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Development of Jackfruit Crackers: Effects of Starch Type and Jackfruit Level

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Abstract*— Crackers are one of the convenient and inexpensive snacks that have high market potential. Most of the commercial crackers are carbohydrate-rich and normally considered as a low value-added product. In this study, innovative value added crackers made of jackfruit were developed. The effect of starches (sago and cassava) and levels of jackfruit (30 and 50%, w/w) on characteristics of the crackers were investigated. Physicochemical properties of the products at each predetermined processing steps (steaming, drying and frying); bulk density, expansion ratio, color and carotenoid contents were measured. A decrease in jackfruit level resulted in crackers with lower bulk density (0.26 to 0.41 g/cm3) and higher volume expansion ratio (2.84 to 4.66 cm3). Blending the cassava and sago starch at 1:1 ratio resulted in lower bulk density and higher expansion ratio compared to crackers made with a single type of starch. The L* and b* values decreased with drying and frying process, indicative of Maillard reactions. The higher L* value was influenced by the starch content, while higher jackfruit led increased the b* values, attributed to the presence of pigments in the fruit. Total carotenoid contents of fried crackers increased following steaming process, ranging from 0.061 to 0.199 mg/100g and samples made with blend of sago and cassava has the highest carotenoid contents. A jackfruit level of 30% (w/w) made with blend of sago and cassava starches (1:1) produced fried crackers with the most acceptable physicochemical characteristics. Crackers with improved nutritional value can be developed by incorporating jackfruit, thus expanding the conventional use of the fruit.

***Keywords*— Jackfruit; sago starch; cassava starch; expansion ratio; carotenoids.**

I. INTRODUCTION

Crackers is one of the most popular ready-to-eat snack food that are readily available throughout the year. In Malaysia, wide selection of crackers have been commercialized. The crackers are made of starch and can be enriched with protein sources such as fish and prawn. The type and level of starch play an important role in cracker production as they influenced the textural and sensory acceptability of the final product.

The effects of cassava, sago, rice and pregelatinized starch on the physicochemical properties of crackers have been reported ([1],[2]). The amylose and amylopectin ratio, size, shapes and rigidity of starch granules have been proposed as important factors affecting the expansion and textural properties of crackers ([3],[4],[1]). Previous studies ([5],[2]) demonstrated that crackers made from cassava starch have higher expansion ratio compared to those made from sago starch, attributed to higher amylopectin content of the former.

In addition, final product quality is strongly dependent on selection of raw material, characteristics of intermediate product, and processing conditions. Steaming, drying and frying are among of the stages involved in crackers production. The dried cracker is considered half-product, and it need to be fried before consumption. These process are critical in producing crackers with desirable characteristics. Many complex physicochemical changes occur during drying and frying of crackers such as starch gelatinization, water evaporation, crust formation, and appearance of golden color ([6],[7]) that eventually affect the product quality such as expansion and crispiness.

Jackfruit (*Artocarpus heterophyllus*) belongs to the Moraceae family and is widely cultivated in Bangladesh, Burma, Indonesia, Malaysia, Philippines, Sri Lanka, and Thailand [8]. The golden yellow ripe bulbs are sweet with fibrous and ‘meaty’ texture. The ripe bulbs are rich in sugar (21 to 30%), low in starch content (0.7 to 5.0%), contain a fair amount of carotenoids (34 to 800 µg/100 g) and vitamins C ([9],[10]). In Malaysia, jackfruit is one of the non-seasonal fruit crops grown widely due to its excellent adaptation in many growing conditions. The fruit commonly consumed in its fresh state or minimally process to extend the shelf life. There are only a few of jackfruit-based products present in markets include canned slice fruit and vacuum-dried.

Most of the commercially available crackers are high in calorie as they are made of mainly carbohydrate, thus considered as low value-added product. Due to the increasing trend of consumer demands towards ready-to-eat, healthy products, jackfruit can be one of the potential sources for the productions value-added crackers. However, the incorporation of jackfruit bulbs in crackers production may affect the physicochemical characteristics of final products due to the presence of high moisture and sugar contents. Therefore, this study was conducted to investigate the effects of different type of starches namely sago, cassava and their blend, and ratio of starch to jackfruit on the physicochemical properties of the crackers at different processing stages. The carotenoid content of the product was analyzed to determine the effect of supplementing jackfruit on the nutritional value of the crackers.

II. Materials and Methods

A. Materials

Jackfruit (variety of Tekam Yellow) was purchased from local seller in Serdang, Selangor. The seeds were removed and the jackfruit bulbs were washed with water. Sago and cassava starches were purchased from local stores in Bangi, Selangor.

B. Preparation of jackfruit crackers

Jackfruit crackers were made at different levels of jackfruit puree (30 and 50%, w/w) using cassava, sago or sago-cassava starches blend (1:1) to obtain products containing starch:jackfruit at 1:1 and 7:3 ratios. The starch-jackfruit mix was kneaded into dough and extruded into a plastic casing of 3.8 cm diameter and 30 cm length, followed by steaming at 100 °C for 90 minutes. Sample was stored at 4 °C for 16 hours before it was sliced to 2 mm thickness. The crackers were dried in hot-air dryer at 50 °C for 4-5 hours. The dried crackers were fried in hot palm oil (180 °C) for approximately 15 s to obtain fried crackers.

TABLE I
FORMULATIONS OF JACKFRUIT CRACKERS

Ingredients	Formulations (grams)					
	Sago		Cassava		Sago-Cassava	
	S1:1	S7:3	C1:1	C7:3	SC1:1	SC7:3
Jackfruit puree	80	48	80	48	80	48
Sago starch	80	112	0	0	40	56
Cassava starch	0	0	80	112	40	56
Water	0	38	0	38	0	38

S: sago starch; C: cassava starch; SC: sago-cassava starches blend at 1:1 ratio. The ratios indicate the weight ratio of starch to jackfruit.

C. Determination of bulk density and volume expansion

The bulk density and volume expansion ratio of fried crackers were determined using volume displacement method according to modified method of Segini et al. (2004)[11].

Bulk density was calculated as:

$\rho = m \times v$

where ρ is density, m is the weight of fried sample, and v is the volume of fried sample.

The volume expansion ratio was calculated as a ratio between volume of cracker before and after frying and calculated according to the method of Suknark et al., (1999)[12].

D. Determination of color

The colors of steamed, dried and fried crackers were measured using a colorimeter (Minolta Chroma Meter R-300, Japan). The lightness (L*), redness (a*) and yellowness (b*) were recorded.

E. Determination of carotenoid content

Total carotenoid contents of the jackfruit puree, steamed dough and fried crackers were determined according to the modified method of Mondal et al. (2013) [13]. Sample (1 g) was stirred in 20 mL of 80% acetone, followed by centrifugation at 3500 rpm for 10 min. Supernatant was transferred to a 100 ml volumetric flask. The carotenoid remaining in the residue was re-extracted following the same steps and the supernatant was combined with the supernatant obtained from the first extraction step. The procedure was repeated until the residue was colorless. The volume of supernatant in the flask was made up to 100 ml with 80% acetone. The absorbance was recorded at 480 and 510 nm against blank. The total carotenoids content was calculated as:

$$\text{mg carotenoids/g sample} = 7.6(A.480) - 1.49(A.510) \times \frac{V}{1000 \times 10}$$

where A is absorbance of the specific wave length, and V is the final volume of carotenoids in 80% acetone.

F. Statistical analysis

Data was analyzed using one-way ANOVA and Tukey's test using Minitab version 16 (State College, PA, USA). Statistical significance was indicated at the 95% confidence level.

III. Results and Discussion

A. Volume expansion ratio of fried crackers

The degree of expansion is one of the most important attributes in cracker production as it reflects of the structure of product and eventually determines the texture of crackers. In general, for all starch type, decreasing level of jackfruit significantly ($p<0.05$) improved volume expansion of fried crackers from 2.84 - 3.79 cm^3 at 50% (w/w) jackfruit to 4.39 - 4.66 cm^3 at 30% (w/w) jackfruit level (Fig. 1). At lower jackfruit content, there was simultaneous increase in starch content. Starch has been reported to play a major role in regulating the expansion of starch-based snack products [4]. The starch content of jackfruit is very low (0.5-5.1%) [9], hence it is suggested that even at high level of jackfruit, it may not play significant role in the expansion of product. Therefore, it was assumed that the expansion ratio was primarily attributed to the added cassava and sago starches.

Combining both sago and cassava starches in the cracker production resulted in the highest expansion ratio at both 50% (4.66 cm^3) and 30% (3.79cm^3) jackfruit levels. Lower expansion ratio were observed in crackers made with sago or cassava starches alone, in which, cassava at 50% jackfruit level exhibited slightly higher expansion than that of sago-based crackers. This was in agreement with previous study [1] that reported fish crackers made with cassava starch had greater expansion than those made by sago starch. It is suggested that the lower amylose content of cassava starch perhaps led to higher swelling of starch granules [1] during steaming, thus induced greater expansion during frying process. The improvement of expansion in crackers made with blend of sago-cassava perhaps was attributed to the alteration of amylose-amylopectin ratio which affected gelatinization such as degree of swelling, solubility and retrogradation characteristics of the starches.

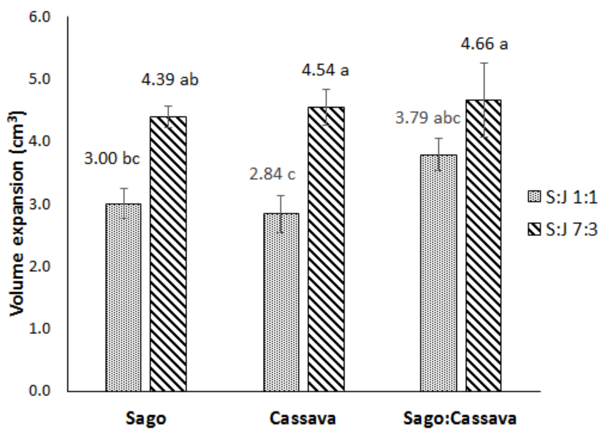

Fig. 1 Effects of different level of jackfruit and type of starches on volume expansion ratio of fried crackers. S:J indicates starch:jackfruit at the stated ratio.

B. Bulk density of fried crackers

Increasing jackfruit levels from 30 to 50% (w/w) significantly increased bulk density of fried crackers made with all type of starches, ranging from 0.26 to 0.41 g/cm^3 (Fig. 2). Cassava-based crackers exhibited significantly lower bulk density (0.26 g/cm^3) at 30% of jackfruit compared to those made with sago starch (0.35 g/cm3) at similar jackfruit level. On the other hand, samples made with 50% (w/w) sago or cassava starches did not showed significant different in bulk density; crackers made with cassava starch had slightly higher density (0.41 g/cm^3). Similar observation has been reported for rice-based snacks, in which, higher amylopectin starch positively correlated with expansion ratio and negatively with bulk density [14].

Blending the sago and cassava starches at 1:1 resulted in crackers that have lower bulk density compared to those made with sago starch, particularly at 30% jackfruit level. These findings implied that bulk density was negatively correlated with volume expansion of the crackers, suggesting greater degree of expansion perhaps produced higher amount of pores attributed to evaporation of entrapped water during frying, hence reducing the bulk density of product.

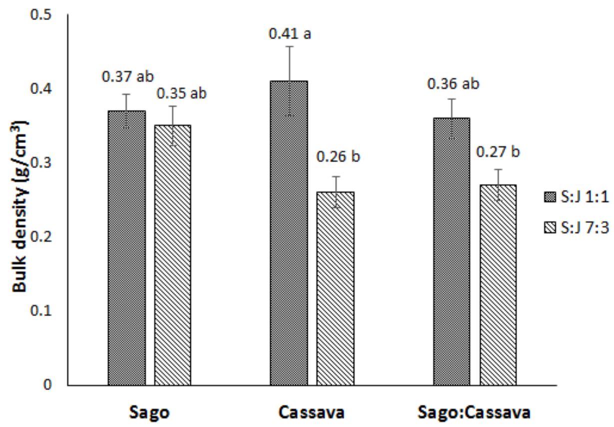

Fig. 2 Effects of jackfruit level and type of starches on bulk density of fried crackers.

C. Color analysis

Color is one of the physical attributes that determines consumer acceptability of crackers. The color of samples was measured across steaming, drying and frying processes. Significant color change was observed at different processing stages (Table 2). Samples made with sago starch alone demonstrated the highest L* (lightness) values (59.6 – 73.4) in comparison to those made of cassava and sago-cassava starches (21.2 – 67.2). In general, most of the samples exhibited significantly ($p<0.05$) lower b* values at 30% of jackfruit compared to those made at 50% jackfruit, perhaps attributed to the yellow color of jackfruit puree due to the presence of carotenoid pigments. On the other hand, the L* values of most the samples at all processing stages were higher at starch to jackfruit ratio of 7:3, implying that starch play a greater role in regulating the lightness of the product. Inconsistent trend was observed for a* (redness) values at various starch types and jackfruit levels.

TABLE II
EFFECTS OF PROCESSING ON COLOR CHARACTERISTICS (L* A* B*) OF STEAMED, DRIED AND FRIED JACKFRUIT-STARCH CRACKERS.

Process	S1:1	S7:3	C1:1	C7:3	SC1:1	SC7:3
	L* values					
Steaming	70.23	73.37	57.51	66.52	59.79	67.24
Drying	65.71	66.54	54.68	55.91	56.38	63.67
Frying	59.97	59.55	57.01	62.93	53.35	51.15
	a* values					
Steaming	4.64	2.38	8.80	7.40	8.26	4.73
Drying	8.56	4.31	11.99	4.44	10.17	2.66
Frying	8.39	2.81	7.36	0.52	16.63	1.56
	b* values					
Steaming	52.71	48.01	44.50	45.16	47.70	42.10
Drying	46.40	40.57	42.65	35.64	42.11	39.32
Frying	34.21	25.59	38.34	24.60	36.01	25.03

*S: sago starch; C: cassava starch; SC: sago-cassava starches at 1:1 ratio. The ratio indicates ratio of starch to jackfruit.

The L* and b* values of all samples regardless of starch type and jackfruit level decreased following the order of steaming > drying > frying. The a * values showed inconsistent trends across the processing line. Darker color was observed when the samples were dried and fried, particularly in samples containing higher level of jackfruit, as indicated by lower L* values at 50% jackfruit. The behaviour was perhaps attributed to the presence of reducing sugars (9.1-14.1%) in jackfruit [9] that induced Maillard reactions during the high temperature process.

D. Carotenoids content

Fig. 3 shows the total carotenoid contents of steamed dough and fried crackers made with 50% (w/w) of jackfruit. The jackfruit puree used in this study contains 0.094 mg/100g of total carotenoids. The total carotenoid contents in steamed dough were in the range of 0.006 to 0.031 mg/100g. Since there was 50% (w/w) of jackfruit incorporated into the formulation, and the jackfruit was measured based on one gram of sample, it can be assumed that the total carotenoid contents of the steamed dough was only slightly lower. Frying the samples led to significant increase of the total carotenoids (0.060 to 0.199 mg/100g), implying a 1.9 to 14.3 times increase. Similarly, Azizah et al. (2009) [15] reported an increase (2-4 times) in β-carotene content of fried pumpkin, indicative of enhanced availability of the carotene with thermal treatment.

Greater increment in carotenoids was observed in fried crackers made with sago-cassava followed by those made with cassava starch, while sago-based crackers has the lowest enhancement of carotenoids following the frying process. The increase in carotenoids content with frying was perhaps attributed to the absorption of carotenoid from the palm oil along with the oil uptake and the enhanced availability of carotenoid following the thermal treatment. It has been reported that all-trans carotenoids were retained in fried samples during the frying process [16]. In addition, the starches could have different ability for oil uptake, in which, cassava starch may contribute to higher oil uptake, hence greater carotenoid absorption.

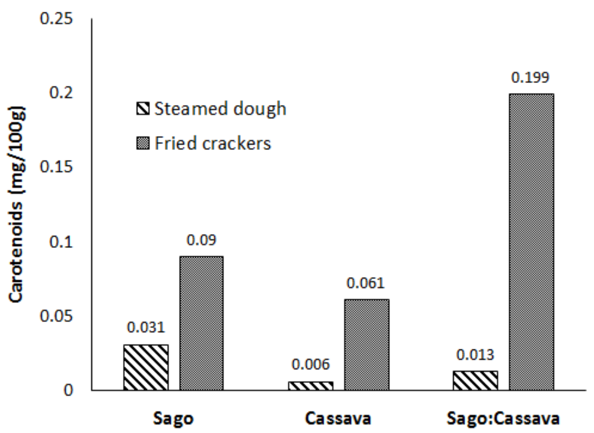

Fig. 3 Effects of steaming and frying on carotenoids contents of jackfruit-starch dough and crackers at 50% (w/w) jackfruit level.

IV. Conclusions

Jackfruit level and starch type significantly influenced the physicochemical characteristics of the half-product (dried) and fried crackers. Greater expansion ratio and lower bulk density obtained in crackers containing higher percentage of starch. Blending sago and cassava starches resulted in improvement of expansion ratio and bulk density. Higher level of jackfruit resulted in yellowish products, while starch level affected the lightness of product. Darker color resulted following drying and frying partly attributed to Maillard reactions. Total carotenoids of cried crackers increased following frying process attributed to oil uptake and enhancement of carotenoids with thermal treatment. A jackfruit level of 30% (w/w) made with blend of sago and cassava starches (1:1) produced fried crackers with the most acceptable physicochemical characteristics.

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