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List of Contributed Paper

Sessions I: Food Bioactives and Health

EFFECTS OF BANANA, EDIBLE CANNA AND MODIFIED HIGH FIBER STARCHES ON FUNCTIONAL PROPERTIES OF FRIED RICE CRACKERS

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Abstract:

Rice and rice products are generally known to have a relatively high starch digestion rate and consequently high glycemic index (GI). Resistant starch (RS) has received much attention for both its potential health benefits (similar to soluble fiber) and functional properties. Rice flours in fried rice crackers were substituted by RS-rich starches from various sources. These included two natural sources (raw banana and edible canna starches) and two commercial modified high fiber starches (Brand A and B). The substitution levels were 15, 20 and 30 g/100g dry solid. Functional properties of the rice crackers were examined including starch digestion rate, and GI values were estimated by a rapid in-vitro enzymatic digestion assay. Physical properties including texture and oil uptake were also evaluated. It was found that all RS-rich starches improved starch digestion properties of the rice crackers, reducing the rate of digestion and lowering the GI values. The higher RS content led to lower GI values. Substitution of all RS-rich starches at 30 g/100g dry solid reduced the GI values of the products from high (GI ≥ 70) to medium levels (GI = 55-69). The effects of banana and edible canna on starch digestibility were either comparable or better than commercial modified starches. Comparing among all the RS-rich starches, banana starch was found to be the best in terms of lowering the glycemic response. However, RS-rich starches affected the texture of rice crackers as they increased the hardness of the products. They also induced the oil uptake providing higher lipid content in rice crackers. This study suggests that RS-rich starches may be used as GI-lowering ingredients in rice products but care must be taken as they also induce changes in physical properties of the products.

Introduction:

Rice is one of the most important cereal crops and is a staple food in Asia. Many products are also derived from rice. However, it is generally known to have a relatively high glycemic index (GI) compared to other starchy foods. It has been reported that GIs of rice ranged from 54 – 121 [1]. Physicochemical and metabolic properties of rice and rice products are influenced by numerous factors. One of these factors is amylose content, which is often used to predict starch digestion rate, blood glucose and insulin responses to rice. Starchy foods that are rich in amylose content are associated with lower GI values. Apart from amylose, resistant starch (RS) has recently received much attention for both its health benefits and functional properties. It positively influences the functioning of the digestive tract, microbial flora, the blood cholesterol level, the GI and assists in the control of diabetes [2].

The rate of starch digestion in foods, and consequently their GIs, can be altered by several techniques. These may involve the modification of key functional ingredients [3,4], using low or no calorie sugars[5], formation of starch lipid complexes[6] or applying processing techniques e.g. heat-moisture treatments or using less degree of polishing of milled rice. As RS positively influences starch digestion rate, therefore, RS-rich foods generally exhibit low GI values. This research aimed to examine the effects of RS-rich starches in order to lower the GI values of rice products. Fried rice crackers were used as a case. The selected RS-rich starches were obtained from various sources. These included two natural sources (raw banana and edible canna starches) and two commercial modified high fiber starches (Brand A and B). They have been reported to contain relatively high in RS [4].

Materials and Methods:

Raw banana and edible canna starches were supplied from Duong Dai Co., Ltd. (Vietnam). Modified starch (Brand A), high-fibre modified corn starch, was purchased from National Starch (Thailand) Co., Ltd. This product is derived from high amylose corn starch. The supplier labeled a minimum 60 g/100g dry sample total dietary fibre. Modified starch (Brand B), high-fibre modified tapioca starch, was purchased from T-fibre Innovation Co., Ltd. (Thailand). The supplier labeled a minimum of 40 g/100g dry sample total dietary fibre. Rice flours and other ingredients including palm oils for producing fried rice crackers were purchased locally from commercial products. All chemicals used were AR grade purchased from RCI Labscan (Thailand) Co., Ltd. All enzymes were obtained from Sigma-Aldrich (Singapore).

Rice flours in fried rice crackers were substituted by RS-rich starches, raw banana, edible canna, modified starches brand A and B. The substitution levels for each starch were 15, 20 and 30 g/100g dry solid. Control samples were produced from normal recipe without substitution. Refined palm oils were used for frying process. Functional properties of the rice crackers were examined. RS, non-RS and total starch (TS) fractions were determined by the Megazyme RS assay kit (Megazyme International, Ireland). Starch digestion rate and estimated GI values were determined using a rapid in-vitro enzymatic digestion assay [7]. Briefly, about 0.5 g of ground sample was treated with artificial saliva containing porcine α-amylase (Sigma A-3176 Type VI-B) before pepsin (Sigma P-6887; pH 2.0) was added and incubated at 37°C for 30 min in a reciprocating water bath. The digesta was neutralized with NaOH before adjusting the pH to 6 (sodium acetate buffer) prior to the addition of pancreatin (Sigma P1750) and AMG (Sigma A-7420). The mixture was incubated for 4 hr, during which the glucose concentration in the digesta was measured with the glucometer (Gluco Dr AGM 3000, Korea) at specific periods (0, 10, 20, 30, 45, 60, 90, 120, 150, 180, 210 and 240 min). Digested starch was calculated and the digestogram (digested starch at a specific time period) was modeled as described in detail elsewhere [8]. The hydrolysis index (HI) of each sample was calculated by dividing the area under its digestogram by the area under the digestogram of a fresh white bread, which was calculated to be about 13,000 min g/100g dry starch from 0 – 240 min. The single-point measurement of starch digestion at 90 min (H_{90}) in the samples was also used to calculate GI values. The average GI (GI_{AVG}) for each sample was defined as the average of GI_{H90} and GI_{HI}.

Physical properties including texture and oil uptake were also evaluated. Oil uptake was determined as residual oils extracted three times for 15 min under agitation with 10 mL of hexane, rinsed and desolventized at room temperature. Product texture, which was expressed as hardness values, was measured by the TA-XT2 texture analyser using a compression mode.

Results and Discussion:

RS, non-RS and TS fractions of the fried rice crackers are shown in Table 1. Digestibility properties including model parameters and GI values as influenced by substitution levels are shown in Table 2. While Table 3 shows the digestibility as affected by starch types (only 30 g/100g substitution level was selected).

It can be seen that the addition of most RS rich starches increased the RS content of rice crackers, except in Brand B, which showed no significant difference. Comparing among all selected starches, banana starch seems to be the best (Table 3). Unripe banana was considered the RS-richest nonprocessed food with more than 10% RS, which could vary with genotype and environment [2]. In this study, the natural source starches were found to be either comparable or better than modified commercial sources. Unripe or green banana could represent an alternative source of indigestible carbohydrates and its starch can be used as a functional ingredient in starchy foods. Processing can also cause an increase or decrease in the RS fraction depending on the process conditions and postprocess handling. The formation of RS was found in frying of potatoes [9]. In terms of digestibility, the presence of the high RS starches reduced the rate of starch digestion in rice crackers to show the beneficial effects of the substitution. This also translated to the reduced GI values in the substituted products. The more RS content the lower the GI values. Therefore, the results were obvious in banana starch. Similar trend was observed in canna starches. In this study, both natural source starches were better in a decrease of the GI values of the products than commercial starches. For the GI values, foods classified as high (70 and above), medium (56 – 69) and low (55 and under). Although the substituted rice crackers still exhibit medium to high GI values, the rice crackers substituted with the edible canna and unripe banana starches provided the lowest GI values compared to the control, and the commercial starches. Banana and canna starches were reported to successfully enhance the nutritional properties in starchy foods [4, 10], and the results obtained in the present study were consistent with the general trend. The results were also remarkable because banana and edible canna were locally available in Thailand.

Table 1. Resistant starch (RS), non-resistant starch (non-RS) and Total starch (TS) fractions of the fried rice crackers substituted with different types and contents of starches

Samples	RS (g/100g dry sample)	Non-RS (g/100g dry sample)	TS (g/100g dry sample)
Control	$1.06^{d} \pm 0.04$	$39.03^{a} \pm 0.72$	$40.09^{d} \pm 0.68$
Banana 15	$2.63^{c} \pm 0.20$	$39.81^{a} \pm 2.27$	$42.02^{c} \pm 0.68$
Banana 20	$3.90^{a} \pm 0.18$	$39.95^{a} \pm 0.68$	$43.95^{b} \pm 0.68$
Banana 30	$3.34^{b} \pm 0.26$	$36.29^{a} \pm 2.29$	$45.88^{a} \pm 0.68$
Control	$1.06^{b} \pm 0.04$	$39.03^{a} \pm 0.72$	$40.90^{a} \pm 0.68$
Canna 15	$1.50^{a} \pm 0.02$	$37.28^{a} \pm 2.74$	$38.78^{a} \pm 2.77$
Canna 20	$1.52^{a} \pm 0.05$	$41.42^{a} \pm 0.60$	$42.96^{a} \pm 0.66$
Canna 30	$1.60^{a} \pm 0.01$	$40.44^{a} \pm 0.47$	$42.04^{a} \pm 0.54$
Control	$1.06^{b} \pm 0.04$	$39.02^{ab} \pm 0.72$	$40.09^{ab} \pm 0.07$
Brand A 15	$1.78^{ab} \pm 1.02$	$35.47^{b} \pm 1.76$	$37.25^{b} \pm 2.78$
Brand A 20	$2.68^{a} \pm 0.30$	$45.29^{ab} \pm 2.57$	$47.97^{ab} \pm 0.79$
Brand A 30	$2.96^{a} \pm 0.06$	$47.09^{a} \pm 1.00$	$50.45^{a} \pm 1.00$
Control	$1.06^{a} \pm 0.04$	$39.03^{a} \pm 0.72$	$40.09^{a} \pm 0.68$
Brand B 15	$1.53^{b} \pm 0.12$	$38.67^{b} \pm 1.45$	$40.20^{a} \pm 1.33$
Brand B 20	$1.54^{b} \pm 0.02$	$36.12^{c} \pm 1.59$	$37.66^{c} \pm 1.61$
Brand B 30	$1.60^{b} \pm 0.15$	$36.79^{c} \pm 1.40$	$38.40^{b} \pm 1.55$

Values are mean ± SD.
For each starch type (column), values with the same letters are not significantly different ($p>0.05$).
These apply to all tables at where they appear.

Table 2. Starch digestibility, model parameters and GI values of the fried rice crackers substituted with different types and contents of starches

Samples	D_0 (g/100g dry sample)	D_∞ (g/100g dry sample)	K (min^{-1})	GI_{AVG}
Control	$3.73^{b} \pm 0.02$	$82.1^{b} \pm 2.97$	$11.9^{a} \pm 0.71$	$90.55^{a} \pm 0.46$
Banana 15	$8.30^{a} \pm 1.89$	$100^{a} \pm 0.35$	$5.42^{b} \pm 0.35$	$82.05^{b} \pm 0.57$
Banana 20	$6.22^{ab} \pm 0.46$	$100^{a} \pm 0.01$	$3.08^{c} \pm 0.98$	$68.37^{c} \pm 0.26$
Banana 30	$6.25^{a} \pm 1.90$	$100^{a} \pm 0.32$	$2.85^{c} \pm 0.01$	$67.30^{c} \pm 0.07$
Control	$3.73^{a} \pm 0.02$	$82.1^{b} \pm 2.97$	$11.9^{a} \pm 0.71$	$90.55^{a} \pm 0.46$
Canna 15	$5.06^{a} \pm 0.25$	$100^{a} \pm 0.35$	$6.52^{b} \pm 0.04$	$85.19^{b} \pm 0.06$
Canna 20	$5.61^{a} \pm 1.63$	$100^{a} \pm 0.01$	$6.19^{b} \pm 0.74$	$84.03^{b} \pm 2.39$
Canna 30	$5.12^{a} \pm 0.14$	$100^{a} \pm 0.32$	$3.02^{c} \pm 0.11$	$67.90^{c} \pm 0.79$
Control	$3.73^{ab} \pm 0.02$	$82.1^{b} \pm 2.97$	$11.9^{a} \pm 0.71$	$90.55^{a} \pm 0.46$
Brand A 15	$7.78^{a} \pm 1.25$	$100^{a} \pm 0.35$	$5.16^{b} \pm 0.14$	$80.61^{b} \pm 0.18$
Brand A 20	$6.10^{ab} \pm 0.27$	$97.7^{a} \pm 4.89$	$4.68^{b} \pm 2.07$	$69.38^{c} \pm 0.71$
Brand A 30	$5.95^{ab} \pm 0.74$	$100^{a} \pm 0.32$	$3.19^{b} \pm 0.08$	$68.90^{c} \pm 0.49$
Control	$3.73^{b} \pm 0.02$	$82.1^{b} \pm 2.97$	$11.9^{a} \pm 0.71$	$90.55^{a} \pm 0.46$
Brand B 15	$7.84^{a} \pm 1.25$	$100^{a} \pm 0.35$	$6.55^{b} \pm 0.01$	$86.65^{b} \pm 0.51$
Brand B 20	$6.87^{a} \pm 0.27$	$100^{a} \pm 3.32$	$5.63^{b} \pm 0.48$	$83.27^{c} \pm 1.59$
Brand B 30	$6.99^{a} \pm 0.74$	$100^{a} \pm 0.32$	$5.59^{b} \pm 0.20$	$82.16^{c} \pm 1.14$

Model equation: $D_t = D_0 + D_{\infty-0}\left(1-\exp\left[Kt\right]\right)$, where D_t is the digested starch at time t, D_0 is the digested starch at time t=0, D_∞ is the digestion at infinite time ($D_0+D_{\infty-0}$), and K is the rate constant. These apply to all tables at where they appear.

Table 3. Starch digestibility, model parameters and GI values of the fried rice crackers substituted with different types of starches at 30 g/100g substitution level

Samples	D_0 (g/100g dry sample)	D_∞ (g/100g dry sample)	K (min^{-1})	GI_{AVG}
Control	$3.73^{c} \pm 0.02$	$82.1^{b} \pm 2.97$	$11.9^{a} \pm 0.71$	$90.55^{a} \pm 0.46$
Banana 30	$6.25^{a} \pm 1.90$	$100^{a} \pm 0.32$	$2.85^{c} \pm 0.01$	$67.30^{c} \pm 0.07$
Canna 30	$5.12^{b} \pm 0.14$	$100^{a} \pm 0.32$	$3.02^{c} \pm 0.11$	$67.90^{c} \pm 0.79$
Brand A 30	$5.95^{b} \pm 0.74$	$100^{a} \pm 0.32$	$3.19^{c} \pm 0.08$	$68.90^{c} \pm 0.49$
Brand B 30	$6.99^{a} \pm 0.74$	$100^{a} \pm 0.32$	$5.59^{b} \pm 0.20$	$82.16^{b} \pm 1.14$

Although, the substitution enhanced digestible properties but it also affected the physical properties of the rice crackers. The oil uptake expressed as residual oils was higher in substituted products than in the control (Figure 1). High oil content was not preferred in deep frying products. Oil uptake in fried foods is a complex process. Most of the oil is absorbed when the food is removed from the fryer, and the product microstructure and surface characteristics, as well as the oil's viscosity, play key roles in affecting the amount of oil uptake [11]. In this study, the substitution may interfere with rice cracker microstructure and enhance the oil absorption. Apart from the oil uptake, textural properties of rice crackers with substitution expressed as hardness values were higher than those of the control (Figure 2). Basically, high amylose starches provided dry and fluffy gel textures while low amylose starches gave moist, chewy and clingy textures after cooking. Amylose positively related to RS. In fried products as shown in this study, the hardness of RS substituted samples tended to be higher than those of the control. Results from published literatures were varied and many factors could affect textural properties of the RS rich products. Cautions should be made for industrial application.

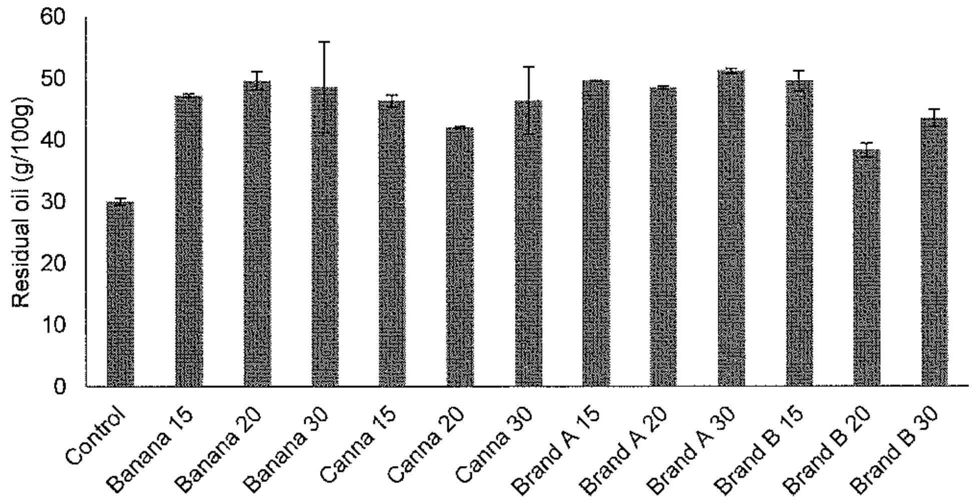

Figure 1. Residual oil content of the samples (Bars show mean and standard deviation values).

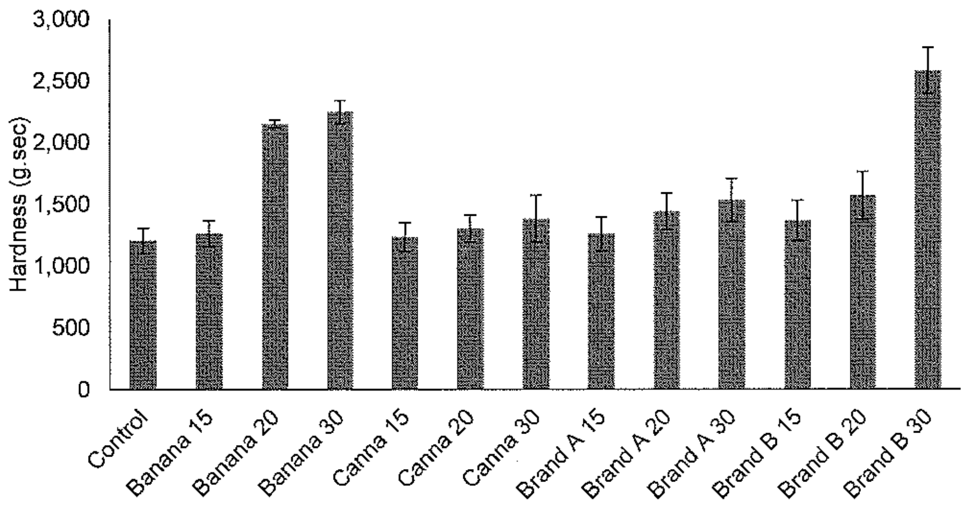

Figure 2. Textural properties (hardness) of the samples (Bars show mean and standard deviation values).

This study concluded that high fiber starches (high RS in this case), specifically unripe banana and edible canna starches, contained significant amount of RS. They also showed the potential to be used as functional ingredients for lowering GIs in starchy food products, fried rice crackers as an example in this study. The inherent characteristics of these starches can help in value addition of these crops and contribute to well-being and food security in the tropical and subtropical regions, where these crops are abundantly grown.

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