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### Reduction of the Glycemic Index in Thai Layer Cakes and Butter Cakes from Sago Flour

Chukkrit Thongkham<sup>1</sup>, Ratchanee Kongkachuichai<sup>2</sup>, Rin Charoensiri<sup>2</sup>, Sunee Sahaspot<sup>3</sup>, Kansuda Wunjuntuk<sup>1</sup>

<sup>1</sup> Department of Home Economics, Faculty of Agriculture, Kasetsart University, Bangkok, 10900, Thailand

<sup>2</sup> Institute of Nutrition, Mahidol University, Nakhon Pathom, 73170, Thailand

<sup>3</sup> Department of Food and Nutrition, Faculty of Home Economics Technology, Rajamangala University of Technology Phra Nakhon, Bangkok, 10300, Thailand

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#### Abstract:

Foods with a low glycemic index (GI) help control blood glucose levels and are associated with a lower risk of adverse health effects. Sago flour is rich in polyphenols and resistant starch, which correlates with a low GI diet. The study developed Thai layer cakes and butter cakes by replacing high-GI flour with sago flour in proportions of 40% to 60%. This is experimental research. The main variable is replacing high-GI flour with sago flour. GI is measured by the *in vitro* method for rapidly available glucose (RAG). The proximate composition of Thai layer cakes had higher fat and ash content and significantly lower carbohydrate content than the standard cake ( $p \leq 0.05$ ). Butter cakes had lower protein content ( $p \leq 0.05$ ) and higher carbohydrate content ( $p \leq 0.05$ ), and sago flour lowered the GI value in cakes from high to low compared with the standard formula. The total polyphenol content and antioxidant activity were higher when replaced by 50% sago flour compared with the standard formula, but without significant difference ( $p > 0.05$ ). Sensory evaluation was most acceptable when replaced with 50% sago flour. Sago flour has significant antioxidant activity, and its use in cake formulations may increase antioxidant activity, particularly in butter cakes. The results suggest that the ORAC method may not be suitable for detecting the antioxidant activity of Thai layer cakes. Using sago flour as an alternative ingredient may benefit individuals with diabetes or health-conscious individuals. Replacing 50% of cassava starch with sago flour in Thai layer cakes and 50% of wheat flour with sago flour in butter cakes reduced the GI from medium to low and high to medium. The levels of polyphenols and antioxidant activity remained unchanged after substitution.

**Keywords:** butter cakes, glycemic index, food, sago starch, Thai layer cakes.

### 使用西米粉降低泰国千层蛋糕和黄油蛋糕的血糖指数

## 摘要:

低血糖指数(胃肠道)的食物有助于控制血糖水平,并降低不良健康影响的风险。西米粉富含多酚和抗性淀粉,这与低升糖指数饮食有关。研究通过以40%至60%的比例用西米粉替代高胃肠道面粉,开发出泰式千层蛋糕和黄油蛋糕。这是实验研究。主要变量是用西米粉代替高胃肠道面粉。胃肠道通过快速有效葡萄糖(抹布)的体外方法测量。与标准蛋糕相比,泰国千层蛋糕的近似成分具有更高的脂肪和灰分含量,并且碳水化合物含量显着降低( $p \leq 0.05$ )。与标准配方相比,黄油蛋糕的蛋白质含量较低( $p \leq 0.05$ ),碳水化合物含量较高( $p \leq 0.05$ ),西米粉将蛋糕的GI值从高降低到低。与标准配方相比,用50%西米粉代替时,总多酚含量和抗氧化活性较高,但差异不显著( $p > 0.05$ )。当用50%西米粉代替时,感官评价最为可接受。西米粉具有显着的抗氧化活性,其在蛋糕配方中的使用可以增加抗氧化活性,特别是在黄油蛋糕中。结果表明,奥拉克方法可能不适合检测泰国夹心蛋糕的抗氧化活性。使用西米粉作为替代成分可能有益于糖尿病患者或注重健康的人。在泰式千层蛋糕中用西米粉代替50%的木薯淀粉,在黄油蛋糕中用西米粉代替50%的小麦粉,将血糖指数从中降至低,从高降至中。取代后多酚和抗氧化活性的水平保持不变。

**关键词:** 黄油蛋糕、血糖指数、食品、西米淀粉、泰式千层蛋糕。

## 1. Introduction

The majority of Thai and Western snacks are primarily made of flour, sugar, and fat (butter, margarine, or shortening). The primary cause of non-communicable diseases (NCDs) such as obesity, type 2 diabetes, coronary heart disease, and cancer is excessive consumption of these substances due to their high glycemic index (GI).

It is advised to follow a gastrointestinal diet to lower these health risks by slowing down the breakdown of carbohydrates and letting the circulatory system absorb the broken-down glucose. Previous research (Amano et al., 2007; Frost et al., 1998; Jenkins et al., 1987b; Ma et al., 2006) has demonstrated the advantages of a low-GI diet, including control of blood glucose, blood insulin, and blood lipid profiles in healthy adults and patients with type II diabetes and hypertriglyceridemia (Amano et al., 2007; Frost et al., 1998; Jenkins et al., 1987b; Ma et al., 2006). Causative factors for a low-GI diet include high fiber content, complex carbohydrates, and resistant starch. In addition, a diet with a low GI increases the feeling of satiety, reduces cravings, and increases the fermentation of indigestible carbohydrates in the colon (Jenkins et al., 1987a; Raben et al., 1994). These health benefits may be crucial for preventing NCDs.

Sago flour is obtained from the stem of the sago palm (*Metroxylon sagu* Rottb.), a plant native to Southeast Asia. The main areas of sago palm cultivation include Malaysia, Indonesia, Papua New Guinea, and Thailand (provinces: Nakhon Si Thammarat, Phatthalung, Songkhla, Pattani, Yala, and Narathiwat) (Ehara et al., 2018; Sriroth et al., 1999). Sago flour has a higher carbohydrate content (84.7 g/100 g) than wheat flour (77.3 g/100 g) and is composed of 24%–31% linear polymer amylose and 73% branched polymer amylopectin (Ahmad et al., 1999; Directorate of Nutrition Ministry of Health, 1979; Ito et al., 1979). Sago flour is also low in calories and fat and may be

suitable for a healthy diet. It also has a low protein content of 0.19–0.25 percent. It is also free of casein and gluten, making it an allergy-free food (Ahmad et al., 1999; Elder et al., 2006).

In addition, due to its composition, sago flour can also be consumed by diabetics because it does not immediately raise blood glucose levels and has a low GI. As a source of dietary fiber, sago flour can reduce the risk of constipation and colon cancer (Karim et al., 2008). Recently, sago-based foods have been developed that are of interest to small and medium enterprises (SMEs) (Hayati et al., 2014) and have an indirect impact on farmers' economies. In many snack products such as white bread, biscuits, and cookies, 30%–40% of wheat flour has been replaced by sago flour without compromising quality or texture (Haryanto & Pangloli, 1992; Konuma et al., 2012).

Despite its traditional use and potential as an industrial food, little has been done in Thailand to modernize sago flour extraction or improve village-level technologies. There is considerable potential to expand and improve traditionally produced value-added products based on sago flour and to market these products to a broader consumer base to create income and employment opportunities.

This study focused on the partial replacement of high-GI flours, including cassava flour and wheat flour, with sago flour in Thai layer cakes and butter cakes, respectively, to investigate the quality and quantity of physiochemical properties, proximate composition, and consumer acceptability. The health-promoting properties were analyzed *in vitro*, including GI, antioxidant capacity, and total polyphenols.

## 2. Materials and Methods

### 2.1. Sago Flour and Snack Ingredient Preparation

Sago flour was obtained from a sago palm

processing factory in Nakhon Si Thammarat, Thailand, and transported in a dark plastic bag in a tightly sealed box to the Department of Home Economics at the Faculty of Agriculture, Kasetsart University. The sample was stored at 4°C and analyzed within 3 months.

For Thai layer cakes, the ingredients are cassava flour, rice flour, arrowroot flour, sugar, and coconut milk. For butter cakes, the ingredients are wheat flour, butter, condensed milk, sugar, egg, baking powder, the EC25K emulsifier, vanilla extract, and salt. All ingredients were purchased from the local market. All reagents and chemicals used in the studies were of analytical grade.

## 2.2. Preparation of the Samples

### 2.2.1. Selection of Standard Formulas for Thai Layer Cakes and Butter Cakes

Using a randomized complete block design (RCBD), we evaluated the sensory quality of Thai layer cakes and butter cakes using 60 tasters. They assessed appearance, color, smell, taste, texture, and general preference using a 9-point hedonic scale. Our goal was to determine the ideal amount of sago flour to substitute for cassava starch and wheat flour in the cakes.

After initial trials, it was evident that using over 60% sago flour negatively affected the cakes' properties. Consequently, we selected three basic formulas: 40%, 50%, and 60% sago flour for Thai layer cakes and butter cakes (Tables 1 and 2). The cakes' overall acceptability was evaluated using the 9-point hedonic scale, and those with the highest scores were chosen for further analysis.

Table 1. Four treatments of Thai layer cakes, replacing cassava flour with sago flour (The authors)

Ingredients	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Cassava flour	200 grams	120 grams	100 grams	80 grams
Sago flour	0%*	80 (40%)*	100 (50%)*	120 (60%)*
Arrowroot flour	105	105	105	105
Rice flour	20	20	20	20
Cane sugar	500	500	500	500
Coconut milk	1,000 ml	1,000 ml	1,000 ml	1,000 ml

\* Percentage of replacing cassava flour with sago flour

Table 2. Four treatments of butter cakes, replacing wheat flour with sago flour (The authors)

Ingredients	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Wheat flour	380	228	190	152
Sago flour	0%*	152 (40%)*	190 (50%)*	228 (60%)*
Baking powder	7	7	7	7
Cane sugar	300	300	300	300
Salted butter	350	350	350	350
Whole milk	240	240	240	240
Egg	300	300	300	300
EC 25 K	40	40	40	40
Vanilla powder	5	5	5	5
Lemonade	30	30	30	30

\* Percentage of replacing cassava flour with sago flour

### 2.2.2. Sensory Evaluation

This study was approved by the Human Research Ethics Committee of the Faculty of Agriculture, Kasetsart University, Thailand, under approval number KUREC-HS64/053.

Sixty students from the Food and Nutrition Program, Faculty of Home Economics Technology, Rajamangala University of Technology Phra Nakhon, participated in the sensory test and rated the appearance, color, odor, taste, texture, and overall liking using a 9-point hedonic scale ranging from 1 for extreme dislike to 9 for extreme liking. The samples were coded with three-digit random numbers, and the order of presentation was determined by random permutation.

## 2.3. Analysis of the Proximate Compositions

All determinations were performed in triplicate. The proximate compositions were expressed as percentages of dry weight (DW). Moisture, total ash, crude protein, crude fat, and total dietary fiber contents were determined using an in-house method inspired by the guidelines set forth by the Association of Official

Analytical Chemists (AOAC) (1990) and a previous study by Wunjuntuk et al. (2022).

The method of moisture analysis is based on measuring the mass of water in a known sample mass by analyzing the mass of a sample before and after the water has been removed by evaporation (AOAC 920.39).

Ash is an inorganic residue from the combustion of organic material. The total ash content is a useful parameter for determining the nutritional value of many foods. Ash content is determined from the loss in weight due to volatilization of organic matter when the sample is completely oxidized at a high temperature ( $550 \pm 5^\circ\text{C}$ ) in a muffle furnace (AOAC 923.03).

Crude protein was quantified using the Kjeldahl method and calculated from total nitrogen multiplied by 6.25 (AOAC 981.10)

Crude fats are the crude mixture of fat-soluble material present in a sample, e.g., triglycerides, diglycerides, monoglycerides, phospholipids, steroids, free fatty acids, fat-soluble vitamins, carotene pigments, chlorophyll, and other substances dissolved in fat. The

crude fat contained in a portion of food was determined by extracting the fat from the sample using petroleum ether as a solvent and then calculating the lipid content of the sample. The result is expressed as a percentage of the initial sample weight after the extracted fat has been dried and weighed (AOAC 991.43).

Total dietary fiber (TDF) was determined enzymatically (AOAC 985.29) on dried and defatted material. TDF content was calculated by deducting the weight of protein and ash from the weight of the filtered and dried residue.

Total carbohydrates were calculated by subtracting moisture, fat, protein, ash, and TDF from 100%.

#### 2.4. GI Determination

The GI was analyzed using *in vitro* rapidly available glucose (RAG) according to the method of Englyst et al. (1999). Briefly, 0.3-0.8 g of the samples were weighed and placed into a 50-mL screw cap tube, and 5-mL pepsin solution was added. The tubes were sealed, and the contents were mixed with a vortex and placed in a water bath at 37°C for 30 min to allow hydrolysis of the proteins by pepsin. Then, 10 mL of 0.1 mol sodium acetate/L (equilibrated to 37°C) was added. Five glass beads were added, and a 2.5-mL enzyme mixture (invertase, pancreatin, and amyloglucosidase) was added. The tube was immediately sealed, and the contents were gently mixed by inverting before being placed horizontally in a 37°C shaking water bath. Each tube was removed from the bath precisely 20 min after the addition of the enzyme mixture and 200 µL of the contents were added to 4 mL of 66% ethanol and vortexed to stop hydrolysis. This mixture was then portioned into G<sub>20</sub>. The tube was placed back in the shaking water bath immediately after sampling. After another 100 min (120 minutes incubation), another 200 µL was added to 4 mL of 66% ethanol and shaken. This step was the G<sub>120</sub> portion. The glucose content of RAG and SAG was determined using the glucoseoxidase-peroxidase kit and calculated as follows (Eq. 1).

$$\% \text{ Glucose (RAG)} = \frac{A_t \times V_t \times C \times D_{as} \times W_t \times 1,000}{1,000 \times 100} \quad (1)$$

RAG - rapidly available glucose at 20 min (G<sub>20</sub>)

SAG - slowly available glucose (G<sub>120</sub>-G<sub>20</sub>)

A<sub>t</sub> - absorbance of the test solution

V<sub>t</sub> - total volume of the test solution

C - standard concentration of glucose (mg/mL)

A<sub>s</sub> - absorbance of the standard

W<sub>t</sub> - weight of the sample

D - dilution factor

% RAG value at 20 min (G<sub>20</sub>)

% SAG value at 120 min (G<sub>120</sub>) – at 20 min (G<sub>20</sub>)

This study focuses on the measurement of RAG in food, which is an *in vitro* method that reflects the glycemic response observed in human studies (Englyst et al., 1999). When a test sample has a high percentage of RAG, it suggests a potentially high GI value for that sample. This simple *in vitro* measurement of RAG and SAG holds physiological significance and can be used

to investigate the impact of carbohydrate quantity, type, and form in the diet on overall health outcomes.

#### 2.5. Determination of the Polyphenol Content

The polyphenol content was analyzed using the Folin-Ciocalteu colorimetric method. In brief, 0.2 mL of the sample extract was mixed with 2.5 mL of deionized water and 0.2 mL of Folin-Ciocalteu phenol reagent. Then, 2 mL of a 7% Na<sub>2</sub>CO<sub>3</sub> solution was added. After 90 min of the reaction at room temperature, the absorbance was determined at 765 nm. The measurement was compared with a standard curve of a prepared gallic acid (GA) solution, and the total phenolic content was expressed in milligrams of gallic acid equivalent (GAE) per 100 g of the samples.

#### 2.6. Determination of Antioxidant Activities

##### 2.6.1. Determination of Ferric Ion-Reducing Antioxidant Power (FRAP)

The assay to determine the ferric ion-reducing antioxidant power (FRAP) is based on electron transfer (ET) to the free radical and measures the antioxidant capacity by changing the color of the solution when the free radical has been reduced. FRAP was analyzed according to the method of Benzie and Strain (1996). Briefly, 0.3 mL of the sample extract was added to 3 mL of mixtures of FRAP and then allowed to stand at room temperature for 30 min. The absorbance was measured at 593 nm. Triplicate measurements were performed. The results are expressed in micromole Trolox equivalents (TE) per 100 g of the samples.

##### 2.6.2. Determination of Oxygen Radical Antioxidant Capacity (ORAC)

The assessment of the oxygen radical antioxidant capacity (ORAC) is a method of evaluating the ability of antioxidants in blood or plasma to remove free radicals by hydrogen atoms. ORAC was analyzed according to the method of Ou et al. (2001). Briefly, 25 µL of the sample extract was added to a 96-wells plate and 150 µL/well fluorescein with 25 µL of AAPH [2,2'-diazobis (2-amidinopropane) dihydrochloride] solution was added to all 96-well plates. Fluorescence was immediately measured at an excitation wavelength (ex) of 485 nm and an emission wavelength (em) of 530 nm using a microplate fluorescence reader. The results are expressed in micromole TE per 100 g of the samples.

#### 2.7. Statistical Analysis

An RCBD with three replicates was used in this experiment. The results were calculated as the mean (X), which was analyzed using analysis of variance (ANOVA). The difference between the means was compared at the 0.05 confidence level using Duncan's new multiple range test (DMRT) and analyzed with a statistical program.

### 3. Results and Discussion

#### 3.1. Sensory Evaluations of the Basic Formulas for Thai Layer Cakes and Butter Cakes

Based on the acceptability ratings for appearance, color, odor, taste, texture, and overall liking, formula one of the Thai layer cakes had the highest score and was significantly higher than formulas two and three. Therefore, formula one of the Thai layer cakes was selected as the base formula for further experimentation.

For butter cake, the sensory evaluation results showed that formula one had the highest scores for appearance, color, texture, and overall liking and was significantly higher than formulas two and three ( $p \leq 0.05$ ). However, there were no significant differences in odor and taste scores among the three butter cake formulas ( $p > 0.05$ ). Butter cake formula one was used as the base formula for further experiments.

#### 3.2. Sensory Evaluations of the Developed Thai Layer Cakes and Butter Cakes

The results show that the appearance and color of the Thai layer cake in which cassava flour was replaced with 50% sago flour had the highest score and was significantly higher than the 40% and 60% sago flour substitutes ( $p \leq 0.05$ ), while there was no significant difference from the basic formula (0% sago flour). In terms of acceptability of odor, taste, texture, and overall liking, the Thai layer cake in which cassava flour was replaced with 40% sago flour had higher acceptability scores than the Thai layer cake with 40% and 60% sago flour, but there was no significant difference ( $p > 0.05$ ). Therefore, the Thai layer cake with 50% sago flour instead of cassava flour was selected to determine the proximate composition, RAG, SAG, total polyphenol content, and antioxidant capacity.

There were no significant differences in appearance acceptability between the basic formula (0% sago flour) and the butter cakes in which wheat flour was replaced with forty-, fifty- and sixty-percent sago flour ( $p > 0.05$ ). However, the acceptability of appearance showed the highest score for the basic formula (0% sago flour) ( $8.17 \pm 0.46$ ), followed by the butter cakes from 50% ( $8.15 \pm 0.76$ ), 40% ( $8.05 \pm 0.91$ ), and 60% ( $7.93 \pm 0.73$ ) sago flour. In color acceptability, the results show that the butter cake from 40% sago flour instead of wheat flour had the highest score ( $8.27 \pm 0.69$ ), followed by the butter cakes from 60% ( $7.95 \pm 0.72$ ) and 50% ( $7.83 \pm 0.81$ ) sago flour. In addition, a formulation of the butter cake from 40% sago flour instead of wheat flour showed no significant differences from the basic formula ( $8.40 \pm 0.49$ ) with a  $p$ -value greater than 0.05. For odor acceptability, the butter cake from 60% sago flour had the highest score on the 9-point scale ( $8.10 \pm 0.73$ ), followed by the butter cakes from 50% ( $7.95 \pm 0.77$ ), 40% ( $7.82 \pm 0.81$ ), and 0% sago flour (the basic formula,  $7.80 \pm 0.55$ ). However, there was no significant difference between the butter cakes from 60% and 50% sago flour ( $p > 0.05$ ). In terms of taste

acceptability, the basic formula had the highest score ( $8.02 \pm 0.60$ ), followed by the butter cakes from 40% ( $7.95 \pm 0.85$ ), 50% ( $7.83 \pm 0.87$ ), and 60% sago flour ( $7.65 \pm 0.84$ ). However, there was no significant difference ( $p > 0.05$ ) between the basic formula and butter cakes from 40% and 50% sago flour. In terms of texture and overall liking acceptability, the basic formula had the highest scores ( $8.22 \pm 0.72$ ;  $8.30 \pm 0.59$ ), followed by the butter cakes from 40% ( $8.03 \pm 0.88$ ;  $8.03 \pm 0.78$ ), 50% ( $7.78 \pm 0.80$ ;  $7.90 \pm 0.71$ ), and 60% ( $7.68 \pm 0.87$ ;  $7.87 \pm 0.75$ ) sago flour. However, there was no significant difference between the butter cakes from 40% and 50% sago flour ( $p > 0.05$ ). Therefore, the butter cake in which wheat flour was replaced by 50% sago flour was selected for further analysis.

In a study by Sumardiono et al. (2022), artificial rice was created using 50% sago flour. Notably, the cooked artificial rice received positive feedback from consumers regarding its color, texture, aroma, and taste.

#### 3.3. Proximate Compositions of Sago Flour and the Developed Thai Butter Cake and Butter Cake from Sago Flour

##### 3.3.1. Proximate Composition of Sago Flour

The proximate composition of sago flour showed that it contains 15.44% moisture content, 0.14% fat, 0.15% protein,  $< 0.10\%$  total dietary fiber, 0.30% ash, and 83.97% carbohydrate.

Previous studies have shown that sago flour contains 0.2% ash, 0.1% lipid, and 0.1% protein (Swinkels, 1985). Ahmad et al. (1999), who analyzed the proximate composition of 11 samples of sago flour, found the content of 10.6%-20.0% moisture, 0.06%-0.43% ash, 0.10%-0.13% fat, 0.26%-0.32% dietary fiber, and 0.19%-0.25% protein. Other studies have shown that sago flour has low contents of minor components such as protein ( $\sim 0.3\%$ ), lipids ( $\sim 0.1\%$ ), dietary fiber ( $\sim 0.3\%$ ), and ash ( $\sim 0.4\%$ ) (Karim et al., 2008). Konuma et al. (2012) found that sago flour has a moisture content of 13.1%, ash of 0.19%, fat of 0.01% and protein of 0.04%. These findings indicate that sago flour is high in carbohydrates but low in calories and fat, whereas its protein content is low and free of casein and gluten, making it suitable as a healthy ingredient and an allergy-free food.

##### 3.3.2. Proximate Compositions of Thai Layer Cakes and Thai Layer Cakes from Sago Flour

The average percentages of fat, protein, total dietary fiber, ash, and carbohydrate in the Thai layer cakes were 17.30, 1.83,  $< 0.18$ , 0.55, and 80.32 by dry weight, respectively. When cassava starch was replaced with 50% sago flour, the average percentages of fat, protein, total dietary fiber, ash, and carbohydrates were 18.56, 1.90,  $< 0.18$ , 0.60, and 78.94 by dry weight, respectively. Thai layer cakes from 50% sago flour had significantly higher fat and ash content and significantly lower carbohydrate content than Thai layer cakes

( $p \leq 0.05$ ), as shown in Table 3.

Table 3. Proximate compositions of Thai layer cakes and Thai layer cakes from sago flour (The authors)

Nutrient g/100 g (dry weight)	Thai layer cake	Thai layer cake from 50% sago flour	p-value sig. (2-tailed)
Fat	17.30 ± 0.04	18.56 ± 0.02	0.00
Protein	1.83 ± 0.04	1.90 ± 0.03	0.056
Total dietary fiber	<0.18	<0.18	-
Ash	0.55 ± 0.03	0.60 ± 0.04	0.026
Carbohydrate	80.32 ± 0.01	78.94 ± 0.04	0.00

In studies by Dudu et al. (2019) and Lu et al. (2020), cassava flour was found to have a fat content ranging from 0.6% to 0.8%, which is higher than the fat content observed in sago flour in our study. In addition, Dudu et al. (2019) reported that cassava flour had an approximate carbohydrate content of 82%, which is similar to the carbohydrate content observed in our proximate analysis of sago flour. These findings further support the inherent differences in fat and carbohydrate content between cassava flour and sago flour, emphasizing the impact of ingredient choice on the proximate composition of food products.

### 3.3.3. Proximate Compositions of Butter Cakes and Butter Cakes from 50% Sago Flour

The average percentages of fat, protein, total dietary fiber, ash, and carbohydrates in the butter cakes were 33.47, 7.06, < 0.14, 1.24, and 58.23 by dry weight, respectively. For butter cakes from 50% sago flour, the average percentages of fat, protein, total dietary fiber, ash, and carbohydrate were 33.31, 5.41, < 0.14, 1.22, and 60.06 by dry weight, respectively. The butter cakes from 50% sago flour showed a significant decrease in protein content ( $p \leq 0.05$ ) and an increase in carbohydrates ( $p \leq 0.05$ ), as shown in Table 4. The results of this study are related to the chemical and physical compositions of Boonying et al. (2009), who found that the nutritional value of wheat flour is characterized by a higher fat content and lower carbohydrate content than those of sago flour.

Table 4. Proximate compositions of butter cakes and butter cakes from sago flour (The authors)

Nutrient g/100 g (dry weight)	Butter cake	Butter cake from 50% sago flour	p-value sig. (2-tailed)
Fat	33.47 ± 0.06	33.31 ± 0.05	0.128
Protein	7.06 ± 0.03	5.41 ± 0.03	0.00
Total dietary fiber	<0.14	<0.14	-
Ash	1.24 ± 0.04	1.22 ± 0.04	0.582
Carbohydrate	58.23 ± 0.07	60.06 ± 0.06	0.001

### 3.4. GI Determination

The Englyst method was used to assess *in vitro* carbohydrate digestibility and allowed for the amounts of RAG and SAG (Englyst et al., 1996, 1999). The method is based on the measurement of glucose released from a test food during time-limited incubation with digestive enzymes. Englyst et al. (2003) showed that the GI of 23 starchy cereal products was positively correlated with RAG ( $r^2=0.54$ ) and negatively correlated with SAG ( $r^2=0.63$ ). The RAG content was low ( $\leq 15.0$  g/100 g) to medium (16.0-24.0 g/100 g), which can be interpreted as low-GI to medium-GI.

Sago flour was digested to glucose during the first 20 min. RAG was 0.93 g/100 g, which is in the low GI range (RAG *in vitro*  $\leq 15.0$  g/100 g). GI was below 55.

The remaining carbohydrates in sago flour were digested to glucose 100 min or 2 h later. The glucose was digested after 120 min. SAG was 13.56 g/100 g, which can be further digested into glucose in the body. These results can cause a long-lasting feeling of satiety. However, this analysis shows that sago flour should have a low GI, which is related to an earlier study by Haska and Ohta (1992) showing that sago flour has a resistant ability to starch-digestive enzymes. Sago flour has been reported to contain a high proportion of linear amylase (Ahmad et al., 1999), which tends to retrograde and recrystallize, resulting in extensively ordered areas that are resistant to starch-digestive enzymes. Sago flour is probably ideal for the development of healthy food (Table 5).

Table 5. GI of sago flour, snacks, and snacks from sago flour (The authors)

Snacks	Mean ± SD		GI
	RAG	SAG	
Sago flour	0.93 ± 0.04	13.56 ± 0.19	Very low
Thai layer cakes	17.35 ± 0.22	5.34 ± 0.23	Medium
Thai layer cakes from sago flour	14.71 ± 0.24	7.47 ± 0.29	Low
Butter cakes	24.73 ± 0.10	3.74 ± 0.16	High
Butter cakes from sago flour	21.54 ± 0.19	5.19 ± 0.17	Medium

The Thai layer cakes were digested to glucose during the first 20 min. The RAG was 17.35 g/100 g, falling within the medium GI range (RAG *in vitro* 16.0-24.0 g/100 g). Starch content (carbohydrates) can still

be further digested into glucose in the body. Glucose was digested at 120 min. SAG was 5.34 g/100 g. The Thai layer cakes were expected to have a medium GI. The GI was 55-70. Eggum et al. (1993) reported that

amylose-lipid complexes were not digestible in the small intestine of rats. The complex consists of more crystallites (Biliaderis & Galloway, 1989). The complete crystal structure may render it less susceptible to enzymatic degradation. Mercier et al. (1980) observed that pure potato amylose and oleic acid complexes are highly resistant to enzymatic degradation. The primary ingredients of Thai layer cakes are cassava starch, sugar, and coconut milk, which cause them to be resistant to enzymatic degradation.

The RAG content of Thai layer cakes with cassava starch replaced with sago flour is measured at 14.71 g/100 g, while the SAG content is 7.47 g/100 g. These values fall within a low GI range, with the RAG *in vitro* being less than or equal to 15.0 g/100 g. The GI was less than 55. Thai layer cakes with cassava starch replaced with sago flour have a lower GI than Thai layer cakes. Tongdang and Meenun (2005) found that sago flour had a higher amylose content than cassava starch. It was found that sago flour had 22.86% amylose, while cassava starch had 17.44% amylose; the amylose content of the starch mixture containing cassava starch and sago flour at concentrations of 6%, 12%, 18%, and 24% of sago flour was found to be 17.89%, 18.35%, 19.80%, and 20.26%, respectively, indicating that the amylose content tended to increase as the content of sago starch increased.

A previous study reported that the amylose content in sago flour ranges from 21.7% to 31%. On the other hand, cassava starch has 15%–18% amylose content, which is much lower than that of sago flour (Noomhorm & Tokiwa, 2006; Tongdang et al., 2008). In addition, Yamasaki et al. (2007) conducted an animal study using different amylose-containing diets (medium and high). The glycemic response of the experimental animals fed a high-amylose diet was lower than that of the animals fed an intermediate-amylose diet. Consequently, foods with a high amylose content can lead to a lower glycemic response or GI. According to the results of another study, if the amylose content is high, starch has a slower rate of digestion and lower GI (Behall et al., 1988, 1989; Frei et al., 2003; Hu et al., 2004). Amylose content is inversely related to the GI, and high amylose content has a lower GI (Foster-Powell et al., 2002). As a result, the Thai layer cakes from 50% sago flour had a lower GI than the Thai layer cake's primary formula.

Butter cakes had a high GI estimated to be in the excellent range of 70 or more because the starch or carbohydrates were digested to glucose in the first 20 min. The RAG content was 24.73 g/100 g, which fell into the high glycemic range (RAG *in vitro* > 24.0 g/100 g). The RAG of butter cakes with wheat flour replaced with sago flour was 21.54 g/100 g, falling within the medium GI range (RAG *in vitro* 15.0–24.0 g/100 g). GI was 55–69. Starch content (carbohydrates) remains in high amounts, which can be further digested into glucose in the body. Glucose was digested at 120 min. The SAG of butter cakes was 3.74 g/100 g, and the

SAG of butter cakes with wheat flour replaced with sago flour was 5.19 g/100 g, which can be further digested into glucose in the body. The GIs of Thai layer cakes from sago flour and butter cakes from sago flour may be significantly reduced by the genotype with a high amylose content of sago flour (amylose content in sago flour in this study was 34.75%) under commonly used food processing conditions. Linear amylose molecules tend to retrograde and recrystallize, resulting in extensively ordered regions resistant to enzyme digestion and absorption in the small intestine. In addition, the enzyme accessibility of high-amylose starch is further hindered by incomplete gelatinization and slight swelling of starch granules during processing (Schwall et al., 2000).

Foods with a low-medium GI are effective as an alternative food for people with diabetes or those who want to lose weight. Because it is a food that is digested and absorbed slowly by contact with the L-cells of the distal small intestine, it produces the hormone GLP-1 (Jenkins et al., 1989; Vollmer et al., 2008). GLP is a digestive tract hormone with hypoglycemic action by inducing insulin secretion that responds to elevated glucose levels. GLP-1 is a glucose-dependent insulin secretion hormone that inhibits glucagon secretion. However, glucose levels were normal, and GLP-1 did not stimulate insulin secretion. Therefore, it does not cause hypoglycemia. GLP-1 is also essential in helping pancreatic  $\beta$ -cells to be more efficient. In addition, Behall et al. (1988, 1989) and Frei et al. (2003) found that starches with high amylose content were negatively correlated with glucose levels and slowed food movement in the intestines. As a result, it feels full for longer than low-amylose starch. It had a beneficial effect on diabetic patients because the carbohydrates in starch are digested and absorbed slowly, thus helping to maintain blood sugar levels in people with diabetes. It also stimulates the activity of the hormone insulin because of the gradual increase in glucose (Behall et al., 1989; Hu et al., 2004).

### 3.5. Polyphenol Content Determination

The polyphenol content of sago flour was determined using the Folin-Ciocalteu colorimetric method and compared to the standard gallic acid. The results showed that sago flour contained 56.83 mg of GAE per 100 g. Sungpud et al. (2019) reported the biological characteristics of the sago palm at three growth stages: Stage 1 (6–7 years old), Stage 2 (8–9 years before flowering), and Stage 3 (flowering antlers older than nine years). The findings revealed that during the second stage, sago palm had a maximum phenolic content of  $133.57 \pm 22.89$ -mg GAE/100 g and the highest percentage of antioxidant ( $62.60 \pm 11.21$ ). Sago flour obtained during Stages 1 and 2 is white, whereas sago flour from Stage 3 is slightly pinkish-white. The difference in the color of sago flour may be due to the oxidation of phenolic compounds present in the flour, resulting in a pink. Karim et al. (2008) reported similar findings, indicating that flour extracted from immature

sago palms displayed a white appearance. As the sago palm reaches the flowering stage, the powder derived from it will exhibit a pink due to the increased production and accumulation of phenolic compounds as the stems age.

In this study, the sago flour used may be from sago palm stage 1, as indicated by its white and limited polyphenol analysis. The polyphenol content of Thai

layer cakes and butter cakes with sago flour as a substitute for wheat flour did not significantly differ from cakes made with traditional ingredients ( $p>0.05$ ) (Table 6). This study recommends utilizing sago flour from sago palm stages 2 and 3 for further development due to its elevated phenolic compound content and antioxidant activity. This has the potential to lower the GI of Thai layer cakes and butter cakes.

Table 6. Total polyphenol content of sago flour, snacks, and snacks from sago flour (The authors)

Snacks	Total polyphenol (GAE mg/100 g)	p-value
Sago flour	56.83 ± 1.55	-
Thai layer cakes	10.62 ± 0.32	0.256 <sup>ns</sup>
Thai layer cakes from sago flour	11.12 ± 0.01	
Butter cakes	41.52 ± 1.29	0.093 <sup>ns</sup>
Butter cakes from sago flour	67.08 ± 4.05	

<sup>ns</sup> Different superscript letters within a column indicate that values are not significantly different at the level of  $p>0.05$ .

### 3.6. Antioxidant Activity Determination

The antioxidant activity of sago flour by the FRAP and ORAC methods was 84.55 µmoles TE/100 g and 417.97 µmoles TE/100 g, respectively.

The findings from Table 7 indicate that substituting cassava starch with 50% sago flour in Thai layer cakes resulted in an increase in antioxidant activity, as

measured by the FRAP method, from 7.94 to 12.74 µmoles TE/100 g. Despite this improvement, there was no significant difference ( $p>0.05$ ) in antioxidant activity between Thai layer cakes and those from 50% sago flour using the FRAP method. Antioxidant activity of Thai layer cakes could not be detected by the ORAC method.

Table 7. Antioxidant activity of sago flour, snacks, and snacks from sago flour by the FRAP and ORAC methods (The authors)

Snacks	FRAP (µmoles T.E.)	p-value	ORAC (µmoles T.E.)	p-value
Sago flour	84.55 ± 1.41	-	417.97 ± 21.18	-
Thai layer cakes	7.94 ± 0.23	0.069 <sup>ns</sup>	ND	-
Thai layer cakes from sago flour	12.74 ± 0.51		ND	
Butter cakes	56.17 ± 0.78	0.089 <sup>ns</sup>	250.03 ± 14.79	0.658 <sup>ns</sup>
Butter cakes from sago flour	86.04 ± 5.18		260.91 ± 11.00	

Notes: ND - not detected; <sup>ns</sup> different superscript letters within a column indicate that values are not significantly different at the level of  $p>0.05$ .

In the case of butter cakes, when wheat flour was replaced with 50% sago flour, the antioxidant activity increased from 56.17 to 86.04 µmoles TE/100 g by the FRAP method and from 250.03 to 260.91 µmoles TE/100 g by the ORAC method. However, there was no significant difference ( $p>0.05$ ) in antioxidant activity between butter cakes and those with 50% sago flour using the FRAP or ORAC method.

In summary, this study indicates that sago flour has significant antioxidant activity, and its use in cake formulations may increase antioxidant activity, particularly in butter cakes. The results also suggest that the ORAC method may not be suitable for detecting the antioxidant activity of Thai layer cakes.

## 4. Conclusions

Thai layer cakes have a medium GI, whereas butter cakes have a high GI, which makes them less suitable for consumption by individuals with diabetes or those concerned about their blood sugar levels. High-GI foods, like these cakes, have been associated with an increased risk of type 2 diabetes (Foster-Powell et al., 2002). This study aimed to investigate the potential of using sago flour as a substitute for cassava starch and wheat flour in Thai layer cakes and butter cakes, respectively, to lower their GI. The findings showed

that replacing 50% of cassava starch with sago flour in Thai layer cakes and 50% of wheat flour with sago flour in butter cakes significantly reduced their GI from medium to low and from high to medium, respectively, consistently with the research by Boonying et al. (2009), which demonstrated that sago starch can reduce sugar level in wheat cookies. The implication of this research is that using sago flour as an alternative ingredient may benefit individuals with diabetes or those concerned about their health. However, there are some limitations of this research that this is only an experimental research with 10 experiments to compare, which is fewer in commercial production. Therefore, future research could explore the addition of dietary fiber or polyphenols to further reduce the GI of the cakes.

## Author Contributions

Conceptualization, methodology design, formal analysis, supervision, writing, and project administration, C.T. and K.W.; preparation of samples, proximate composition analysis, statistical analysis, C.T.; sensory evaluation, S.S.; antioxidant activity and polyphenol content analysis, R.K.; GI analysis, R.C. All authors have read and agreed to the published version of the manuscript.

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