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In vitro Starch Hydrolysis Rate, Physico-chemical Properties and Sensory Evaluation of Butter Cake Prepared Using Resistant Starch Type III Substituted for Wheat Flour

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ABSTRACT

Resistant starch type III (RS III) derived from enzymatically debranched high amylose rice starch was prepared and used to make butter cake at different levels (0, 5, 10, 15 and 20%) in place of wheat flour. Physico-chemical properties, sensory evaluation, and *in vitro* starch hydrolysis rate of the developed butter cake were investigated. This study showed that the content of resistant starch in butter cake increased significantly ($P \leq 0.05$) as the level of substitution with RS III increased from 2.1 to 4.4% of resistant starch content. The butter cake with RS III replacement had a significantly lower *in vitro* starch hydrolysis rate compared to the control cake (0% RS III). The rates of starch hydrolysis from 0 to 180 min digestion time for 0, 5, 10 15, and 20% RS III in place of wheat flour in butter cakes were 3.70 to 67.65%, 2.97 to 64.86%, 2.86 to 59.99%, 2.79 to 55.96 and 2.78 to 53.04% respectively. The physico-chemical properties of 5 to 10% RS III substituted with wheat flour in the butter cake were not significantly different from the control cake and were moderately accepted by panellists in the sensory evaluation test.

INTRODUCTION

The use of resistant starch (RS) as a functional food ingredient is of great interest among food manufacturers keen to develop new nutritional food products. RS is described as starch that escapes digestion in the small intestine (Englyst, Kingman & Cummings, 1992; Topping & Clifton, 2001). RS has been classified into four general subtypes called RS I- RS IV (Englyst *et al*.1992). RS can be found naturally in food and its contents vary depending on its botanical source and starch granular structure (resistant starch types I and II). In addition, RS could also be produced from retrogradation of gelatinised starch known as resistant starch type III (RS III). RS III, a product of the starch retrogradation process, has been reported to cause a reduction in glycemic response due possibly to increased resistance to digestive enzymes (Frei, Siddhuraju & Becker, 2003; Pongjanta *et al*., 2007).

The food industry is being continually challenged to redesign traditional foods for optimal nutritional value, whilst still maintaining desirable characteristics of appearance, taste and texture. One way to achieve this challenge is to reduce calorie-laden ingredients, especially that of carbohydrates and fat. Most carbohydrate-

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rich food is characterised and dominated by the high-glycemic effect, which has been associated with an increased risk of chronic disease (Barclay *et al*., 2008). Modulating the glycemic response of dietary carbohydrate may offer benefits to those individuals at risk. A reduction in the glycemic response of carbohydrate food appears to be accompanied by a higher content in resistant starch (Bjorck, Liljeber & Ostman, 2000), and RS type III promotes slow to moderate post-prandial glucose and insulin response (Jenkin *et al*., 2002).

The butter cake is a complex fat and water emulsion system containing flour, sugar, fat, eggs and baking powder. A proper combination of these ingredients could give a high quality cake product with desirable flavour and texture (Sahi & Alava, 2003). Cakes are generally well liked by most consumers the world over. However, due to its high glycemic index, over-consumption may contribute to chronic diseases. Foster-Powell *et al*. (2002) revealed that the glycemic indices of cake products vary continuously from about 67 to 87%. This study has been carried out to investigate the effects of using RS III as wheat flour replacement on the physio-chemical properties, sensory evaluation and *in vitro* starch hydrolysis rate of the developed butter cakes.

MATERIALS AND METHODS

Sample preparation

High amylose rice starch (HARS) was supplied by a commercial food manufacturer (Cho Heng Rice Vermicelli Factory Co., Ltd., Nakornpathom, Thailand). Cake flour, shortening, salt, sugar, baking powder, whole eggs, high fructose corn syrup (HFCS-55) and skim milk were purchased from a local market. Pullulanase enzyme from *Bacillus acidopullulyicus* (E.C. 232-983-9P; $\geq$ 400 international units/ml), pepsin (EC 3.4.23.1; 2,980 unit/mg), α-amylase (E.C. 3.2.1.1; 20.4 unit/mg), amyloglucosidase (A-3042; 69.65 unit/mg), glucose assay kit (GAGO-20) and potato amylose were purchased from Sigma Chemical Company, St. Louis, USA. Resistant starch assay kit was obtained from Megazyme International Ireland Ltd. Wicklow, Ireland.

Resistant starch type III formation and determination

Resistant starch type III (RS III) was prepared from enzymatic debranching of high amylose rice starch as described by Pongjanta *et al*. (2008). In brief, the RS III was scaled up (1 litre of starch suspension) prepared by pullulanase hydrolysis (EC. 232-983-9P, 12 unit /g starch at 55 °C for 16 h) of 15% gelatinised high amylose rice starch and followed by one cycle of freeze-thawed process (-10 for 16h /30°C for 3 h). Degree of pullulanase hydrolysis and degree of syneresis as well as the resistant starch content were determined according to Hizukuri (1995), Karim, Norziah & Seow (2000) & AOAC Method (2002) by Resistant Starch Assay kit (Megazyme, Wicklow, Ireland) respectively. The moisture, protein, fat and ash content (%) of the RS III and wheat flour samples were determined according to the AOAC (2002) method. Triplicate tests were conducted for each analysis.

Preparation of butter cake with RS III substituted for wheat flour

According to Gallagher, Gormley & Arendt (2004), baked goods made in part with rice flour tend to be crumbly. In addition, preliminary reports from their study show that the 25% rice starch substituted for wheat flour in the butter cake did not rise during the baking process, which left the final products dense and heavy. Thus, it was decided that 20% of RS III derived from high amylose rice starch was the maximum amount that would be used in butter cake formulation. The RS III was substituted for wheat flour in the cake formulation at levels of 0, 5, 10, 15 and 20%. The control butter cake had no RS III added (0% RS III). The formulation system (100% component) was set at 33.01% wheat flour, 1.34% corn flour, 0.21% baking powder, 13.40% eggs, 16.08% HFCS, 10.72% sucrose, 0.10% salt, and 25.13% butter (Pongjanta *et al*., 2006). The RS III replacement, depending on the percentage substituted, was done in combination with the cream part of the cake formula. The butter cake was prepared according to the creaming method (Nielson, 2002). First, the butter was beaten at speed 6 (medium) with the paddle attachment in a stand mixer (KitchenAid Europa, Inc, Strombeek-Bever, Belgium) for 5 min. Then, sifted wheat flour combined with RS III (depending on % substituted), corn flour, salt, and baking powder were added and mixed for 5 min at speed 6 (medium). Whole eggs were whipped until soft peaks formed and then sucrose and fructose were added to the whole egg bowl and whipped to form moist peaks. The cake batter was then poured into the egg foam part and mixed until all of the foam parts were incorporated into the cake batter. The mixed batter was used to determine the specific gravity of each cake batter. The batter was then placed into a greased 9 x 5" loaf pan and baked for 50 min in a 160°C Hotpoint electric oven (Miller Brothers, South Yorkshire, UK). The cakes were allowed to cool for 3 h and were packed in low-density polyethylene and stored at room temperature for 1 to 4 h prior to physio-chemical analysis, *in vitro* starch hydrolysis rate and sensory evaluation.

Determination of physio-chemical properties of the butter cake

Specific gravity was determined by dividing the weight of a material by the weight of an equal volume of water (AACC, 2000). Cake volume and colour were measured after cooling for 1 h at room temperature. The volumes of cakes was measured using rapeseed displacement and specific volumes were calculated (AACC, 2000). Colour was measured using a Minolta spectrophotometer (Minolta, Japan). The moisture, protein, fat and ash content (%) of the butter cake samples were determined based on AOAC (2002) methodology.

Resistant starch (RS) was determined using a Megazyme Resistant Starch kit (Megazyme, Wicklow, Ireland) according to the AOAC Method (2002). Briefly, the samples were incubated in a shaking water bath with pancreatic α-amylase and amyloglucosidase for 16 h at 37°C to hydrolyse digestible starch to glucose. The indigested RS III was solubilised in 2 M potassium hydroxide in an ice bath, neutralised with 8 ml sodium acetate (1.2 M) and the RS hydrolysed to glucose with the addition of amyloglucosidase (0.1 ml, 3300 Uml^{-1}, 50°C). The Glucose Assay kit (GAGO-20, Sigma Chemical Company, St. Louis, USA.) was used to measure glucose released from the digested starch and the resistant starch. Absorbance was read (510 nm) after a 20-min incubation period at 50°C. Resistant starch (RS) and digested starch (DS) were calculated as glucose x 0.9 (McCleary & Monaghan, 2002). The total starch (TS) was calculated as the sum of resistant starch and digested starch (McCleary & Monaghan, 2002).

In vitro starch hydrolysis rate and hydrolysis index

In vitro starch hydrolysis rate and hydrolysis index were determined according to Goòî, Garãîa & Saura-Calixto (1997). Butter cake samples (50 mg) were incubated with 1 mg pepsin in 10 ml HCl-KCL buffer (pH 1.5) at 40°C for 60 min in a shaking water bath. The digest was diluted to 25 ml by adding Tris maleate buffer (pH 6.9), and then 5 ml of α-amylase solution containing 2.6 IU of α-amylase in Tris maleate buffer was added. The samples were incubated at 37°C in a shaking water bath. 0.1 ml sample was taken from each flask every 30 min from 0 to 3 h and boiled for 15 min to inactivate the enzyme. Sodium acetate buffer (1 ml 0.4 M, pH 4.75) was added and the residual starch digested to glucose by adding 30 ml amyloglucosidase and incubating at 60°C for 45 min. Glucose concentration was determined by using a Glucose Assay kit (GAGO-20, Sigma Chemical Company, St. Louis, USA.). The rate of starch digestion was expressed as the percentage of starch hydrolysed at different times. An equation: $C=C_{\infty}(1-e^{-kt})$ is used to described the kinetics of starch hydrolysis, where C, C_{∞} and k are the concentration at time t, the equilibrium concentration and the kinetic constant respectively. The area under the hydrolysis curve (AUC) was calculated using the equation:

$$AUC = C_{\alpha}\left(t_f - t_0\right) - \frac{C_{\alpha}}{k}\left(1 - e^{-k(t_f - t_0)}\right)$$

where, C_{∞} corresponds to the concentration at equilibrium (t_{180}), t_f is the final time (180 min), t_0 is the initial time (0 min) and k is the kinetic constant. A hydrolysis index (HI) was calculated by comparison with the AUC of a reference food (fresh white bread; Farmhouse from the local supermarket). Goòî, Garãîa & Saura-Calixto (1997) showed this hydrolysis index to be a good predictor of glycemic response. Expected GI was thus estimated using the model: GI= 39.71 + (0.549 ´ HI)(Gooi *et al.*, 1997)

Sensory evaluation

Sensory evaluations were conducted by a total of 30 trained panellists, consisting of Kasetsart University staff and students. The butter cakes were evaluated by these trained panellists based on their appearance, odour, flavors, texture and overall acceptance with the use of the 9-point hedonic scale where 9 indicates 'most liked' and 1 represents 'most disliked' (Lawless and Heymann, 1998).

Experimental design and statistical analysis

Completely randomised design (Smith *et al.*, 2003) was used to evaluate the means of physiochemical analysis of butter cake samples. A randomised complete block design (Smith *et al.*, 2003) was used to evaluate the means of the sensory scores of the butter cake samples. The data obtained for the physic-chemical properties and sensory evaluations were subjected to analysis of variance (ANOVA), followed by Duncan's Multiple Range Test procedure for differences between treatment by using SPSS for Windows Release 12.0.

RESULTS AND DISCUSSION

Physio-chemical properties of RS III and wheat flour

Chemical composition of wheat flour and RS III-formation by enzymatically-debranching at 4.74% degree of hydrolysis and 56.66% degree of syneresis are showed in Table 1. Moisture content, protein, fat and ash content in wheat flour and RS III were 13.50, 7.96, 2.5, 1.4, 0.89, 88.45, 89.34% and 9.45, 1.16, 1.0, 0.9, 20.01, 74.04 and 94.06 % respectively. The resistant starch content of RS III was higher (20.01%) than that for wheat flour (0.89%) which could be attributed to the retrogradation of the high amylose rice starch which has a starch-water ratio of 15:75 (w/w) as explained in a previous work (Pongjanta *et al.*, 2008).

Physical properties of butter cake prepared with RS III substituted for wheat flour

Physical properties of the control butter cake (% RS III) and butter cake with RS III substitution of wheat flour at 5, 10, 15 and 20% are presented in Table 2. The butter cake with 15% and 20% RS III substituted for wheat flour had significantly ($P \leq 0.05$) higher mean specific gravity than that of the 0, 5 and 10% replacement. These results suggest that the 0%, 5% and 10% of RS III replacement have a similar ability to retain air during cake mixing (Baixauli *et al.*, 2008). The results revealed that butter cake with 20% of RS III substituted for wheat flour had a lower specific volume than the 0, 5, 10 and 15% replacement. The greater rising volume

Table 1. Chemical composition of resistant starch type III (RS III) and wheat flour per 100 gram

Samples	*Chemical composition (%)**						
	Moisture	*Protein*	*Fat*	*Ash*	*Resistant starch*	*Digested starch*	*Total starch*
Wheat flour	13.5±1.3	7.96±1.2	2.5±1.01	1.4±0.17	0.89±0.6	88.45±0.2	89.34± 0.4
RS type III	9.45±1.7	1.16±0.7	1.0±0.34	0.9±0.29	20.1±0.7	74.04±0.3	94.06± 0.9

*Means± standard division (*n* = 3)

Table 2. Mean values for specific gravity and colour value of batter and baked butter cakes prepared with RS III substituted for wheat flour at 0, 5, 10, 15 and 20%

RS III replacement (%)	*Batter specific gravity(g/ml)*	*Volume (cm³)*	*Baked butter cakes*					
			*Crust colour**			*Crumb colour**		
			*L**	*a**	*b**	*L**	*a**	*b**
Control (0)	0.65[a]	1833.66[a]	49.81[a]	15.34[c]	34.94[b]	76.27[a]	6.62[ns]	35.42[b]
5	0.69[a]	1832.05[a]	49.45[a]	16.39[b]	35.29[b]	75.99[a]	6.71	36.75[b]
10	0.70[a]	1830.93[a]	49.02[ab]	16.70[b]	35.49[b]	74.96[b]	7.44	36.73[b]
15	0.75[b]	1827.10[b]	48.82[b]	16.69[b]	36.71[a]	74.19[b]	7.45	36.67[b]
20	0.77[b]	1814.00[c]	47.21[c]	17.89[a]	37.08[a]	73.94[b]	7.81	37.88[a]

a,b,c… Means (*n*=3) within the same column with different letters are significantly different (P< 0.05) with ANOVA followed by Ducan's New Multiple Range Test (DMRT).
ns = Not significantly different
* The Hunter *L**, *a** and *b** values correspond to lightness, redness, and yellowness, respectively.

Table 3. Mean values for chemical composition and *In vitro* starch digestibility of butter cakes prepared with RS III substituted for wheat flour at 0, 5, 10, 15 and 20%.

RS III		*Chemical composition (%)*			*In vitro starch digestibility **		
replacement (%)	*Moisture content*	*Fat*	*Protein*	*Ash*	*DS(%dwb)*	*RS(%dwb)*	*TS(%dwb)*
Control (0)	24.06[b]	25.06[a]	12.37[a]	2.65[a]	31.23[a]	1.79[d]	33.03[ns]
5	24.82[ab]	24.96[a]	12.12[a]	2.64[a]	30.84[b]	2.10[c]	32.95
10	25.24[a]	24.89[a]	11.43[a]	2.63[a]	29.97[c]	2.74[c]	32.72
15	25.37[a]	24.76[ab]	11.28[ab]	2.60[a]	28.64[c]	3.91[b]	32.56
20	25.53[a]	24.07[b]	10.84[b]	2.27[b]	27.73[d]	4.44[a]	32.67

a,b,c…. Means within the same column with different letters are significantly different (P>0.05) with ANOVA, followed by Ducan's New Multiple Range Test (DMRT).
ns = Not significantly different
* DS, RS, and TS correspond to digested starch, resistant starch and total starch, respectively.

for the wheat flour cake over the mixed RS III cake probably resulted from the higher ability of gluten to trap CO_2 gas liberated from baking powder (Nielson, 2002). Butter cake crust and crumb colour values displayed significant differences (P≤0.05) at *L* a** and *b** values and treated cakes with RS III replacement had a high yellow index colour compared to the control butter cake (0% RS III). RS III replacement of wheat flour resulted in a darker crust because the reducing end in the debranched high amylose rice starch prior to the RS III formation promotes Maillard browning reaction (Pongjanta *et al*., 2008).

Chemical composition of butter cake prepared with RS III substituted for wheat flour

The moisture, fat, protein, and ash content as well as *in vitro* starch digestibility of butter cake samples prepared by RS III substituted for wheat flour at 0, 5, 10, 15 and 20% are shown in Table 3. An increase in moisture content was observed, ranging from 24.06 to 25.53% in tandem with the increased percentage of RS III (0 to 20%) substituted for wheat flour. The higher moisture content of the cake crumb of the cakes whose wheat flour portion was part replaced by RS III was apparently caused by the higher water-holding capacity of RS III. Crosby (2003) reported that resistant starch (RS III) derived from amylomaize VII absorbed much more water (water-holding capacity of 2.5 ml/g) as compared to wheat flour (0.5 ml/g). A butter cake formulated with 0 to 15% of RS III substituted for wheat flour showed no significant difference (P0.05) in fat, protein and ash content which was 24.76–25.06%, 11.28–12.37%, and 2.60–2.65 % respectively. However, a 20% RS III replacement for wheat flour was found to be significantly (P≤0.05) lower in fat, protein and ash content than the other treatments. This was because RS III has lower protein, fat and ash (1.16%, 0.88% and 0.81%) than wheat flour (7.45%, 1.18% and 0.98%), as shown in Table 3.

The butter cake with RS III substituted for wheat flour had a significantly (P≤0.05) lower amount of digested starch (DS) which could be due to the substitution of the RS III fraction for the wheat flour. The DS content in 0, 5, 10, 15 and 20% RS III treatment were 31.23, 30.84, 29.97, 28.64 and 28.73 respectively. As hypothesised, resistant starch (RS) content in RS III-butter cake (5 - 20% replacement) was markedly higher than in the control butter cake. RS content in butter cake increased significantly (P≤0.05) as the level of RS III addition increased, ranging from 2.10 to 4.40% of RS content. This showed that RS III contributes significantly to the final content of RS III in butter and this confirms that the baking process does not alter this indigestible component (Crosby, 2003).

***In vitro* starch hydrolysis rate and hydrolysis index**

The average hydrolysis curves of butter cakes prepared with RS III substituted for wheat flour are depicted in Figure 1. The corresponding hydrolysis rate, the hydrolysis index and the glycemic index are summarised in Table 4. White bread, used as reference, showed a hydrolysis rate of about 76.76% after 180 min, which is comparable with the values reported by Goòî *et al.* (1997). The hydrolysis rate was markedly slower for the 10 to 20 % RS III substituted for wheat flour in the butter cake but was faster for the control butter cake, which contained 100% wheat flour. Replacement of wheat flour with RS III in the butter cake seems to affect the susceptibility of glucose released in starch composition of the butter cakes (Brown, 2004). The starch hydrolysis rates from 0 to 180 min digestion time for 0, 5, 10 and 15% RS III substituted for wheat flour in the butter cake were 3.70 to 67.65%, 2.97 to 64.86%, 2.86 to 59.99%, 2.79 to 55.96 and 2.78 to 53.04% respectively.

Starch hydrolysis index (HI) of each butter cake was obtained by using the Area

Table 4. Area under curve (AUC), hydrolysis index (HI) and glycemic index (GI) value from butter cakes prepared with RS III replacement for wheat flour at 0, 5, 10, 15 and 20%.

RS III replacement(%)	*AUC**	*HI(%)*	*GI value **(%)*
Control (0)	1667.84± 7.27[c]	59.30 ± 4.30[c]	74.93 ± 6.45[b]
5	1417.84± 3.69[c]	50.41 ± 3.61[c]	69.65 ± 5.16[c]
10	1347.23± 3.59[d]	47.90 ± 4.03[d]	68.16 ± 3.85[d]
15	1258.34± 9.27[e]	44.74 ± 3.84[e]	66.16 ± 4.59[c]
20	1225.32± 8.54[f]	43.57 ± 4.17[d]	65.58 ± 3.21[c]
RS III	711.76± 5.66[g]	25.31 ± 4.31[f]	54.74 ± 2.65[d]
White bread	2812.47±13.34[a]	99.89 ± 2.89[a]	99.04 ± 4.99[a]

a,b,c… Means within the same column with different letters are significantly different (P<0.05) with ANOVA, followed by Ducan's New Multiple Range Test (DMRT).

Table 5. Mean sensory scores of butter cakes prepared with RS III replacement for wheat flour at 0, 5, 10, 15 and 20%.

% RS III replacement	*Sensory scores*					
		Texture		*Flavour*		
	Colour appearance	*Moist-ness*	*Tender-ness*	*Sweetness*	*Aroma*	*Overall liking*
Control (0)	7.20[a]	6.63[ns]	6.85[ns]	6.40[ns]	5.86[b]	6.53[b]
5	6.40[b]	6.73	6.66	6.56	5.66[b]	6.63[b]
10	6.73[b]	6.86	6.75	6.66	6.60[a]	6.83[ab]
15	6.86[b]	6.43	6.83	6.86	6.70[a]	6.96[a]
20	6.40[b]	6.30	6.66	6.76	6.06[a]	6.06[b]

a,b,c… Means within the same column with different letters are significantly different (P< 0.05) with ANOVA, followed by Ducan's New Multiple Range Test (DMRT). Hedonic scale of 1= dislike extremely, 5 = neither like nor dislike, 9 = like extremely (Lawless & Heymann (1998).

ns = Not significantly different

Under Curve (AUC) for the starch hydrolysis rate from 0 to 180 min of the butter cake samples divided by AUC of that for white bread (Goòî, Garãîa & Saura-Calixto, 1997). The butter cakes with RS III replacement had a significantly lower HI than the control butter cake (Table 4). The hydrolysis index of 0, 5, 10, 15 and 20% RS III -replaced for wheat flour-cakes were 59.30%, 50.41%, 47.90%, 44.74% and 43.57% respectively (Table 4). Similarly, significant decreases in glucose or insulin have been reported when the test meal contained over 12 g of resistant starch (Behall, Scholfield & Hallfrisch, 2002).

Estimated glycemic index (GI) value for the 5, 10, 15 and 20% RS III substituted flour in butter cake samples was significantly ($P \leq 0.05$) lower than that for the control butter cake (Table 4). The estimated GI value for 0, 5, 10, 15 and 20% RS III substituted for wheat flour in butter cake samples were 74.93%, 69.65%, 68.16%, 66.16% and 65.58% respectively. Jenkins *et al*. (2002) classified GI values of 70% or more as high, a GI of 56 to 69% as medium, and a GI of 55% or less as low. Thus, the 0, 10, 15 and 20% RS III replacement for wheat flour in the butter cake formula could result in a medium GI butter

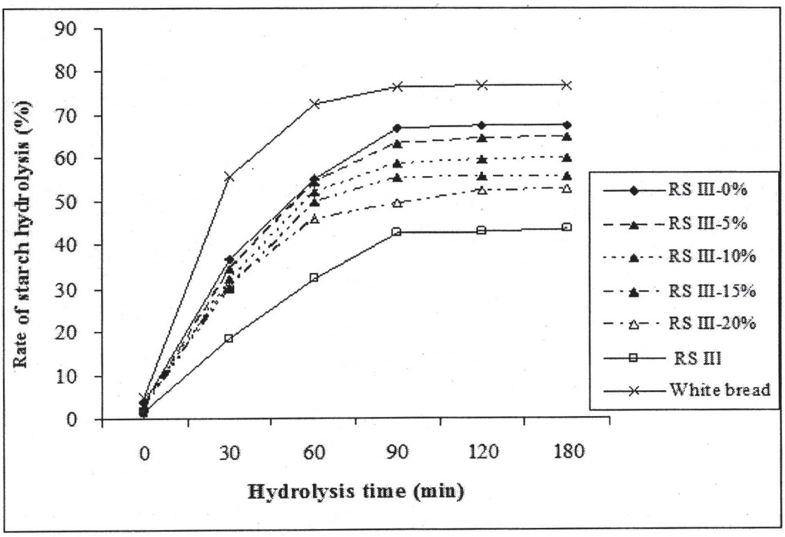

Figure 1. Hydrolysis rate of butter cake prepared with RS III replacement for wheat flour in butter cake at 0, 5, 10, 15 and 20%.

cake product. The control butter cake was classified as a high GI butter cake.

Sensory evaluation

The results of the sensory evaluation of butter cakes prepared with RS III in part replacement of wheat flour is presented in Table 5. Colour appearance scores of the butter cake samples were significantly different ($P \leq 0.05$) at 0, 5, 10, 15 and 20% RS III replacement for wheat flour, which was 7.20, 6.40, 6.73, 6.86 and 6.40 respectively. No differences for moistness (6.30 to 6.93) and tenderness (6.66 – 6.85) were found among the five treated butter cakes. Tenderness scores decreased as the level of RS III substitution increased up to 20%. However, the cakes with 5 to 15% RS III replacement of wheat flour were still considered tender (sensory scores of between 6.66 and 6.86). Non-significant differences for sweetness were found among the butter cake treatments. The control butter cake was found to have the lowest score for sweetness (6.40) compared to the other treated cakes. However, butter cake formulations that contained RS III were slightly sweeter than control (0% RS III). The scores for aroma of the butter cakes prepared from 0, 5, 10, 15 and 20% RS III replacement for wheat flour were 5.86, 5.66, 6.60, 6.70 and 6.06 respectively and these were awarded by the panellists. It was found that RS III butter cakes had a typical aroma which was not sour, musty or objectionable (Baixauli *et al.*, 2008). The formulation with the highest (6.96) overall favourable score was the formulation with 15% RS III replacement and it was not significantly different ($P^{3}0.05$) from the 10% RS III replaced butter cake (6.83). The formulation with 5% RS III replacement had the next highest overall score (6.63) but was not significantly different from that of the control. The control cake (0% RS III) and the 20% RS III replacement butter cake had the next overall favourable scores of 6.53 and 6.06 respectively.

CONCLUSIONS

When RS III was used to replace 5- 20% of wheat flour, resistant starch content was increased. At a replacement level of 10% RS III for wheat flour in butter cake, the quality was similar to that of the control butter cake. At higher RS III replacement levels (15 and 20%), the cake volume decreased and texture firmed. The optimum formula for the butter cake was found to be 29.79% cake flour, 3.31% RS III, 16.08% HFCS, 10.72% sucrose, 25.13% butter, 0.21% baking powder, 0.10% salt, 1.34% corn flour and 13.40% eggs. Further studies should be carried out to determine the formula and methods for maximising the amount of RS III without adversely affecting the quality of the butter cake. Furthermore, the possible application of the RS III developed butter cake to diabetic metabolism need further studies, including *in vivo* trials.

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