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Effects of Non-Allergen Binders on the Physicochemical Properties and Sensory Acceptability of Jackfruit Patty

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Abstract: The market for plant-based meat substitutes is expanding rapidly, but many of these products contain ingredients that are recognized as high-priority allergens. Thus, the simplest lattice mixture design generated 13 formulations in order to optimize jackfruit patties with potato starch, pea starch, and rice flour in order to identify the optimum allergen replacement ingredients. Physicochemical properties such as colour, moisture, pH, and texture along with sensory acceptance were evaluated. The results showed that the addition of 6.8% rice flour to the patty resulted in greater L* and b* values compared to other non-allergen ingredients, whereas adding 6.8% potato starch resulted in higher a* values. Jackfruit patties made with pea starch had an ideal texture. The moisture content of the patty contained 2.2% potato starch, 2.2% pea starch, and 2.2% rice flour was the highest as compared with other formulations. Sensory evaluation test revealed that jackfruit patties prepared with pea starch were significantly preferred due to a high liking score, with sensory values ranging from 6 to 7 for appearance, taste, texture and overall acceptability. In conclusion, the jackfruit patties formulated with potato starch, pea starch, and rice flour are viable and would provide the industry with a variety of options for selecting the non-allergen ingredients that enable product differentiation and satisfy the rising demand for allergen-free foods.

Keywords: Meat Analogue, Jackfruit Patty, Potato Starch, Pea Starch, Rice Flour

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1. Introduction

The increasing consumer demand for less meat or non-meat food products encourage the formulation and development of products using meat analogues. A meat analogue is a food that resembles meat in structure but differs in composition. A typical meat analogue is made up of water (50-80%), non- textured proteins (4-20%), textured vegetable proteins (10-25%), fat (0-15%), flavorings (3-10%), binding agents (1-5%), and coloring agents (0-0.5%) [1]. Recently, the "clean label" trend for food products has massively increased during the previous ten years [2]. Products with a clean label are typically ones that have undergone less processing or processing using only natural or organic ingredients and no artificial additives [3]. Such product's ingredient lists are short, simple, and free from chemicals or elements that can cause food allergies and intolerance [4]. Despite the affordable, continuously available and high quality of meat analogues products, the key concern is its safety.

Allergens in meat alternatives could be dangerous. This is especially true with soy and wheat, which are two of the eight foods that are most commonly linked to food allergies and are present in many plant-based diets [5]. In meat analogues, soy and wheat will act as a binder, enhancing the products' textural qualities and enabling the desired gelling and thickening [6]. However, given their relevance in the functionality of processed meat analogues, just removing these current binders to produce allergen-free products is not viable.

Thus, rice flour, pea starch, and potato starch were selected as the study's alternate non-allergen binders. These three components all have one thing in common, they are vegan and gluten-free in addition to being non-allergens. Potato starch is a good allergen-free binder that tightens the bond between the proteins in ground meat to make it more neatly slice-able, absorbs and retains water better, and helps ensure a juicy and tender product. Pea starch, on the other hand, contains a high percentage of amylose, which gives it outstanding thickening and gelling properties, making it suitable for use as a binder. Rice flour also includes around 80% starch, which has the potential to assist retain water during the cooking process, extending the shelf life and providing the correct texture to meat analogues due to its unique gelatinization and binding capabilities.

Therefore, the development of meat analogue by using young and unripe jackfruit were done and studied on replacing traditional allergen binders with allergen-free ingredients which are potato starch, pea starch and rice flour. Young and unripe jackfruit is preferred to be used for development of meat analogue due to its high composition in both carbohydrates and dietary fiber. Unripe jackfruit pulp has a smooth and texture that is strikingly similar to chicken, makes it a good replacement for meat-based products [1]. The effect of all these non-allergen ingredients on meat analogue were studied in terms of physicochemical properties such as color, texture, pH and moisture as well as sensory acceptability of jackfruit burger as meat analogue to evaluate how well they are received by the general public.

1. Materials and Methods

1.1 Materials

Young jackfruit, mushrooms, potato starch, pea starch, rice flour, shortening, paprika, onion powder, garlic powder, salt, and black pepper were purchased from local supermarket in Pagoh (L&L Supermarket). The instruments used in this study are a spectrophotometer (MiniScan EZ 4500), a moisture analyzer (Thermo Scientific, Eutech pH 700), a pH meter (Thermo Fisher Scientific, Ottawa, ON, Canada), and a texture analyzer (TA.XT plus Stable Micro System Ltd., Godalming, United Kingdom).

1.2 Methods

1.2.1 Jackfruit patty formulation

The jackfruit patty was prepared according to the composites mixtures as shown in Table 1 with each sample contained 60% jackfruit, 22% mushroom, 10% fat, 1.2% flavoring agent (salt, black pepper, paprika, onion powder, garlic powder) and 6.8% binding agent (potato starch, pea starch, rice flour) [1]. As presented in Table 2, a total of 13 different samples with different ratios of binding agents were obtained from using Design Expert software (Stat-Ease, Inc., Trial Version 13.0.11.0, Minneapolis, USA) in determining the formulation of three components in jackfruit burger patty. The jackfruit burger patties will have a distribution weight of 55 grams per patty in 600 grams dough.

Table 1: Ingredients used in jackfruit patty

Ingredients	Measurement (g)	Percentage (%)
Jackfruit	300	60
Mushroom	110	22
Fat	50	10
Flavoring agents	6	1.2
Binding agents	34	6.8

Table 2: Experimental design of three components in jackfruit patty formulations according to Design Expert Software

Formulation	Potato Starch (g)	Pea Starch (g)	Rice Flour (g)
1	0	34	0
2	0	0	34
3	34	0	0
4	22.7	5.7	5.7
5	34	0	0
6	17	0	17
7	5.7	22.7	5.7
8	17	17	0
9	11.3	11.3	11.3
10	0	17	17
11	0	34	0
12	5.7	5.7	22.7
13	0	0	34

1.2.2 Jackfruit patty preparation

Young jackfruit was peeled and chopped into smaller pieces. After been washed, the texture was softened by blanching in boiling water. The water will then be squeezed out of the blanched jackfruit and kept aside. Using a food processor, the jackfruit and mushroom were minced together into fine chunks. Other ingredients such as black pepper, paprika, garlic powder, onion powder and salt, as well as binding agents including potato starch, pea starch and rice flour, were mixed with the mushrooms and jackfruit according to the amount of formulation that has been set. The dough is then divided into equal-sized patties with 55 grams for each. The jackfruit patties were frozen in -18˚C first and then thawed in the refrigerator before being fried for sensory evaluation.

1.3 Physicochemical analysis

1.3.1 Color

A handheld spectrophotometer (MiniScan EZ 4500) was used to determine the color of each of the formulated jackfruit patties through CIE system approach (L*, a*, and b*). Cooked patties were cut horizontally into two pieces with a knife and the interior color was measured [7].

1.3.2 pH

A pH meter (Thermo Fisher Scientific, Ottawa, ON, Canada) was used to measure the pH of each formulated cooked jackfruit patties. Each sample of formulated jackfruit patties with weight 20 g were homogenized with 20 ml deionized distilled water for 2 minutes [7].

1.3.3 Moisture content

A moisture analyzer (Thermo Scientific, Eutech pH 700,) was used to determine the moisture content of each formulated jackfruit burger patties. The plate was calibrated first. Then, the air bubble was ensured at the center of the level indicator by turning the leveling screw. The samples were put in the aluminum dish. 2 grams of each sample was put in the aluminum dish, heated at 200˚C for 27 minutes [8].

1.3.4 Texture Profile Analysis (TPA)

A texture analyzer (TA.XT plus Stable Micro System Ltd Godalming, United Kingdom) was used for determining hardness and cohesiveness of each formulated cooked jackfruit patties. The samples were cut into a square form with a dimension of 3 × 2 × 1 cm (LxWxH). The samples were compressed to 40% of the original height using cylindrical probe with a speed of 5.0 mm/s and at ambient temperature (25°C) [9].

1.4 Sensory evaluation

The sensory evaluation was assessed through an affective test which is a 9-point hedonic scale method to measure subjective reactions towards these jackfruit patties based on its sensory characteristics. This sensory evaluation involved 60 panelists. It was conducted in two sessions with six and seven formulations respectively. Panelists were asked to rate overall acceptability of the formulated jackfruit burger patties samples in terms of color, taste, texture, aftertaste and overall acceptance using a 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely) [7].

2. Results and Discussion

2.1 Physicochemical Properties Analysis

The physicochemical properties analyzed in this research study include color, pH, moisture and texture. The color changes caused by the addition of binders might vary depending on the type and percentage of binders used. As stated by Bakhsh *et al.* [10], in terms of calorimetric analyses, the substitution of plant proteins will cause the lightness (L*) and redness (a*) values of meat analogue patty will be lowered. The results of the color measurement are shown in Table 3.

As can be seen from the table, after being cooked, all of the jackfruit patties had significant differences ($p < 0.05$) in term of lightness (L*), redness (a*) and yellowness (b*), but they were all still within their respective ranges of values. In term of the L*values, incorporation of 6.8% of rice flour in Formulation 2 and 13 as replicate had higher lightness value compared to other formulations while incorporation of combination between 4.5% potato starch, 1.2% pea starch and 1.2% rice flour in Formulation 4 had the lowest value of L*. The fact that the jackfruit patties underwent shallow frying throughout the cooking procedure has caused the L* values to decrease after being cooked. Redness and yellowish appearance of jackfruit patties were determined by a positive value in the a* and b*, respectively.

Formulation 5 with addition of 6.8% potato starch recorded a higher value of a* compared to other formulations while Formulation 1 with addition of 6.8% pea starch shown a lowest value of a*. Values of a* for all of the formulations are still within the ranges of 5.60 to 6.77. In the other hand, Formulation 2 with addition of 6.8% of rice flour had the highest b* values while Formulation 7 with incorporation of 1.2% potato starch, 4.5% pea starch and 1.2% rice flour have the lowest values of b*. Values of b* for all of the formulations were in ranges of 16.00 to 19.10. Each formulation of these jackfruit patties' lightness and yellowness values can be impacted by the oyster mushrooms used in this study. This claim is backed up by research from Wan Rosli *et al*. [11], who found that chicken patties' lightness and yellowness were reduced by up to 50% when oyster mushrooms were added, but their redness remained unaffected. As a result, depending on the type of binders used and the incorporation ratio, color changes caused by the addition of binders may vary.

Table 3: Color of jackfruit patties after being cooked

Formulation	L*	a*	b*
1	48.19 ± 0.03	5.69 ± 0.03	16.44 ± 0.06
2	54.86 ± 0.06	6.54 ± 0.04	19.02 ± 0.06
3	51.27 ± 0.02	6.77 ± 0.15	18.96 ± 0.05
4	47.05 ± 0.27	6.30 ± 0.35	17.61 ± 0.01
5	51.33 ± 0.41	6.83 ± 0.04	18.91 ± 0.14
6	48.39 ± 0.26	5.85 ± 0.01	17.43 ± 0.36
7	47.90 ± 0.91	6.14 ± 0.04	16.10 ± 0.55
8	48.08 ± 0.40	5.91 ± 0.10	17.21 ± 0.28
9	52.09 ± 1.08	6.28 ± 0.07	18.39 ± 0.47
10	48.77 ± 0.66	6.10 ± 0.08	17.82 ± 0.15
11	48.23 ± 0.14	5.73 ± 0.04	16.38 ± 0.07
12	47.88 ± 0.25	6.33 ± 0.02	16.14 ± 0.05
13	54.77 ± 0.11	6.45 ± 0.04	18.94 ± 0.36

Table 4 shows the presented data for pH, moisture and texture analysis of cooked jackfruit patties. In this study, there were significant ($p < 0.05$) differences among tested binders in the pH, moisture and texture of cooked jackfruit patties. Gök *et al.* [12], reported that the pH range of meat burgers was from 5.83 to 6.08. pH of meat analogues should be slightly higher around 6.00 to 6.50. Based on Table 4.2, the pH range obtained from all jackfruit patties formulations is in the range between 5.4 to 5.8 which is slightly lower than it should be. This might be due to improper storage where the meat analogues were frozen for too long before fried. According to Kamani *et al.* [13], meat's pH value was much lower after freezing and thawing than it was before freezing. Some protein solutions denatured, the hydrogen ion concentration increased, and the pH level dropped during the freezing and thawing process. During the freezing and thawing processes, the juice loss also raises hydrogen ion concentration, which lowers the pH.

Table 4: Results of pH, moisture and texture of cooked jackfruit patties

Formulation	pH	Moisture (%)	Texture	
			Hardness (N)	Cohesiveness
1	5.78 ± 0.00	53.36 ± 0.23	32.65	0.80
2	5.78 ± 0.01	52.46 ± 0.23	10.92	0.86
3	5.77 ± 0.01	53.46 ± 0.55	19.78	0.85
4	5.75 ± 0.01	52.28 ± 0.30	12.01	0.85
5	5.76 ± 0.01	53.59 ± 0.32	21.59	0.82
6	5.77 ± 0.01	51.48 ± 0.56	12.03	0.65
7	5.76 ± 0.01	52.42 ± 0.21	20.90	0.79
8	5.77 ± 0.01	52.59 ± 0.16	19.53	0.78
9	5.69 ± 0.01	53.77 ± 0.40	6.20	0.90
10	5.67 ± 0.01	51.85 ± 0.24	4.28	0.89
11	5.78 ± 0.01	53.37 ± 0.22	32.03	0.79
12	5.68 ± 0.01	53.24 ± 0.12	19.79	0.73
13	5.78 ± 0.01	52.61 ± 0.57	14.54	0.82

The moisture content is crucial since it can contribute to the juiciness of the cooked meat substitute. In this research, there were significant ($p < 0.05$) differences among all of the formulations. Due to the proteins' tendency to denature during cooking, burgers frequently lose water and fat with shrinkage [7]. As can be seen from the presented data, the addition of binding agents from combination of 2.2% potato starch, 2.2% pea starch and 2.2% rice flour in Formulation 9 recorded the highest moisture contents which is 53.77% while Formulation 6 with combination of 3.4% potato starch and 3.4% rice flour is the patty that having the lowest moisture content with 51.48%. According to research conducted from Yang [7], treatments with 4% potato starch, pea starch and rice flour did not result in significant (p<0.05) differences in moisture but incorporation of non-allergen binders at 4% contributed to higher moisture than those incorporated at 2% level. This show that increasing incorporation level of binders significantly improved cooking properties.

For texture, Formulation 1 with 6.8% of pea starch has the highest hardness compared to other formulations. Higher values for hardness indicate a texture that is more tough. This may be because pea starch has a higher amylose content than other regularly used starches, giving it greater thickening and gelling capabilities. On the other hand, a combination of 3.4% of pea starch and 3.4% of rice flour makes the Formulation 10 the lowest in hardness. Previous studies have suggested that the moisture and fat retention in ground meat products are important factors for the texture. Gao [14] reported that softer textures in beef patties were obtained with the increase of fat content. Rice flour has higher moisture absorption and fat retention; therefore, the burger patty has softer texture. According to Yang [7], the difference in hardness on the patty can also be due to the formation of crust on the surface of patties during grilling that might have affected the results. Cohesiveness describes how well a food retains its form between the 1st and 2nd chew. Cohesiveness value is directly related to the tensile and compression strength of the meat analogue.

2.2 Sensory Evaluations

In general, the liking of appearance, taste, texture, aftertaste as well as overall acceptability were influenced by the addition of different binding agents used in the formulations. Table 5 shows the score given by the panelists in sensory evaluation. Based on the results obtained, most of the panelists preferred Formulation 1 which is 6.8% pea as alternative non-allergens binders in meat analogue due to its higher score achieved in appearance, taste, texture and overall acceptance.

In terms of appearance, panelists give scores for all of the formulations between 6 to 8. This might be as a result of its resemblance to a chicken patty, where the color is not overly dark after frying. In terms of taste, all of the formulations get scores range from 6.44 to 7.49. For individuals who attempt to consume plant-based meat for the first time, this may persuade the panels to accept it. For texture, Formulation 1 with addition of 6.8% of pea starch had the highest score compared to others formulation. The use of pea starch able to prevents the patty from having an overly fragile, mushy, or hard texture since it has superior thickening and gelling properties due to its high amylose content. However, Formulation 1 had slightly bitter aftertaste that cause it to get the lowest scores than other formulations.

Table 5: Hedonic scores of cooked jackfruit patties formulated with different binders evaluated by the sensory panelist

Formulation	Attributes				
	Appearance	Taste	Texture	Aftertaste	Overall Acceptance
1	7.50 ± 0.59	7.49 ± 0.77	7.07 ± 0.58	4.97 ± 0.64	7.03 ± 0.72
2	6.73 ± 0.78	6.69 ± 0.72	5.70 ± 0.65	5.04 ± 0.61	6.23 ± 0.73
3	6.71 ± 0.74	6.91 ± 0.90	5.93 ± 0.91	5.35 ± 0.61	6.27 ± 0.69
4	6.85 ± 0.64	6.44 ± 0.63	5.97 ± 0.81	5.37 ± 0.76	6.30 ± 0.75
5	7.10 ± 0.66	6.73 ± 0.66	5.87 ± 0.63	5.91 ± 0.87	6.37 ± 0.72
6	6.80 ± 0.96	6.84 ± 0.81	6.20 ± 0.71	5.24 ± 0.76	6.50 ± 0.82
7	6.77 ± 0.90	6.68 ± 0.86	6.20 ± 0.55	5.30 ± 0.68	6.33 ± 0.84
8	6.80 ± 0.85	6.80 ± 0.76	6.53 ± 0.51	6.22 ± 0.87	6.37 ± 0.76
9	7.00 ± 0.64	7.01 ± 0.68	6.40 ± 0.50	5.30 ± 0.78	6.33 ± 0.84
10	7.03 ± 0.67	7.00 ± 0.72	6.20 ± 0.41	5.20 ± 0.81	6.30 ± 0.84
11	7.00 ± 0.83	7.20 ± 0.79	7.10 ± 0.66	5.06 ± 0.82	7.07 ± 0.83
12	6.87 ± 0.68	6.85 ± 0.78	5.87 ± 0.57	5.23 ± 0.86	6.13 ± 0.82
13	6.83 ± 0.86	6.79 ± 0.63	6.47 ±0.51	5.17 ± 0.79	6.43 ± 0.82

2.3 Statistical Simplex Lattice Mixture Design

The findings of mixture design studies show that low predicted sum of squares, low standard deviation, and high predicted R-squared define the ideal model [15]. Following these guidelines, the linear model as the best fit for lightness, yellowness, flavor, and texture was discovered. Additionally, the special cubic model was found to be the best fitted for redness, the special quartic model was found to be the best fitted for moisture and cohesiveness, and the quadratic model was found to be adequately fit to the responses of pH, hardness, aftertaste, and overall acceptability. All of the model types are significant ($p < 0.05$) which means the statistical significance indicates that changes in the independent variables correlate with shifts in the dependent variable [16]. Lack of fit analyses for all of the model types were shown not significant ($p > 0.05$), indicating less model error [17]. The model gives the experimental data a good fit. R-squared ranged from 0.4552 to 0.9461.

2.4 Optimization of Simplex Lattice Mixture Design

Simultaneous optimization can be accomplished by maximizing, minimizing, or limiting parameters. In this study, the response for moisture was minimized while the responses for L*, a*, b*, pH and hardness were set in the range and the sensory qualities of the jackfruit patties' appearance, flavor, texture, and general acceptability were maximized. From the optimization results, jackfruit patties from Formulation 1 with 6.8% pea starch should be used. The desirability value was 0.574 out of 1.00 which indicates high meet of optimization criteria compared to other desirability.

3. Conclusion

In this study, jackfruit patties incorporated with non-allergens binders (potato starch, pea starch, rice flour) were successfully formulated and optimized by using simplex-lattice mixture design. According to physicochemical properties analysis, the integration of 6.8% rice flour resulted in Formulations 2 and 13 having higher lightness values. Formulation 5, which contained 6.8% potato starch, had higher values of a*, while Formulation 2, which included 6.8% rice flour, had the greatest values of b*. The pH of all formulations was found to be between 5.4 and 5.8, which is slightly lower than it should be. The addition of binding agents from a combination of 2.2% potato starch, 2.2% pea starch, and 2.2% rice flour in Formulation 9 resulted in the highest moisture content. Formulation one with 6.8% pea starch has the maximum hardness due to the higher amylose content which gives it greater thickening and gelling properties. The sensory results revealed that all 13 jackfruit patty formulations were moderately acceptable by the panelists, with sensory scores ranging from 6 to 7. Jackfruit patty Formulation 1 had the highest sensory scores for appearance, taste, texture and overall acceptability among the other samples. Regarding optimization on sensory and physicochemical properties, jackfruit patties from Formulation 1 with 6.8% pea starch was the optimized sample.

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