Development of a Highly Nnutritional and Functional Gluten Free Cupcake with Red Kidney Bean Flour for Older Adults

Pavalee Chompoorat[1,*] and Jakraphong Phimphimol[1]

Abstract

People ranging age 65 and older has increased their life expectancy. Their physical and sensory capabilities have declined which would lead to a high demand for functional foods. Consequently, transgenerational food needs to be created in order to maintain their activities. The aim of this study was to develop a functional cupcake for older adults. In this study, the functional cupcake was developed by using red kidney bean flour as a main ingredient. Proximate composition of red kidney bean flour and nutrition profile of gluten free cupcake were evaluated. In addition, baking properties, texture analysis and sensory test of this gluten free cupcake were also assessed by comparing with commercial gluten free cupcakes. The results showed that the crude protein and crude fiber of red kidney bean flour was greater than wheat flour (50% and 88%, respectively). With a high percentage of protein and fiber of red kidney bean flour, the nutritional value of gluten free cupcake was high in protein (4 g/serving) and fiber (3 g/serving). Moreover, functional and commercial gluten free cupcake had no significantly difference in overall likeness from sensory evaluation ($p > 0.05$). Consuming only one serving of this cupcake could obtain 8% Daily Intake of protein. In conclusion, this bakery product could be a good choice to purchase for older adults.

Keywords: Product development, Red kidney bean flour, Gluten free product, Older adult

1. Introduction

Red kidney bean (*Phaseolus Vulgaris* L.) is a crop grown extensively in northern part of Thailand. It is a major source of vegetable protein and dietary fiber as well as other nutrients which required for older adult or people who have over 65 years of age (Drewnowski and Evans, 2001; Lichtenstein, 2017). According to the World Health Organization (WHO), in order to meet the nutritional needs of older adults, healthy legume-based dishes are highly recommended. Red kidney bean is considered to be a gluten free grain with high nutritional value. Thus, red kidney bean could be an alternative food for the older adults as well as celiac patient's and healthy consumer. Nowadays, a number of patients with celiac disease and gluten free consumer have been increased up to 1% of world population (Caruso *et al*., 2013). The study has shown that 26–49% of young Indian population was diagnosed to be this celiac disease (Cataldo and Montalto, 2007). In order to treat this celiac disease, consuming gluten free diet is the only treatment option available at this moment (Vici *et al*., 2016).

[1] Faculty of Engineering and Agro-Industry, Maejo University, Chiang Mai, Thailand

* Corresponding author(s), e-mail: pchompoorat@gmail.com

Received: 31 July 2018/ Revised: 5 November 2018/ Accepted: 7 March 2019

Cupcake with its beautiful decoration is a dessert that has been widely sold in bakery stores in Thailand. Originally, wheat flour with low protein content (8%) is contained as a main ingredient in cupcake. Thus, cupcake products usually contain gluten higher than 20 ppm which is considered to be dangerous for celiac patients according to the Food and Drug Administration (FDA) announcement (Navarro *et al*., 2017). Gluten or a protein in wheat flour plays a major role in the soft texture of cupcake after baking (Dobraszczyk, 2004). It is a long chain polymer of amino acid with cysteine residues, thus it can form a disulfide bond required for viscoelastic properties in its structure after hydration (Chompoorat *et al*., 2013; Hernández-Estrada *et al*., 2017). In order to develop a gluten free product, rice flour has been applied as a main ingredient to replace wheat flour (Marco and Rosell, 2008). Rice flour has a high potential for developing gluten free product because it does not contain gluten without color and odor (Gallagher *et al*., 2004). Moreover, rice flour with buckwheat flour performed optimal starch properties during heating (Torbica *et al*., 2010). There were numerous studies showed that rice was suitable for gluten free products in terms of its functionality (Vici *et al*., 2016). However, gluten free diet using rice flour could lead to nutrient deficiencies because they are usually low in fiber and other necessary nutrients (Vici *et al*., 2016). Thus, to improve nutritional quality of gluten free product, red kidney bean flour is a good option to be a main ingredient. Therefore, the objective of this study was to develop a gluten free cupcake using red kidney bean flour.

2. Materials and Methods

2.1 Ingredients

Gluten free cupcake was formulated with red kidney bean (RKB) (*Phaseolus vulgaris* L.) flour, rice flour, sugar, soybean oil, egg, cocoa powder, salt, gum, baking powder and baking soda acquired from local market in Chiang Mai, Thailand.

2.2 Red kidney bean flour evaluation

The whole RKB flour was prepared using a hammer mill (model) (W.J. Fit Company, Chicago, IL, U.S.A) and sieved for particle size less than 250 μm. The whole RKB flour was then stored at 4 °C in sealed polyethylene bags until further analysis. The proximate composition of protein (Method 46-11A), fat (Method 46-11A), fiber (Method 46-11A) and moisture content (Method 44-15A) of RKB flour were analyzed using standard methods from AACCI (American Association of Cereal Chemists). Water and oil absorption of RKB flour were also measured following the method of Sosulski *et al*. (1976).

2.3 Processing method of gluten free cupcake

Three treatments which were gluten free cupcake with red kidney bean flour, commercial gluten free cupcake Brand 1 and commercial gluten free cupcake Brand 2 were studied. The cupcake making process was depicted in Figure 1. Nutritional profiles of the samples were also provided.

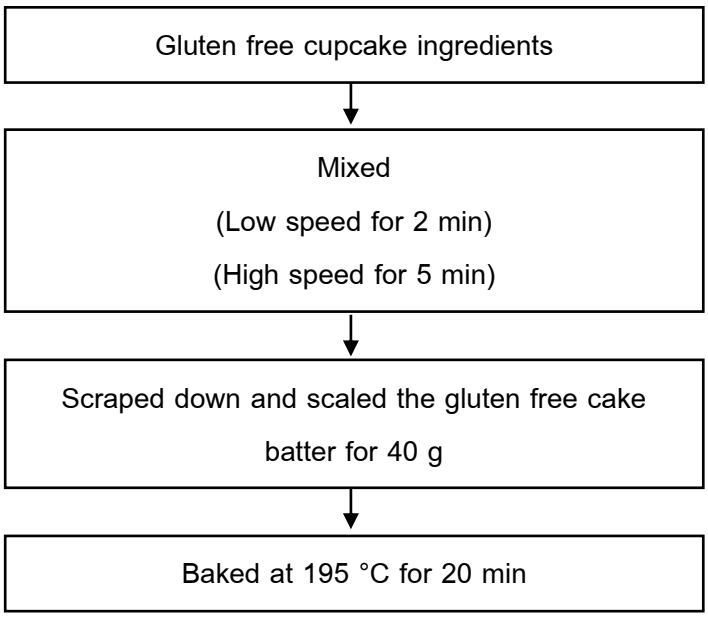

Figure 1 A schematic of the gluten free cupcake process used in this study.

2.4 Pasting properties of gluten free cupcake samples

The pasting properties of samples were assessed using Rapid Visco Analyzer (Model RVA series 4; Newport Scientific Pty Ltd., Warriewood, Australia) according to the method of (REF). The samples (3 g) were dispersed in aluminum canister with distilled water (25 mL). According to standard profile 1, the flour-water suspension was held at 50 °C (1 min), heated to 95 °C (10 min) and cooled down to 50 °C (2 min). The viscosity parameters measured were pasting temperature (°C), peak viscosity (cp), breakdown viscosity (cp), final viscosity (cp), trough viscosity (cp), setback viscosity (cp) and peak time (min).

2.5 Physical properties of gluten free cupcake samples

The height variable of gluten free cupcake was measured after baking by using a digital caliper (Model 01407A; Neiko Tools, Ontario, California, U.S.A). For crumb texture study, gluten free cupcake samples were packed in polypropylene bags, and stored at the room temperature. At day 1 of storage, the gluten free cupcake from each treatment were randomly selected and measured their freshness by applying firmness method (AACC 74-09.02). Firmness test was carried out using TA-XT plus texture analyzer with a 50 kg load cell

(Stable Microsystem, Godalming, U.K.) and Texture Exponent 32 software (version 6.0, Stable Microsystems). An Aluminium 25 mm diameter cylindrical probe was used to penetrate the gluten free cupcake samples. Firmness was performed using a test speed of 1.7 mm/s with a 40% strain. The pre- and post- test speeds were 1.0 mm/s. A trigger a force of 5 g was selected. This test measured force in compression or firmness (N).

2.6 Sensory test of gluten free cupcake samples

Sensory test was performed on the cupcake samples on day 1 of storage. The cupcake samples were cut into half for each panel. All cupcake samples were coded and tested for degree of liking or disliking using descriptive categories with a nine-point hedonic scale: 1, 5 and 9 representing extremely dislike, neither like nor dislike, and extremely like, respectively. A total of 30 untrained panelists participated in this study.

2.7 Statistical analysis

Gluten free cupcake with red kidney bean flour, commercial gluten free cupcake Brand 1 and commercial gluten free cupcake Brand 2 were investigated in this study. Analysis of variance procedures were used to assume a model in a completely randomized design (CRD) using SAS program (Version 16.1.1, Lead Technologies, Inc, Cary, NC, U.S.A.). The mean significant difference was tested by using Tukey's multiple comparison test (α = 0.05). The relationships of pasting properties, physical properties of cupcake and sensory properties were tested using Pearson correlation. It was tested by using CORR procedure in SAS program (Version 9.1 SAS Institute Inc., Cary, NC, U.S.A.).

3. Results and Discussion

3.1 Chemical and functional properties of red kidney bean flour

Properties of red kidney bean flour used in this study are shown in Table 1. Red kidney bean flour had high protein and fiber contents compared to wheat flour which were 50% and 88% higher, respectively. It contained 1.42% fat and 10.28% moisture content. Proximate composition of red kidney bean flour used in this study revealed similar chemical properties to other bean varieties (Martínez-Preciado *et al*., 2014). Thus, it is suitable to be used as an ingredient in gluten free cupcake products to improve nutritional profile of end product. Water and oil absorption were 125.1 and 120.3%, respectively. Water and oil absorption indicate amount of water needed in cake making formulation depending on formulation. Hence, using this particular red kidney bean flour required less amount of water and oil to hydrate the flour compared to wheat flour (approximately 140% water absorption and 146% oil absorption) (Chandra *et al*., 2015).

Table 1. Properties of red kidney bean flour

Flour properties (n = 4)	Red kidney bean flour	Wheat flour
Crude protein (% dry basis)	24.5 ± 0.02	12.0 ± 0.02
Fat (%)	1.4 ± 0.02	1.4 ± 0.03
Crude fiber (%)	7.8 ± 0.02	0.9 ± 0.01
Moisture (%)	10.3 ± 0.02	10.1 ± 0.01
Water absorption (%)	125.1 ± 0.02	-
Oil absorption (%)	120.3 ± 0.02	-

3.2 Pasting properties of gluten free cupcake samples

Pasting properties revealed flour viscosity during heating and gelatinization processes. They are important parameters to determine cake making quality. The results showed that pasting properties (Peak viscosity, breakdown viscosity, trough viscosity, final viscosity, setback viscosity and peak temperature) of all gluten free cupcake mixes showed significantly difference among each other ($p < 0.05$) except for peak time (Table 2). Gluten free cupcake brand 1 (GF Brand 1) had the highest final viscosity, setback viscosity and peak temperature; while, this gluten free brand 2 showed the lowest in peak viscosity, trough viscosity and breakdown viscosity ($p < 0.05$). The red kidney bean gluten free cake flour had a closer value of all pasting parameters to gluten free brand 2 except for trough viscosity and setback viscosity. Peak viscosity indicated water binding capacity of starch during heating. Peak viscosity is negatively correlated with amylose content, while, final viscosity is positively correlated with amylose content (Baik and Lee, 2003). Thus, commercial gluten free cupcake brand 1 tended to have a higher amount of amylose content compared to the others.

Table 2. Pasting properties of gluten free cupcake mix

Sample ID	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown viscosity (cP)	Final viscosity (cP)	Setback viscosity (cP)	Peak Time (min)	Peak temperature (°C)
RKB GF cake	525.2^{b} ± 0.1	450.3^{a} ± 0.1	102.2^{b} ± 0.3	430.2^{c} ± 0.2	218.3^{b} ± 0.2	6.7^{a} ± 0.2	82.3^{b} ± 0.2
GF Brand 1	395.8^{c} ± 0.2	324.0^{c} ± 0.1	71.8^{c} ± 0.4	599.0^{a} ± 0.3	275.0^{a} ± 0.2	6.4^{a} ± 0.1	94.2^{a} ± 0.2
GF Brand 2	557.7^{a} ± 0.1	334.3^{b} ± 0.3	223.3^{a} ± 0.5	492.7^{b} ± 0.2	158.3^{c} ± 0.2	6.9^{a} ± 0.2	88.9^{b} ± 0.3

Note: *RKB GF cake: red kidney bean gluten free cupcake, GF Brand 1: gluten free cupcake brand 1, GF Brand 2: gluten free cupcake brand 2.

Means (n=3) in each column with different superscripts are significantly different ($p < 0.05$).

3.3 Nutritional profile of gluten free cupcake

The nutrition facts of each gluten free cupcake treatment is shown in Table 3. Red kidney bean gluten free cupcakes had a lower calories of gluten free cupcake compared to other commercial gluten free cupcake products (GF Brand 1 and 2). It also showed high in protein (8% daily intake) and fiber amount (12% daily intake).

Table 3. Nutritional profiles of gluten free cupcake.

Nutrition facts (43 g/serving size)	RKB GF cake	GF Brand 1	GF Brand 2
Calories, Kcal	126	260	220
Total Fat, g	7	10	11
Saturated Fat, g	1	10	6
Cholesterol, mg	35	87	91
Total Carbohydrates, g	12	37	20
Dietary Fiber, g	3	0	0
Sugars, g	9	15	17
Protein, g	4	1	1

Note: *RKB GF cake: red kidney bean gluten free cupcake, GF Brand 1: gluten free cupcake brand 1, GF Brand 2: gluten free cupcake brand 2.

3.4 Physical properties of gluten free cupcake

Physical properties and appearance of gluten free cupcake are presented in Table 4 and Figure 2, respectively. Commercial gluten free cupcake brand 1 had the highest height ($p < 0.05$). Gluten free cupcake with red kidney bean flour and commercial gluten free cupcake brand 2 were not significantly different in height and crumb firmness ($p > 0.05$), while, commercial gluten free cake brand 1 had the lowest in firmness. However, the crumb structure of gluten free cupcake brand 1 had a big bubble which is undesirable for consumer as shown in Figure 2. This bubble in crumb could lead to a high value of height and low value of crumb firmness. Based on the visual observation, gluten free red kidney bean cupcake had smaller and more uniform cell aeration structure compared to the other samples (Figure 2). Moreover, the presence of red kidney bean in gluten free cupcake resulted in a better symmetrical curve, which is desirable in cupcake.

Table 4. Physical properties of gluten free cupcake

Sample	Height (mm)	Firmness (N)
RKB GF cake	36.0^{b} ± 0.1	4.8^{a} ± 0.2
GF Brand 1	42.5^{a} ± 0.1	4.1^{b} ± 0.1
GF Brand 2	36.6^{b} ± 0.1	5.0^{a} ± 0.2

Note: *RKB GF cake: red kidney bean gluten free cupcake, GF Brand 1: gluten free cupcake brand 1, GF Brand 2: gluten free cupcake brand 2.

Means (n=3) in each column with different superscripts are significantly different ($p < 0.05$).

(a) (b) (c)

Figure 2 Appearance of gluten free cupcakes (a) red kidney bean gluten free cupcake (b) mgluten free brand 1 (c) gluten free brand 2.

3.5 Organoleptic properties of gluten free cupcake

The average of sensory scores for appearance, texture, color, taste, and overall characteristics of all gluten free cupcakes are shown in Table 5. These results showed that there was no significant difference in appearance, color, and overall characteristics among the samples ($p > 0.05$). However, panelists tended to prefer the gluten free cupcake with red kidney bean flour as depicted by the higher score in appearance, texture and taste criterions. One of the reasons for this preference may be due to the uniform cell aeration structure of crumb as shown in Figure 2. Any gluten free cupcake with a sensory panel score (i.e., appearance, texture, color, taste, and overall characteristics) higher than 5 is considered to be acceptable. Therefore, all gluten free cupcakes in this study were acceptable for consumer (Torbica *et al*., 2010). Therefore, all gluten free cupcakes in this study were acceptable for consumer.

Table 5. Sensory properties of gluten free cupcake

Sample ID	Appearance	Texture	Color	Taste	Overall
RKB GF cake	$7.8^{a} \pm 0.1$	$7.9^{a} \pm 0.2$	$7.4^{a} \pm 0.0$	$7.5^{a} \pm 0.1$	$7.5^{a} \pm 0.2$
GF Brand 1	$7.8^{a} \pm 0.0$	$7.8^{a} \pm 0.2$	$7.4^{a} \pm 0.0$	$7.4^{a} \pm 0.2$	$7.5^{a} \pm 0.1$
GF Brand 2	$7.7^{a} \pm 0.1$	$7.5^{b} \pm 0.2$	$7.4^{a} \pm 0.1$	$7.3^{b} \pm 0.2$	$7.5^{a} \pm 0.2$

Note: *RKB GF cake: red kidney bean gluten free cupcake, GF Brand 1: gluten free cupcake brand 1, GF Brand 2: gluten free cupcake brand 2.

Means (n=3) in each column with different superscripts are significantly different ($p < 0.05$).

3.6 Pearson correlation between gluten free cupcake properties.

The relationship among pairs of parameters from flour pasting, cupcake physical and cupcake sensory properties across treatments are shown in Table 6. Cupcake height had a strong positive correlation with final viscosity, stability viscosity, setback viscosity peak temperature, while, it had a strong negative correlation with peak viscosity and peak time. Firmness had a negative correlation with height (r = -0.91). Therefore, the higher height, the lower cupcake firmness was obtained. Overall acceptance of sensory test had no correlation with other parameters. Moreover, taste form sensory evaluation showed a positive correlation with texture of sensory test (r = 0.92) and trough viscosity (0.82); while, it had a negative correlation with breakdown viscosity (r = -0.75).

Table 6. Pearson correlation of gluten free cupcake properties.

Parameter	Pasting properties						Physical properties			Sensory properties				
	PV	TV	BV	FV	SV	PT	PTM	Height	Firmness	Appearance	Texture	Color	Taste	Overall
PV			0.78	-0.85	-0.94	0.97	-0.75	-0.96	0.98					
TV				-0.82			-0.90						0.82	
BV					-0.95	0.90			0.85		-0.92		-0.75	
FV						-0.71	0.98	0.95	-0.77					
SV						-0.99		0.81	-0.97		0.78			
PT								-0.88	0.99		-0.69			
PTM								0.90						
Height									-0.91					
Firmness														
Appearance														
Texture													0.92	
Color														
Taste														
Overall														

Note: *PV = Peak viscosity, TV = Trough viscosity, BV = Breakdown viscosity, FV = Final viscosity, SV = Setback viscosity, PT = Peak time, PTM = Peak temperature.

4. Conclusion

Physical characteristics, flour pasting properties, and sensory properties of gluten free cupcakes were different extents by each treatment (gluten free cupcake with red kidney bean flour, commercial gluten free cupcake Brand 1 and commercial gluten free cupcake Brand 2). A gluten free cupcake with red kidney bean flour appeared to be suitable ingredient for gluten free cupcake product since it had no significant difference in overall likeness with other commercial gluten free cupcakes. The incorporation of the red kidney bean flour provided the gluten free cupcake with better symmetry and more uniform aeration structure. Moreover, the red kidney bean flour also helped improve the protein and fiber amount in gluten free cupcake.

Acknowledgements

This research was funded by Agricultural Research Development Agency (Public Organization). The authors are grateful to acknowledge our funding providers.

References

AACC International (American Association of Cereal Chemists). Approved Methods of Analysis, 11th Ed. Method 46-10.01. Crude Protein-Improved Kjeldahl Method. Approved November 3, 1999. AACC International: St. Paul, MN.

AACC International (American Association of Cereal Chemists). Approved Methods of Analysis, 11th Ed. Method 30-10.01. Crude Fat in Flour, Bread, and Baked Cereal Products Not Containing Fruit. Approved November 3, 1999. AACC International: St. Paul, MN.

AACC International (American Association of Cereal Chemists). Approved Methods of Analysis, 11th Ed. Method 32-05.01. Crude Fiber in Flours, Feeds, and Feedstuffs. Approved November 3, 1999. AACC International: St. Paul, MN.

AACC International. Approved Methods of Analysis, 11th Ed. Method 44-15.02. Moisture—Air-Oven Methods. Approved November 3, 1999. AACC International: St. Paul, MN.

Baik, B.K. and Lee, M.R. 2003. Effects of starch amylose content of wheat on textural properties of white salted noodles. Cereal Chemistry 80: 304–309.

Caruso, R., Pallone, F., Stas,i E., Romeo, S. and Monteleone, G. 2013. Appropriate nutrient supplementation in celiac disease. Annals of Medicine. 45(8): 522–31.

Cataldo, F. and Montalto, G. 2007. Celiac disease in the developing countries: a new and challenging public health problem. World journal of gastroenterology: WJG 13: 2153.

Chandra, S., Singh, S. and Kumari, D. 2015. Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. Journal of Food Science and Technology. 52: 3681–3688.

Chompoorat, P., Ambardekar, A., Mulvaney, S. and Rayas-Duarte, P. 2013. Rheological characteristics of gluten after modified by DATEM, ascorbic acid, urea and DTT using creep-recovery test. Journal of Modern Physics. 4: 1–8.

Dobraszczyk, B.J., 2004. The physics of baking: rheological and polymer molecular structure–function relationships in breadmaking. Journal of Non-Newtonian Fluid Mechanics. 124: 61–69.

Drewnowski, A. and Evans, W.J. 2001. Nutrition, physical activity, and quality of life in older adults summary. The Journals of Gerontology: Series A. 56: 89–94.

Gallagher, E., Gormley, T.R. and Arendt, E.K. 2004. Recent advances in the formulation of gluten-free cereal-based products. Trends in Food Science and Technology. 15: 143–152.

Hernández‐Estrada, Z.J., Rayas‐Duarte, P. and Cárdenas, J.d.D.F. 2017. Creep recovery of wet gluten and high‐molecular‐weight glutenin subunit composition: Relationship with viscoelasticity of dough and breadmaking quality of hard red winter wheat. Cereal Chemistry. 94: 223–229.

Lichtenstein, A.H., 2017. Optimal nutrition for the older adults, Nutrition in Lifestyle Medicine. Springer. pp. 355–366.

Marco, C. and Rosell, C.M. 2008. Functional and rheological properties of protein enriched gluten free composite flours. Journal of Food Engineering. 88: 94–103.

Martínez-Preciado, A.H., Estrada-Girón, Y., González-Álvarez, A., Fernández, V.V.A., Macías, E.R. and Soltero, J.F.A. 2014. Physicochemical, morphological and rheological properties of canned bean pastes “negro Queretaro” variety (Phaseolus vulgaris L.). Journal of Food Science and Technology. 51: 1795–1805.

Navarro, V., del Pilar Fernández-Gil, M., Simón, E. and Bustamante, M.Á. 2017. Gluten: General aspects and International regulations for products for Celiac people, Nutritional and analytical approaches of gluten-free diet in Celiac disease. Springer. pp. 15–27.

Torbica, A., Hadnađev, M. and Dapčević, T. 2010a. Rheological, textural and sensory properties of gluten-free bread formulations based on rice and buckwheat flour. Food Hydrocolloids. 24: 626–632.

Vici, G., Belli, L., Biondi, M. and Polzonetti, V. 2016. Gluten free diet and nutrient deficiencies: A review. Clinical Nutrition. 35: 1236–1241.