

## Effect of replacing wheat flour with coconut flour to carrot cake on *in vitro* starch digestion rate and sensory evaluation

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### Abstract

Thai coconut flour obtained from by-product of the coconut milk industry were utilized as a source of dietary fiber in carrot cake and its effect on starch digestibility and sensory evaluation of modified carrot cakes were evaluated. Replacement rate of coconut flour (CF) were 20, 30 and 40% w/w from a control recipe. *In vitro* starch digestion was studied using the Englyst's method (Englyst *et al.*, 2000) with modification. The glucose released values were recorded at time 0, 20, 60 and 120 min of digestion and converted to available glucose released. Results showed that mean values of released glucose from all levels of replacement at every time point except zero time were significantly less than the control. However, 40%CF replacement had significantly lowest released glucose and also increment area under the curve of released glucose of 120 min (IAUC). There were significantly negative correlations between G20 (released glucose at 20 min), G60, G120 and IAUC with levels of dietary fiber contents. The sensory evaluation was assessed by 31 panelists (19 females, 12 males) with type 2 diabetes at Ramathibodi hospital. It was done for seven attributes like appearance, color, flavor, taste, softness, texture and overall liking using a 9-point hedonic scale. Median values of sensory scores of all the attributes were between 7 and 8 meaning that the modified carrot cakes were evaluated as liked moderately to like very much, and there were no significant differences in the all attributes among the three levels of CF studied. Hence up to 40% of wheat flour can be replaced by coconut flour to produce carrot cake with acceptable sensory quality. Replacing wheat flour with Thai coconut flour in carrot cake, may potentially reduce the glycemic index of the cake to benefit diabetic, as well as non-diabetic individuals.

**Keywords:** coconut flour, dietary fiber, glycemic response, *in vitro* digestion rate, sensory evaluation

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## 1. Introduction

Result from Thai national health examination survey IV (Ministry of public health, 2008–2009) showed that prevalence of types 2 diabetes in population aged over 15 years was 6.9% (3.46 million people). Attention has focused on dietary strategies which target the reduction of postprandial hyperglycemia both as a treatment and possible prevention or delay of diabetic complication (Brand-Miller *et al.*, 2003; Jenkins *et al.*, 1981; Liu *et al.*, 2007; Rizkalla *et al.*, 2004). Most dietary recommendations for diabetic have emphasized with avoid the consumption of quickly digested and absorbed carbohydrates in starchy food which would induce more rapid postprandial glucose response, so low GI food are preferable recommended (Diabetes association of Thailand, 2011). Trinidad *et al.* (2006) showed that coconut flour (solid particle obtained after the extraction of coconut milk or oil from the grated coconut or comminuted fresh coconut meat) is a rich source of dietary fiber and the coconut flour supplement foods could decrease glycemic index (GI) when increasing levels of coconut flour.

The glycemic index (GI) was developed to quantify different postprandial glycemic response induced by different carbohydrate food. Intrinsic and extrinsic factors that alter the rate of gastrointestinal motility, digestion and absorption, and the nature of the starch, cooking method, particle size, and the presence of fiber, fat, and proteins were all found to result in differences in the glycemic index (Krezowski *et al.*, 1986; Throne *et al.*, 1983). The low GI diet had been reported the useful effect on glycemic control in patients with diabetes (Brand-miller *et al.*, 2003), its effect can induce lower postprandial plasma glucose, insulin profiles and improve glycemic control and some lipid profiles in type 2 diabetes (Rizkalla *et al.*, 2004). Studies by Englyst *et al.* showed a high correlation between the rate of starch digestion and the glycemic response by *in vitro* starch digestion method that mimic the *in vivo* situation (Englyst *et al.*, 1996; Englyst *et al.*, 2003).

The use of coconut waste material in the Thai food industry as added-value ingredients has been limited. So, this study aimed to evaluate the potential use of Thai coconut flour, developed from by-product of coconut milk industry that may consist of different chemical composition as a dietary fiber source for developing low GI bakery products which generally have high GI values. Particular attention was focused on whether replacing wheat flour with Thai coconut flour in carrot cakes may lower postprandial glycemia by using *in vitro* starch digestion rate with acceptable sensory quality by sensory evaluation.

## 2. Materials and Methods

### 2.1 Coconut flour preparation

The coconut flour was produced from coconut residue, a by-product of the coconut milk industry at Samut Songkhram province. Coconut residue was dried and ground to have particle size 80–100 mesh by pin mill to produce the coconut flour. Coconut flour was stored in plastic containers at under refrigeration (4°C). The proximate composition of coconut flour were analyzed for moisture (AOAC 925.10, 2005), protein (Nx6.25) (In house method base on AOAC, 2005), fat (In house method base on AOAC, 2005), ash (AOAC 923.03, 2005), carbohydrate (CHO) and dietary fiber (In house method based on AOAC 985.29, 2005).

### 2.2 Selection of carrot cake formula and preparation

Origin formula of carrot cake was selected from various conventional recipes from popular cooking websites and cookbooks. Twenty percentages, 30% and 40% of replacing wheat flour with coconut flour were chosen. The raw materials were purchased from local supermarket and bakery stores in Bangkok area. Wheat flour (Royal Fan, United Flour Mill Public Co., LTD, BKK, Thailand) contained moisture 11.82%, ash 0.37%, protein 8.74%, fat 0.67%, carbohydrate 78.4% and dietary fiber 2.07% were used in this study. Ingredients were whipped in the bowl of a standing mixer (KitchenAid, Professional 600 series, Michigan, USA). Carrot cake was baked at 180°C for 35–40 min. All the cake samples were cooled at room temperature and stored under refrigeration (4°C) in super lock plastic boxes for sensory evaluation and *in vitro* analysis which was done in a day after. All carrot cakes were performed in two replicates for *in vitro* starch digestion analysis.

### 2.3 Determination of potential glycemic response with *in vitro* starch digestion rate

*In vitro* measurement of the glucose released was determined by the method of Englyst (Englyst *et al.*, 2000) with modifications. This procedure measures the glucose released by the action of enzymatic hydrolysis. Samples were analyzed 'as eaten' and mixed to be a homogeneous mixture. The homogenized samples were immediately weighed to 0.4±0.001 g of each sample (weighed should be between 0.2 to 2.0 g depend on the amount of CHO content in each sample, which should less than 0.3 g of CHO) and treated with pepsin to disrupt any starch-protein interactions in a water-bath for 30 min at 37°C. Five glass balls and sodium acetate were added to each tube and placed in the water-bath at 37°C to equilibrate. Then, aliquots of samples were withdrawn and determined at 0 min (T<sub>0</sub>; before adding enzyme solution). The freshly prepared enzyme solution [invertase (A7095, Sigma Chemical Co., St. Louis, USA) to hydrolyse sucrose, pancreatin from porcine pancreas (P1625, Sigma Chemical

Co., St. Louis, USA) and amyloglucosidase from *Aspergillus niger* (A7095, Sigma Chemical Co., St. Louis, USA)] was added and incubated at 37°C in a shaking water bath (secured horizontally). Aliquots were taken at 20, 60 and 120 min intervals and mixed with 66% ethanol. The hydrolyzed glucose content was measured by using the glucose oxidase-peroxidase (GOPOD-FORMAT) assay (K-GLUC, Megazyme Bray, Co., Wicklow, Ireland) by absorbance at 510 nm against the reagent blank. Each sample was analyzed in triplicate. The glucose released (G) were converted to available glucose released as by Englyst's method. The glucose released was expressed as a percentage (g/100 g wet wt of sample) at different times (0, 20, 60 and 120 min) of digestion. Experimental carrot cakes were compared with the control. Data presented were the mean of the two replicates. Increment area under the released glucose curves of 120 min (IAUC) were calculated using the trapezoid rule and ignoring the area beneath the baseline.

#### 2.4 Sensory evaluation of carrot cakes

Sensory evaluation of carrot cake was assessed by 31 panelists with type 2 diabetes at Ramathibodi hospital with questionnaire. The acceptability was evaluated in seven attributes like appearance, color, flavor, taste, softness, texture and overall liking by using a 9-point hedonic scale from 1 (dislike extremely) over 5 (neither like nor dislike) to 9 (like extremely). The carrot cakes were prepared one day before sensory evaluation. On the testing day, carrot cakes were placed at room temperature and cut in 1x1 inch per piece and placed on dish for sensory test. The test samples were labeled with three-digit number code selected from a random number table and served three samples to each panelist. Panelists were asked to rinse their mouth with water between samples.

#### 2.5 Statistical analysis

SPSS version 16.0 (SPSS Inc., Chicago, Illinois, USA) was used. The significant differences in mean values were analyzed by one-way ANOVA using LSD for post-hoc comparison. Correlation of any parameters was analyzed by Pearson's correlation in bivariate correlation. Because there were not normally distributed, the significant differences of sensory scores were performed by non-parametric test with Kruskal-Wallis test. Statistical significance was set at  $p < 0.05$ .

### 3. Results and Discussion

Our coconut flour has nutrient composition different from coconut flour of the study of Trinidad (2006) and Gunathilake (2007) confirmed the concept that coconut flour obtains from different methods has come up with different figures composition (Marquez, 1979), depended on the retention of components after the extraction of coconut milk or oil from scraped/desiccated coconut (Table 1). Our coconut flour has dietary fiber similar to Trinidad but much higher than Gunathilake. Data showed that coconut flour used in this study had dietary fiber 57.9% (or g/100 g of sample), 28 fold greater than fiber in wheat flour (1.7%) and also higher than other flour such as rice flour (2.4%) and oat flour (6.5%) including other dietary fiber sources such as oat bran (8.3%) and flaxseed (28.0%).

**Table 1** Nutrient composition of coconut flour compared with previous studies

Composition	g/100g sample		
	Our study	Trinidad,2006 * (Philippines)	Gunathilake,2008 ** (Sri Lanka)
Moisture	4.1	3.6	4.2
Ash	1.5	3.1	5.96
Protein	3.9	12.1	21.65
Fat	25.5	10.9	8.42
Carbohydrates	65.0	70.3	59.77
Dietary fiber	57.9	56.8	10.45

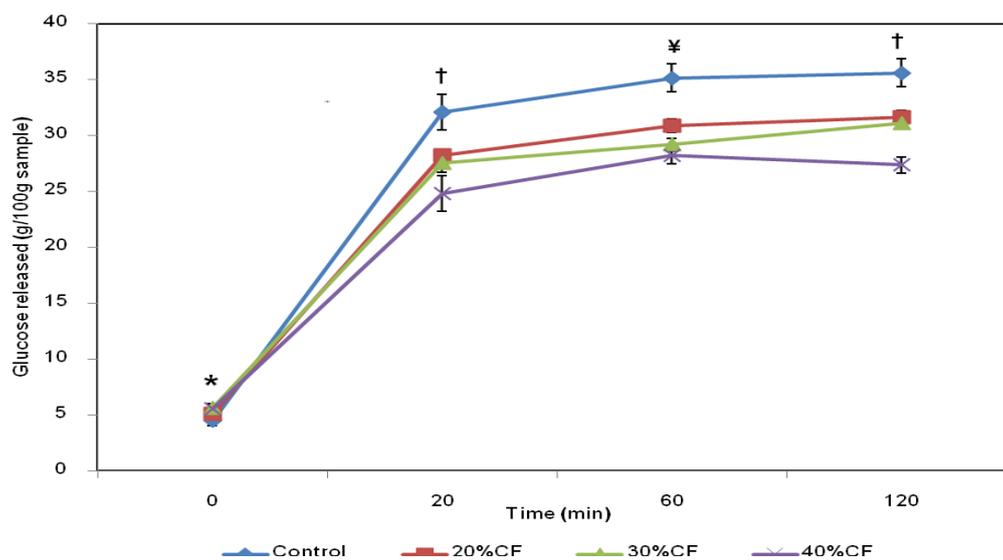
**Note:** \* Coconut flour obtained after extracting coconut milk

\*\* Coconut flour obtained after extracting coconut oil by cold press method

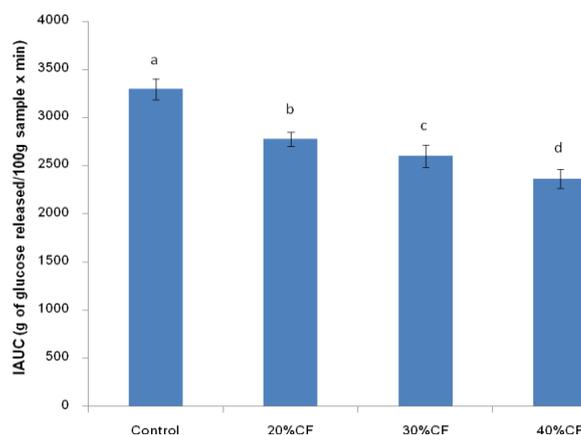
The dietary fiber compositional profile of the control, 20, 30 and 40% CF replaced carrot cakes were 1.46, 3.95, 5.22 and 6.48 g/100g sample, respectively which increased the amount of total dietary fiber content in the carrot cakes gradually. It should be remarked that replacing wheat flour with 40% coconut flour reach fiber content to 6.48 g/100g sample that could claim as high fiber food due to announcement number 182 of Nutrition Fact by Ministry of Public Health that food can claim high fiber should have dietary fiber  $\geq 6$  g/100 g food. The high fiber diets have been recommended for the general population (US Department of agriculture, 2005) and for the nutritional management of patients with type 2 diabetes (American Diabetes Association, 2008).

Figure 1 showed the effect of replacing wheat flour with coconut flour for the modified cake samples on glucose released determined by *in vitro* digestibility compared to the control

(100% wheat flour). Coconut flour exerts a significant reduction in term of glucose release throughout the 120 min starch digestion process ( $p < 0.05$ ). For instance, the 20 and 30% CF replaced samples exhibited non significantly different reduction from each other but significantly from the control, Decreasing 12–14% in glucose released during the time 0–20 min (G20), 12–17% reduction of glucose released up to 60 min (G60) and 11–13% reduction throughout 120 min (G60) whereas 40% CF exhibited significantly lowest values of the glucose released at all-time points (23, 20 and 23% reduction at T20, 60 and 120 min). This fact is further illustrated when the average IAUC for the carrot cake samples were examined (Figure 2), which in turn demonstrated that the replacement of CF significantly reduced overall AUC of the replaced samples in a dose response. Nevertheless, there were significantly negative correlations between G20, G60, G120 and IAUC with levels of dietary fiber content.



**Figure 1** Average glucose released during in vitro digestion of carrot cake samples. Error bars represent standard deviation of 2 replicates. Values with different superscripts are significantly different ( $p < 0.05$ ).



**Figure 2** Average incremental area under the curve values (IAUC) for carrot cake samples as determined using *in vitro* digestion. Error bars represent stand deviation of 2 replicates. Values with different superscripts are significantly different ( $p < 0.05$ ).

In addition, the glucose released at 20 min (G20) also represented the rapidly available glucose (termed by Englyst). The designation of rapidly available glucose is designed to reflect the rate at which glucose (from sugars and starch, including maltodextrins) becomes available for absorption in the human small intestine and found correlation with glycemic response (Englyst *et al.*, 1999). Therefore, replacing wheat four with coconut flour in carrot cake demonstrated the lower glucose released which may potential lower glycemic response. Moreover, the study of Trinidad (2006) showed that coconut flour supplement foods could decrease glycemic index (GI) with increasing levels of coconut flour and this may be due to its high dietary fiber content (60 g/100g similar to our study, 58 g/100g). In ten test foods with coconut flour, the significantly low glycemic index foods ( $\leq 55$ ) investigated were macaroon (GI=45.7) and carrot cake (GI=51.8) which contained 20–25% coconut flour.

Table 2 showed sensory evaluation scores of carrot cake done by 31 patients with type 2 diabetes (19 females, 12 males), target population for our low GI bakery product development. Their mean (SD) age and body mass index were  $59.5 \pm 12.6$  years and  $25.4 \pm 4.3$  kg/m<sup>2</sup>, respectively. Median values of sensory scores of all attribute were between 7 to 8 meaning that the modified carrot cakes were evaluated as liked moderately to liked very much and there were no significant differences in the scores of all attributes among 3 levels of CF. This result revealed that up to 40% replacement of coconut flour is possible to produce carrot cake with acceptable sensory quality. Further work is required to assess glycemic index value and postprandial glucose response of these modified carrot cakes in human study to make low GI products. Moreover it should be try to use coconut flour in other kinds of food to increase utilization of coconut residue from Thai industry for value-added.

**Table 2 Sensory evaluation scores of carrot cake samples**

Sample	Appearance	Color	Flavor	Taste	Softness	Texture	Overall-liking
20% CF	8 (6,8)*	8 (7,8)	7 (6,8)	7 (7,8)	7 (7,8)	7 (7,8)	7 (7,8)
30% CF	7 (6,8)	8 (7,8)	7 (6,8)	7 (7,8)	7 (7,8)	7 (6,8)	7 (7,8)
40% CF	8 (7,8)	8 (6,8)	7 (6,8)	7 (6,8)	7 (6,8)	7 (6,8)	7 (7,8)

**Note:** \* Values expressed as median (25<sup>th</sup>, 75<sup>th</sup> percentile), n = 31

#### 4. Conclusion

The results demonstrated that replaced wheat flour with Thai coconut flour in carrot cake may potential lower glycemic response that also is of benefit for diabetic patients including healthy individuals. This result revealed that up to 40% replacement of coconut flour is possible to produce carrot cake with acceptable sensory quality.

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