness acceptance due to a lack of vital wheat gluten. There was no significant difference between the juiciness of sample F3 and F4. However, based on all attributes, sample F3 (58% jackfruit by-products + 20% vital wheat gluten) was significantly different from other samples and chosen as the best formulation.
Table 2. Sensory characteristics of vegetarian patties with different percentages of jackfruit by-products.

| Characteristic   | F1 (Mean ± SD) | F2 (Mean ± SD) | F3 (Mean ± SD) | F4 (Mean ± SD) |
|------------------|----------------|----------------|----------------|----------------|
| Appearance       | 4.70 ± 1.17a   | 4.80 ± 1.16a   | 4.84 ± 1.23a   | 4.66 ± 1.15a   |
| Aroma            | 4.35 ± 1.07b   | 4.88 ± 0.82a   | 5.00 ± 1.11a   | 4.40 ± 1.19b   |
| Taste            | 4.06 ± 1.15bc  | 4.64 ± 1.18ab  | 5.13 ± 1.09a   | 4.25 ± 1.23b   |
| Colour           | 4.89 ± 1.06a   | 4.40 ± 1.04b   | 4.99 ± 1.11a   | 3.79 ± 1.14c   |
| Hardness         | 4.38 ± 0.98ab  | 4.77 ± 0.70a   | 4.72 ± 1.31a   | 4.20 ± 1.24b   |
| Juiciness        | 4.46 ± 1.04b   | 4.53 ± 1.35b   | 5.27 ± 0.84a   | 4.93 ± 1.28ab  |
| Overall acceptability | 4.75 ± 1.02bc | 4.97 ± 0.82ab  | 5.14 ± 1.17a   | 4.36 ± 0.96c   |

Samples F1, control = 18% jackfruit by-products + 60% vital wheat gluten; F2 = 38% jackfruit by-products + 40% vital wheat gluten; F3 = 58% jackfruit by-products + 20% vital wheat gluten; F4 = 78% jackfruit by-products + 0% vital wheat gluten. Different superscript alphabets indicates that there is significantly different (p<0.05) within same row.

3.3. Nutritional composition

The best formulation of jackfruit by-products meat analogue (58% jackfruit by-products + 20% vital wheat gluten) was used to determine nutritional composition. It is also compared with the commercial of meat analogue product. The nutritional composition of jackfruit by-products meat analogue and commercial meat analogue product are shown in table 3.

Table 3. Nutritional value of Jackfruit by-products meat analogue and commercial meat analogue product, per 100 g (mean± SD).

| Composition    | Brand of meat analogue | Jackfruit by-products | Commercial product |
|----------------|------------------------|-----------------------|--------------------|
| Carbohydrate (g) | 16.90 ± 2.56a         | 7.92 ± 1.67b         |
| Fat (g)         | 13.00 ± 2.68a         | 13.90 ± 0.94a        |
| Protein (g)     | 20.67 ± 3.96a         | 14.26 ± 1.38b        |
| Crude fibre (g) | 3.41 ± 0.75a          | 1.67 ±0.58b          |
| Ash (g)         | 3.76 ± 0.86a          | 2.88 ± 0.76b         |
| Moisture content (g) | 42.27 ± 2.26b    | 60.74 ± 3.87a        |
| Dietary fibre (g) | 9.12 ± 1.70a         | 5.76 ± 1.26b         |
| Energy (kcal/g) | 271.65 ± 5.65a        | 265.65 ± 4.87a       |

As the results above, jackfruit by-products meat analogue had significantly higher (p<0.05) of protein content as compared to the commercial product. This is because of jackfruit by-products meat analogue contained wheat gluten and soy protein, which have high protein content. Vital wheat gluten is also called Seitan can range in protein content from above 70%, according to the United States of America Patent No. US20190191725A1 (2019). Jackfruit seeds are also a good source of protein with the protein content of 17.8-37.0 %, depending on the variety of jackfruit [7]. Jackfruit by-products meat analogue had higher fiber content than commercial meat analogue. This is due to the addition of jackfruit rind, which has high fiber content. However, the jackfruit by-products meat analogue had shown slightly higher fat content than commercial meat analogue. The higher fiber content in jackfruit by-products meat analogue may be due to the oil holding capacity (OHC) in the patty. According to Ozyurt and Ötles [20], oil holding capacity (OHC) is the amount of oil retained by the fibers after mixing, incubation with oil, and centrifugation. A finding was reported by Felli et al. [21], which showed that dietary fiber has strong OHC, and variation in the amount of dietary fiber could be a vital factor in the oil holding capacity. Jackfruit by-products meat analogue has higher dietary fiber as compared to commercial meat analogue. Besides, the surface properties, charge density, and/or hydrophilic nature also play an important role in OHC of the fibers [20]. This could be the reason why
jackfruit by-products meat analogue has slightly higher fat content than commercial meat analogue. On the other hand, commercial meat analogue had a higher content of carbohydrate than jackfruit by-products meat analogue.

4. Conclusion
The potential of jackfruit by-products to develop a healthy meat analogue was studied. Four formulations meat analogues had been produced with different jackfruit by-products to wheat gluten ratio. The decreased hardness and chewiness were due to the lower content of wheat gluten. The F3 consists of 58% jackfruit by-products, 20% vital wheat gluten was the most preferred meat analogue among all the samples, based on appearance, aroma, taste, color, hardness, juiciness and overall acceptability. In addition, it also contained a higher content of protein and dietary fiber compared to another commercial meat analogue patty. This was due to the addition of wheat gluten and soy protein. Jackfruit by-products such as rind also contributed to the source of dietary fiber. Overall, jackfruit by-products were considered as the main ingredient in the production of a healthy meat analogue.

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