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Date Submitted: 2020-05-18

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Record Type: Published Article

Submitted To: LAPSE (Living Archive for Process Systems Engineering)

Citation (overall record, always the latest version):	LAPSE:2020.0462
Citation (this specific file, latest version):	LAPSE:2020.0462-1
Citation (this specific file, this version):	LAPSE:2020.0462-1v1

DOI of Published Version: https://doi.org/10.3390/pr8030318 processes

Article

The Effect of Tamarind Seed Gum on the Qualities of Gluten-Free Cakes

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Received: 14 February 2020; Accepted: 5 March 2020; Published: 9 March 2020

Abstract: The effect of 0.2%, 0.4%, and 0.8% cold-water soluble tamarind seed gum on batter density, viscosity, and volume of gluten-free layer cakes made with rice flour was evaluated herein. It was observed that the addition of 0.4% tamarind seed gum gave better cake batter volume and was similar to cakes made with wheat flour. Texture profile analysis, color, proximate composition, water activity, total phenolics content, shelf life, and a sensory evaluation of a gluten-free cake with 0.4% tamarind seed gum were compared to a cake made with wheat flour and rice flour. Gluten-free cakes made with 0.4% tamarind seed gum had higher dietary fiber, sensory scores (appearance, texture, and overall acceptability), and longer shelf life than that of the control. Incorporation of 0.4% tamarind seed gum is recommended for gluten-free baked products as it results in more desirable sensory scores and a longer shelf life.

Keywords: tamarind seed gum; gluten-free cake; sensory evaluation

1. Introduction

Celiac disease, a genetic condition experienced by 0.5–1.0% of the population worldwide, is gluten-sensitive immune-mediated enteropathy [1]. Those with celiac disease cannot consume the protein gliadin, which is found in barley, wheat, and rye. When wheat flour is mixed with water, the gluten in the flour produces unique characteristics, such as gas retention in yeast-leavened bread and chemically leavened cakes and snacks. Other characteristics are coagulability, extendibility, and elasticity found in the protein starch matrix for noodles [2].

Although flour made from sorghum, oats, corn, and rice are suitable for preparing gluten-free products, these cereal products lack a continuous gluten network that incorporates fiber and starch granules [3]. However, various hydrocolloids, such as agarose, hydroxypropyl-methylcellulose, pectin, guar, locust bean, and xanthan gum can provide the same viscoelastic characteristics found in the gluten network to produce gluten-free baked goods [4].

Tamarind (*Tamarindus indica* L.) seed gum is a branched polymer with a main cellulose-type backbone, which carries xylose and galactoxylose residues (65–72%) at a molar ratio of glucose, galactose, and xylose at 3:2:1 [5,6]. The molecular weight of tamarind seed gum is in the range of 720–880 kDa [7]. When dissolved in water, it can form a viscous solution [8]. It provides applications as fiber, rheology modifier, and emulsifier [5]. There is little information about the effects of tamarind seed gum on the quality of gluten-free cakes and its optimal concentration in the production of baked goods. The aim of this research was to determine the most suitable tamarind seed gum concentration for gluten-free cakes made with rice flour. A further aim was to compare the quality of cakes made with wheat flour and cakes made with rice flour and tamarind seed gum for the purpose of developing gluten-free baked products.

2. Materials and Methods

2.1. Raw Materials and Chemicals

Water-soluble tamarind seed gum (Glyioid 3S) was obtained from DSP Gokyo Food and Chemical Co Ltd. (Osaka, Japan); Japonica rice flour (Taiken 9, 18.5% amylose) was obtained from Pingtung county Farmers' Association (Pingtung County, Taiwan); and wheat flour, fresh milk, eggs, sunflower oil, sugar, and double-action baking powder were purchased from a local market. The chemicals used for analysis were purchased from Panreac Applichem (Gatersleben, Soaxony-Anhalt, Germany), Merck (Darmstadt, Germany), and Sigma Aldrich (St. Louis, MO, USA). Ethyl ethylether was obtained from Nihon Shiyaku industries (Taipei, Taiwan).

2.2. Cake Preparation

Gularte et al.'s [9] single-bowl mixing method was followed in preparing yellow layer cakes using different ratios of tamarind seed gum, as shown in Table 1. Using a Kitchen-Aid mixer (St. Joseph, MI, USA), all the ingredients were mixed at speed 4 for 1 min and at speed 6 for 9 min. The cake batter (390 g) was put into rectangular (17.5 × 8.5 × 7.0 cm) metal pans lined with baking paper and baked in an electric oven (Chung Pu Baking Machinery Co., Ltd., Taichung, Taiwan) at 180 °C for 35 min. The baking pans were rotated from front to back after 20 min. After baking, the cakes were removed and allowed to cool at the ambient temperature. Cake samples were packed in low density polyethylene (LDPE) bags for subsequent tests.

Table 1. Formulation of cake and gluten-free cake.

Ingredient (%)	WF	RF	0.2TRF	0.4TRF	0.6TRF	0.8TRF
Wheat flour	100	-	-	-	-	-
Rice flour	-	100	100	100	100	100
Tamarind seed gum	-	-	0.2	0.4	0.6	0.8
Milk	75	75	75	75	75	75
Egg	62.5	62.5	62.5	62.5	62.5	62.5
Sunflower oil	37.5	37.5	37.5	37.5	37.5	37.5
Sugar	112.5	112.5	112.5	112.5	112.5	112.5
Baking powder	3.75	3.75	3.75	3.75	3.75	3.75

WF: cake made with 100% wheat flour; RF: gluten-free cake made with 100% rice flour; 0.2 TRF: gluten-free cake with 0.2% tamarind seed gum addition; 0.4 TRF: gluten-free cake with 0.4% tamarind seed gum addition; 0.6 TRF: gluten-free cake with 0.6% tamarind seed gum addition; 0.8 TRF: gluten-free cake with 0.8% tamarind seed gum addition.

2.3. Measurement of the Batter

Batter density was calculated by measuring the weight of the batter and its volume in a standard beaker. The volume of the beaker was determined by filling the beaker with water, with its weight divided by volume of the beaker (1 g/cm^3) [10]. The viscosity of the cake batter was determined at 25 °C by using the Toki Sangyo Viscometer (TVC-7, Toki Sangyo Co. Ltd., Tokyo, Japan). After the start of the experiment, three measurements for apparent viscosity (Pa·s) were recorded for each formulation in a 50 mL beaker.

2.4. Analysis of the Texture Profile

An analysis of the texture profile of the cake was measured before storage and thereafter at 2, 4, and 6 d. A TA-XT2 texture analyzer (Stable Micro Systems Ltd., Surrey, United Kingdom) with a 25 mm diameter aluminum cylindrical probe was used, according to the method of Gularte et al. [9]. Cake slices of 20 mm thickness (texture profile analysis: TPA) were compressed two times with a compression up to 50% depth at the test speed of 2 mm/s with a 30 s delay between compressions. Firmness (N), springiness, cohesiveness, and resilience were calculated following the method of Gomez et al. [11] from the TPA graph.

2.5. Color Measurement

Color was measured via CIE L*a*b* color space using a color spectrophotometer (TC-1800MK-II, Tokyo Denshoku, Japan) as per Cruz-Romero et al. [12]. Absolute color difference (ΔE) and whiteness index (WI) were calculated following the formula described by Lewandowicz and Le Thanh-Blicharz [13].

2.6. Proximate Chemical Composition of Gluten-Free Layer Cake

The proximate chemical composition of the gluten-free cake, which included moisture, ash, crude fat, and crude protein (using a 6.25 conversion factor), was determined according to the Association of Official Analytical Chemists method [14]. The available carbohydrate content of the cake samples was calculated by subtracting 100 g from the sum of moisture, ash, fat, and protein expressed in g/100 g.

2.7. Water Activity

Water activity of the cakes was determined with a water activity meter as used by Mathlouthi [15]. The water activity of cake crust and crumb was measured before storage and thereafter at 2, 4, and 6 d at room temperature (25 °C). The homogenized cake sample was placed in a chamber of the water activity meter (RTD-33, Novasina Co. Ltd., Pfaffikon, Switzerland).

2.8. Total Phenolics

The total phenolics were determined using the Folin–Ciocalteau reagent, as per Singleton and Rossi [16]. The extracted solution (0.1 mL), water (0.1 mL), and Folin–Ciocalteau reagent (1:5 H_2O) were mixed and left to stand for 3 min. Then, 2 mL of sodium carbonate (100 g/L) was added, mixed, and left to stand for 30 min. Absorbance at 700 nm in a microplate reader (Model AMR-100, Allsheng Instruments Co., Ltd., Hangzhou City, China) was recorded.

2.9. Sensory Evaluation

Sensory evaluation was carried out on cakes made with rice flour, rice flour with 0.4% tamarind seed gum, and wheat flour. Three cake samples were cut into cubes approximately 2.5 cm in size and coded with three random digits. Seventy untrained faculty (21 males and 49 females) from I-Mei Foods Co., Ltd. (Taoyuan County, Taiwan) between the ages of 26 and 50 were asked to evaluate the appearance, odor, texture, flavor, and overall acceptability of the samples. This was done by means of a nine-point Likert scale from 1 = "strongly disapprove" to 9 = "strongly approve", according the method of Sudha et al. [17]. Water was offered for participants to rinse their mouths between each cake sampling.

2.10. Test for the Shelf-Life of the Cake

The cake samples were stored at 25 °C at 70% relative humidity in the environmental test cabinet for 10 days. During the shelf-life test, the percentage of mold spots on the surface area of crumb was evaluated every day.

2.11. Statistical Analysis

Data were examined with an analysis of variance using the Statistical Products and Services Solution (SPSS) statistic program (SPSS, 12.0.1C, 2000). One-way analysis of variance and Duncan's multiple range test was used to identify the difference between the test groups' α values at a 5% significance level ($p < 0.05$).

3. Results and Discussion

3.1. Measurement of Cake Batter and Batter Viscosity

The batter density of the gluten-free cakes to which tamarind seed gum had been added (0.2–0.4%) was lower than that of the control batter made with 100% rice flour. It was higher (0.4–0.8% tamarind seed gum addition) than that of the cake made with 100% wheat flour (Figure 1A). Although the viscosity increased proportionally with the addition of 0.2–0.8% tamarind seed gum (Figure 1B), the batter volume of gluten-free cake batter reached the maximal value at 0.4–0.8% tamarind seed gum, which was similar to the batter volume of cake made with wheat flour (Figure 1C). This indicated that the higher batter viscosity from the addition of 0.2–0.4% of tamarind seed gum could thicken the batter during the mixing of the ingredients, thereby improving the volume of the batter to a level comparable to that of cakes made with wheat flour. The tamarind seed gum could be used as a thickening agent instead of gluten in the gluten-free cake. Nevertheless, the addition of over 0.6% of tamarind seed gum did not significantly increase the batter viscosity and batter volume (Figure 1B,C). The batter viscosity (Figure 1B) of the cake made with rice flour and 0–0.8% tamarind seed gum was significantly lower than that of the cake made with 100% wheat flour ($p < 0.05$). Of the different percentages (0.2–0.8%) of tamarind seed gum used in the study, the highest batter volume and lowest batter density gluten-free cakes were obtained by the addition of 0.4–0.8%. Therefore, 0.4% of tamarind seed gum would be used in the subsequent study to assess the quality of the gluten-free cake.

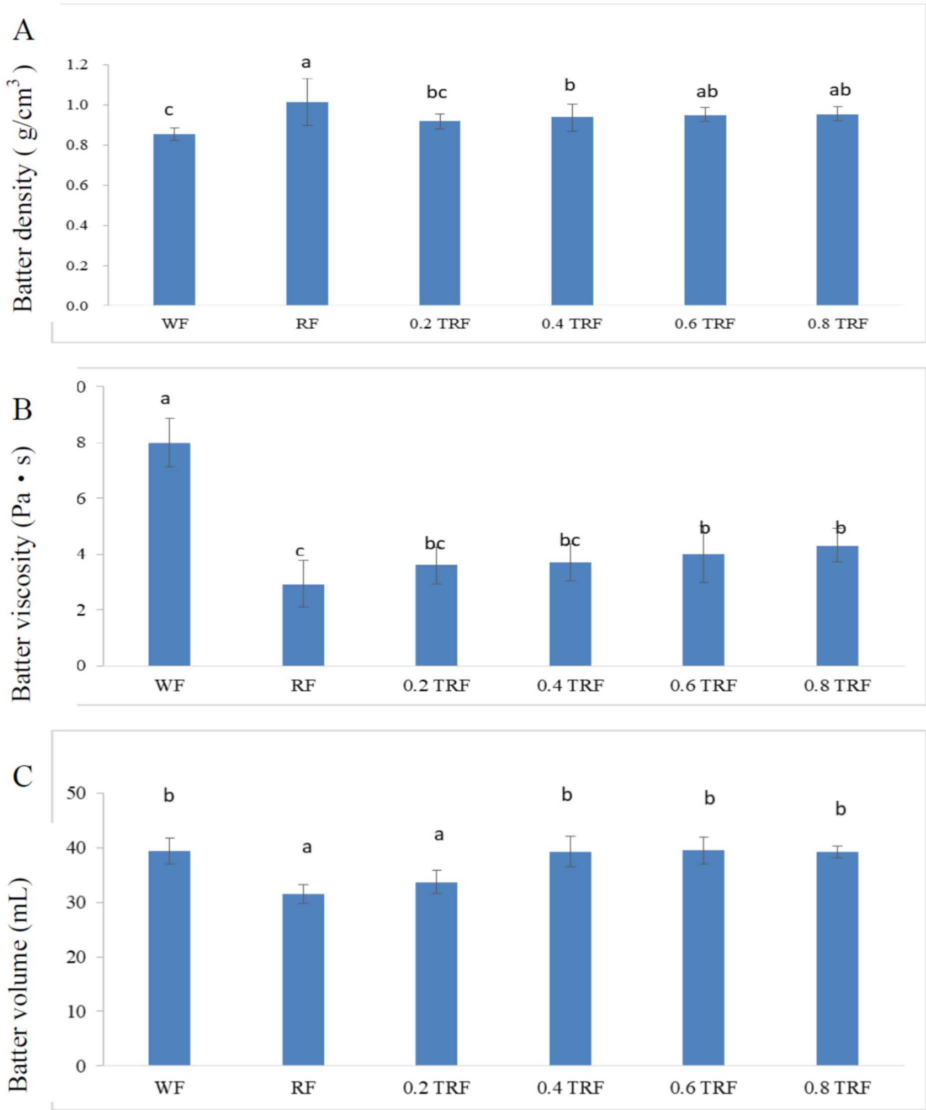

Figure 1. Comparison on batter density (**A**), batter viscosity (**B**), and batter volume (**C**) of gluten-free cake added with tamarind seed gum. [a-b] Different letters indicate significant difference between different samples (n = 3; $p < 0.05$). WF: cake made with 100% wheat flour; RF: gluten-free cake supplemented with 100% rice flour; 0.2 TRF: gluten-free cake with 0.2% tamarind seed gum addition; 0.4 TRF: gluten-free cake with 0.4% tamarind seed gum addition; 0.6 TRF: gluten-free cake with 0.6% tamarind seed gum addition; 0.8 TRF: gluten-free cake with 0.8% tamarind seed gum addition.

No differences in the appearance of gluten-free cakes were observed according to the percentage of gum used (0–0.8%), but when 0.8% was added, the cakes were flatter than cakes made with wheat flour (Figure 2).

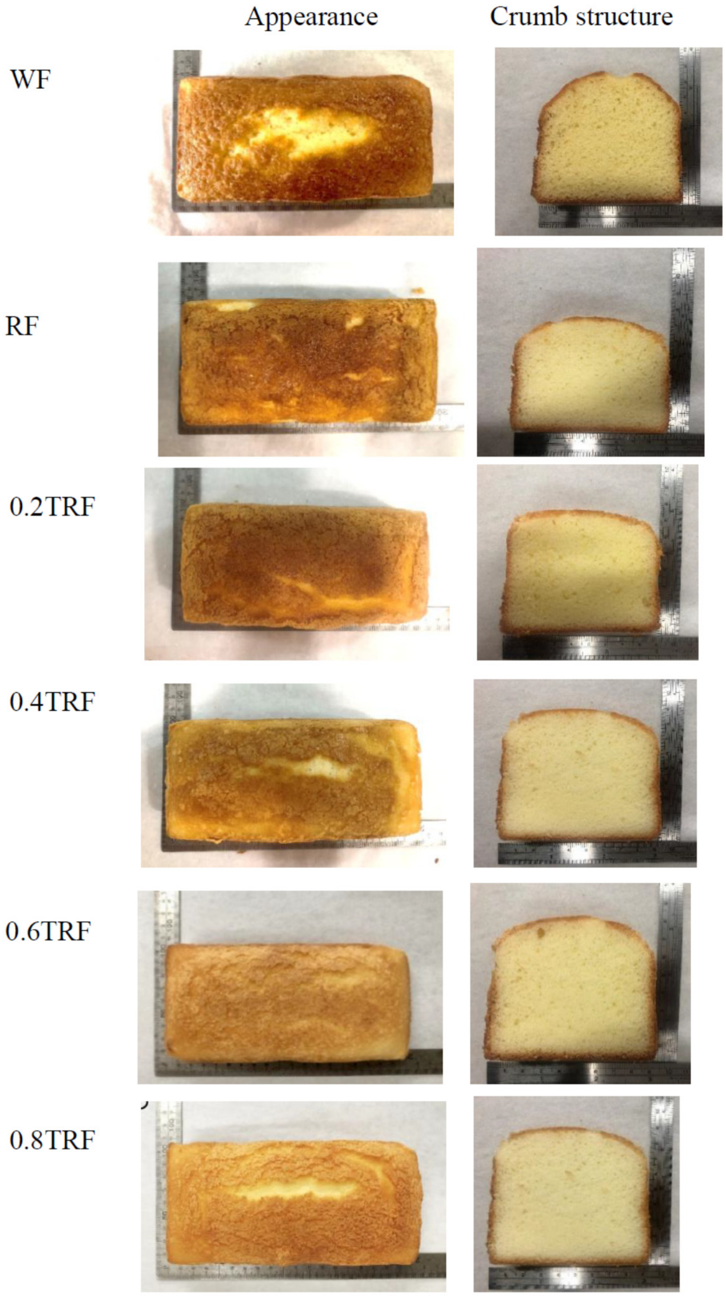

Figure 2. Appearance of cake and gluten-free cake. WF: cake made with 100% wheat flour; RF: gluten-free cake made with 100% rice flour; 0.2 TRF: gluten-free cake with 0.2% tamarind seed gum addition; 0.4 TRF: gluten-free cake with 0.4% tamarind seed gum addition; 0.6 TRF: gluten-free cake with 0.6% tamarind seed gum addition; 0.8 TRF: gluten-free cake with 0.8% tamarind seed gum addition.

3.2. Texture of Cake

Firmness of the cakes did not increase significantly except in the gluten-free cake made with rice flour after 6 days of storage (Figure 3A), although sugar, egg, and margarine bind the ingredients to form a barrier preventing moisture migration during storage. After 6 days of storage, the gluten-free cake with 0.4% tamarind seed gum showed similar firmness as the cake made with 100% wheat flour. However, the initial firmness of this cake was due to the low level of gluten formation and no gum resulted in low batter viscosity (Figure 1B). Springiness, cohesiveness, and the resilience of the cakes decreased during the 6 days of storage (Figure 3B–D).

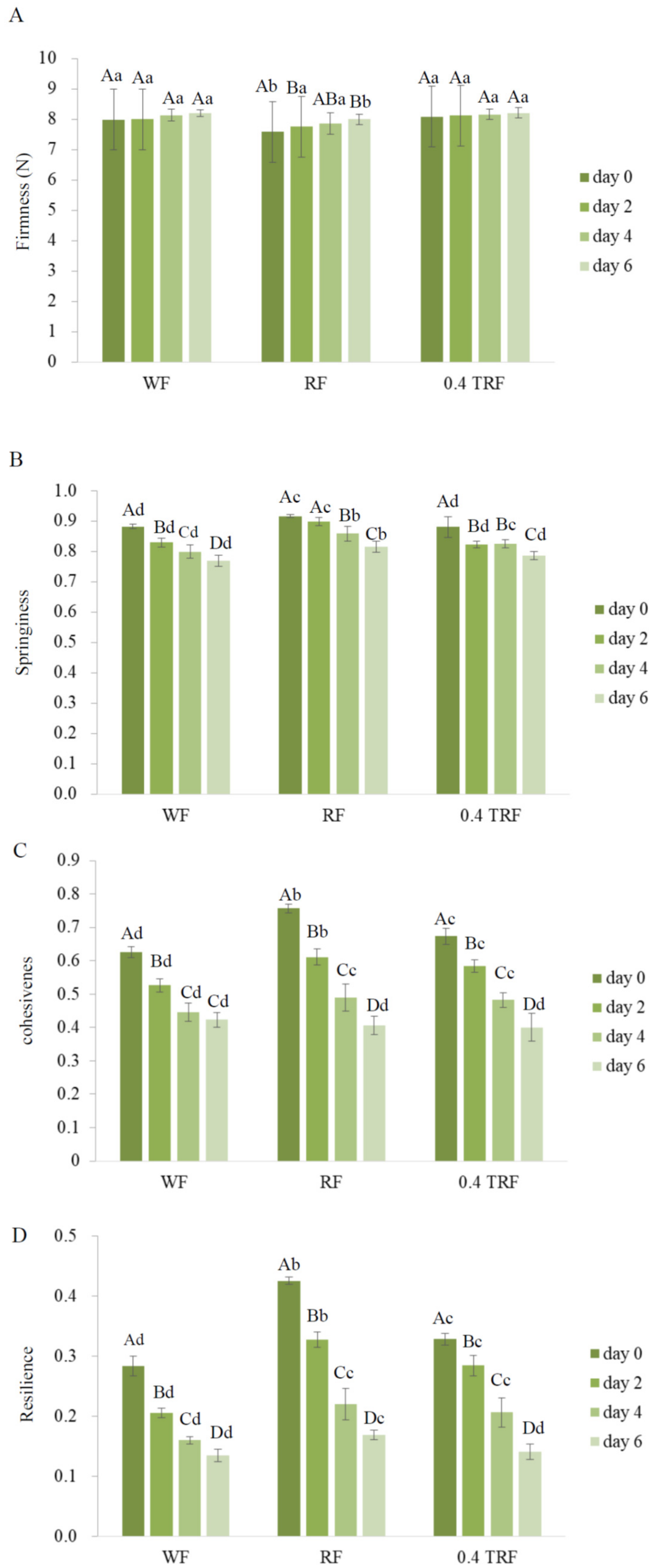

Figure 3. Texture parameters of cake and gluten-free cake: firmness (**A**), springiness (**B**), cohesiveness (**C**) and resilience (**D**). a-c Different letters indicate significant difference between different samples (n = 3; $p < 0.05$). A-D Different letters indicate significant difference between different days (n = 3; $p < 0.05$). WF: cake made with 100% wheat flour; RF: gluten-free cake made with 100% rice flour; 0.4 TRF: gluten-free cake with 0.4% tamarind seed gum addition.

This result indicates that the cakes became stale and hard. When 0.4% of tamarind seed gum was added, the firmness of the gluten-free cakes increased and springiness, cohesiveness, and resilience decreased. This tendency was obvious. However, similar texture parameters were observed in cakes made with wheat and rice flour, to which 0.4% tamarind seed gum had been added. This could be related to the amount of air retained by the batter contributing to gluten from wheat and tamarind seed gum.

3.3. Proximate Composition of Gluten-Free Cake

An increase of dietary fiber and moisture content was due to the addition of tamarind seed gum (Table 2), which could partially increase the fiber content of gluten-free food products made with rice flour (Table 2).

Table 2. Proximate composition of cake.

	Moisture (%)	Crude Protein (%)	Crude Fat (%)	Ash (%)	Carbohydrate* (%)	Total Sugar (%)	Dietary Fiber (%)
WF	25.44 ± 0.88 ^{a}	6.96 ± 0.57 ^{a}	13.72 ± 0.41 ^{a}	0.74 ± 0.05 ^{a}	53.07 ± 0.54 ^{b}	29.00 ± 1.31 ^{a}	ND*
RF	23.62 ± 0.33 ^{b}	6.05 ± 0.66 ^{ab}	13.11 ± 0.44 ^{ab}	0.66 ± 0.03 ^{b}	56.56 ± 1.23 ^{a}	25.99 ± 1.14 ^{b}	0.20 ± 0.03
0.4TRF	26.61 ± 0.68 ^{a}	5.32 ± 0.29 ^{b}	12.22 ± 0.51 ^{b}	0.65 ± 0.02 ^{b}	55.21 ± 1.01 ^{a}	26.04 ± 0.19 ^{b}	0.40 ± 0.05

*ND = not detectable. Express as mean ± standard deviation (n = 3). Values followed by the different letter within each column are significantly different ($p < 0.05$). *Carbohydrate: 100% - moisture - crude protein - crude fat - ash. WF: cake made with 100% wheat flour; RF: gluten-free cake supplemented with 100% rice flour; 0.4TRF: gluten-free cake with 0.4% tamarind seed gum addition.

3.4. Color Characteristics

The crumb and crust color parameters L*, a*, b*, ΔE, and whiteness index are presented in Table 3. Addition of tamarind seed gum in 0.4% level led to a fall ($p < 0.05$) in the lightness (L* value) and yellowness (b* value) of crumb when compared to the cake made with 100% of rice flour (Table 3). The crumb color difference (ΔE) between the cake made with 100% wheat flour and the gluten-free cake with 0.4% tamarind seed gum addition was less than three. Therefore, it is not easy to tell the difference between these two cakes. Addition of 0.4% tamarind seed gum significantly increased the whiteness index of the gluten-free cake in comparison to the cake made of 100% rice flour. However, no significant difference was found in the crust whiteness index between cakes (Table 3).

Table 3. Color of gluten-free cake crumb and crust.

Crumb	**L***	**a***	**b***	**ΔE**	**Whiteness Index**
WF	84.65 ± 1.07 ^{c}	−7.78 ± 0.18 ^{d}	59.05 ± 0.09 ^{a}	8.31	38.48
RF	91.62 ± 0.12 ^{a}	−10.54 ± 0.04 ^{f}	55.53 ± 0.01 ^{b}	0	42.86
0.4TRF	88.38 ± 0.30 ^{b}	−9.15 ± 0.14 ^{e}	50.61 ± 0.45 ^{c}	6.07	47.28
Crust	L*	a*	b*	ΔE	Whiteness Index
WF	43.53 ± 0.25 ^{e}	16.77 ± 0.11 ^{a}	33.43 ± 0.61 ^{e}	7.45	32.27
RF	42.16 ± 0.36 ^{f}	10.17 ± 0.74 ^{c}	30.29 ± 0.16 ^{f}	0	33.92
0.4TRF	48.70 ± 1.54 ^{d}	13.90 ± 0.32 ^{b}	39.93 ± 1.61 ^{d}	12.23	33.50

Express as mean ± standard deviation (n = 3). Values followed by the different letter within each column are significantly different ($p < 0.05$). WF: cake made with 100% wheat flour; RF: gluten-free cake made with 100% rice flour; 0.4TRF: gluten-free cake with 0.4% tamarind seed gum addition. ΔE (absolute color difference): $[(L_{sample} - L_{control})^2 + (a_{sample} - a_{control})^2 + (b_{sample} - b_{control})^2]^{1/2}$; Whiteness index: $100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2}$.

3.5. Water Activity and Moisture Content of Cake during Storage

Tamarind seed gum changed the water activity and moisture content (Figures 4 and 5) of the cake, extending the shelf life of the cake (Table 4). Water activity of cake crumb remained higher than 0.9 during 6 days storage at room temperature (Figure 4A).

Table 4. Storage observation on crust mold appearance percentage on cake surface.

Storage Days	WF	RF	0.4TRF
0	ND*	ND*	ND*
2	ND*	ND*	ND*
4	ND*	ND*	ND*
6	ND*	ND*	ND*
8	11%	22%	ND*
9	33%	55%	ND*
10	55%	66%	11%

*ND = not detectable. Express as mean ± standard deviation (n = 9). WF: cake made with 100% wheat flour; RF: gluten-free cake made with 100% rice flour; 0.4TRF: gluten-free cake with 0.4% tamarind seed gum addition.

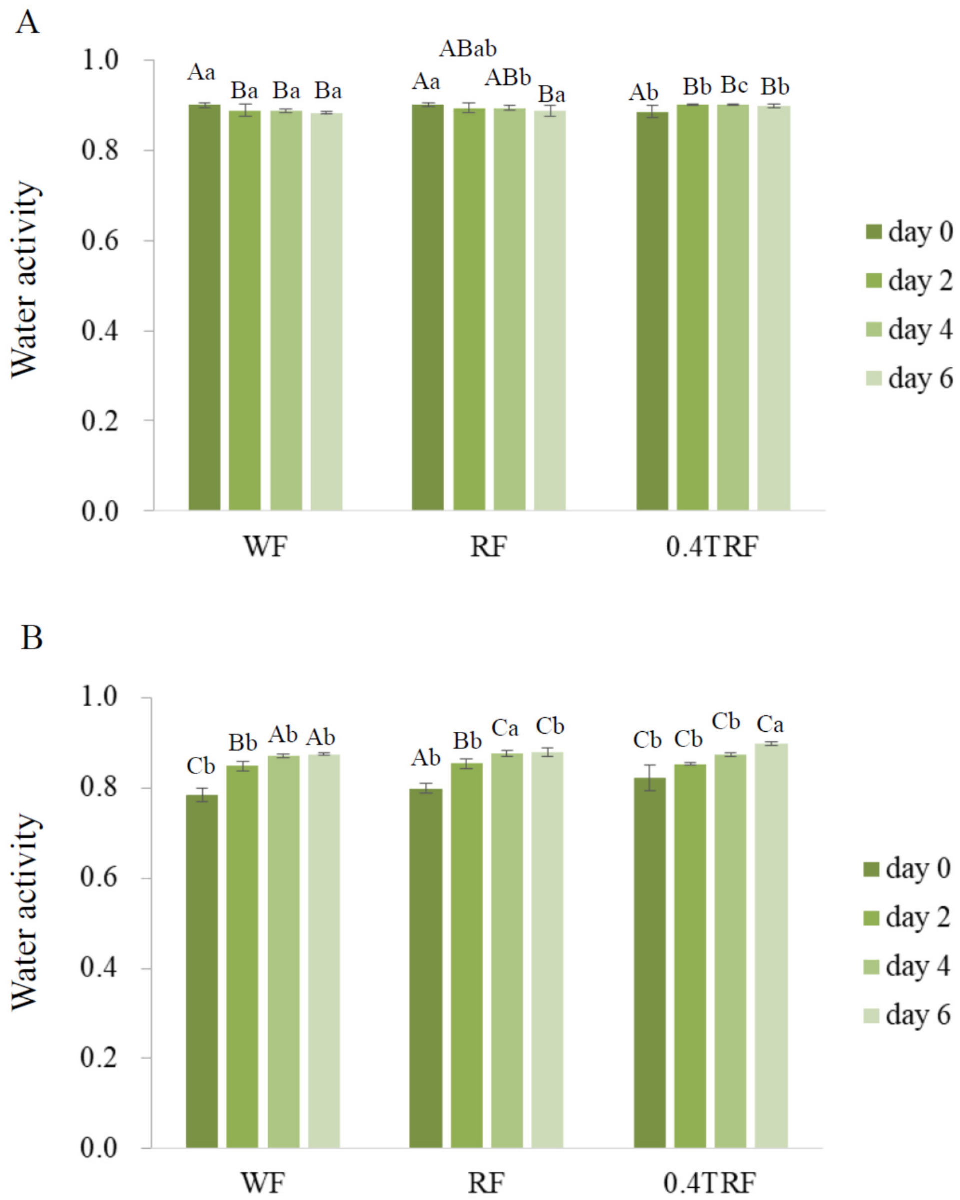

Figure 4. Water activity change of cake and gluten-free cake: crumb (**A**) and crust (**B**). [a-b] Different letters indicate significant difference between different samples (n = 3; $p < 0.05$). [A-C] Different letters indicate significant difference between different days (n = 3; $p < 0.05$). WF: cake made with 100% wheat flour; RF: gluten-free cake made with 100% rice flour; 0.4TRF: gluten-free cake with 0.4% tamarind seed gum addition.

After 6 days of storage, the effect of the 0.4% tamarind seed gum on decreased moisture migration on the cake crumb and crust was observed (Figure 5A,B). The water activity on the crust was significantly higher than in the other two groups (Figure 4B) in the cakes with 0.4% tamarind seed gum. The addition of tamarind seed gum could maintain moisture in the cake crust after baking (Figure 5B). Mold appeared on the surface of the cakes made with 100% rice flour and 100% wheat flour after being stored for 8 days, whereas it only appeared after 10 days on cakes with tamarind seed (Table 3).

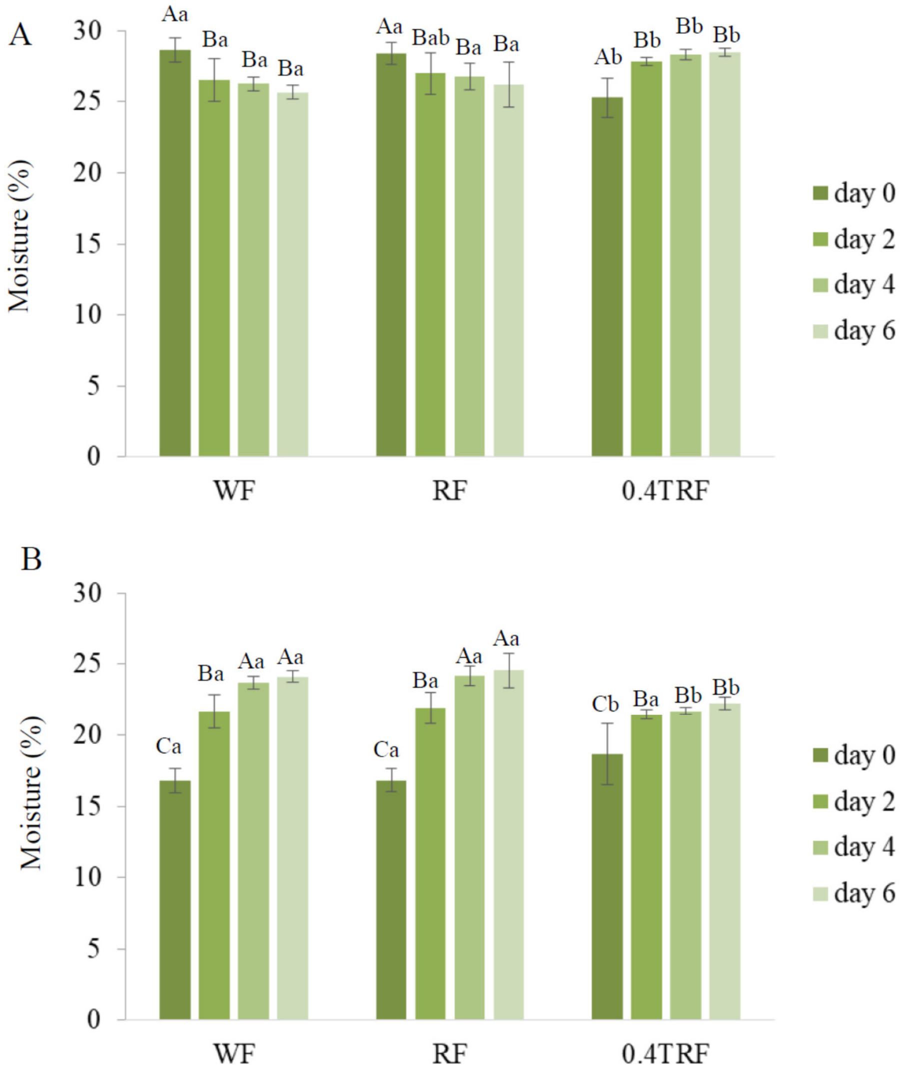

Figure 5. Moisture content change of cake and gluten-free cake: crumb (**A**) and crust (**B**). [a-b] Different letters indicate significant difference between different samples (n = 3; $p < 0.05$). [A-C] Different letters indicate significant difference between different days (n = 3; $p < 0.05$). WF: cake made with 100% wheat flour; RF: gluten-free cake supplemented with 100% rice flour; 0.4TRF: gluten-free cake with 0.4% tamarind seed gum addition.

The antibacterial and antifungal qualities of tamarind fruit have been reported by several researchers [18–22]. Extracts from the pulp of tamarind fruit have also shown molluscicidal activity. It is believed that disease and pest control are due to the effects of saponins for the molluscicidal effect [23] and triterpenoids in the tamarind extracts [24,25]. Although the water activity of the gluten-free cake crust with 0.4% tamarind seed gum was higher than 0.8, the former has a 2 day longer shelf life compared with that of both the control and the cake made with wheat flour. This is possibly because the higher water retention capacity and the presence of saponins, alkaloids, and triterpenoids, as well as the total phenolics content of the former preventing the growth of microorganisms.

Increased water activity in the crust is mainly attributed to crumb dehydration [26]. Water activity in the gluten-free cake with 0.4% tamarind seed gum was higher ($p < 0.05$) than that of the control and the cake made from wheat flour after 6 days of storage (Figure 4B). Tamarind seed gum aids moisture retention during storage.

3.6. Total Phenolics Content of Cake

Tsuda et al. [27] demonstrated that the skin of the tamarind seed, a byproduct of the tamarind seed gum industries, containing 2-hydroxy-3′,4′-dihydroxyacetophenone, methyl-3,4-dihydroxybenoate, 3,4-dihydroxyphenyl acetate, and epicatechin, shows strong antioxidative activity. The addition of tamarind seed gum incurred an 8.2% addition in the total phenolics content of the cake made with rice flour (data not shown).

3.7. Sensory Evaluation of Cakes

The scores given to the appearance of cakes made with wheat and rice flour with 0.4% tamarind seed gum were significantly higher than those of the cake made with only with rice flour (Table 5). The scores for the gluten-free cake with 0.4% tamarind seed gum were significantly better in terms of odor, texture, flavor, and overall acceptability than for gluten-free cakes without tamarind seed gum (Table 5).

As can be seen in Figure 2, the color of the crust and the body of the gluten-free layer cakes became lighter when more tamarind seed gum was added because the gum binds and emulsifies more water and tiny air bubbles than gluten-free cakes without tamarind seed gum. It was observed that cakes made with rice flour obtained lower scores in all the sensory characteristics (Table 5). This seems to be because cakes made with rice flour have a lower specific volume and a denser texture than the other cakes. The texture of the gluten-free cake with tamarind seed gum was more delicate and moister. It also tasted more like traditional cakes, with scores being similar to those of cakes made with wheat flour (Table 5).

Table 5. Sensory evaluation of cake.

	Appearance	Odor	Texture	Flavor	Overall Acceptability
WF	6.20 ± 0.63^{a}	5.41 ± 0.65^{b}	4.83 ± 0.82^{b}	5.24 ± 0.98^{b}	5.94 ± 0.56^{a}
RF	3.21 ± 0.72^{b}	4.93 ± 0.89^{c}	3.31 ± 0.47^{c}	4.29 ± 0.66^{c}	3.97 ± 0.61^{b}
0.4TRF	6.09 ± 0.61^{a}	5.83 ± 0.38^{a}	5.51 ± 0.68^{a}	5.73 ± 0.74^{a}	6.13 ± 0.59^{a}

Express as mean ± standard deviation (n = 70). Values followed by the different letter within each column are significantly different ($p < 0.05$). WF: cake made with 100% wheat flour; RF: gluten-free cake made with 100% rice flour; 0.4 TRF: gluten-free cake with 0.4% tamarind seed gum addition.

4. Conclusions

Gluten-free cakes with addition of 0.4% tamarind seed gum can be perceived as good products in terms of appearance; texture; and acceptable batter density, viscosity, and volume. The gluten-free cake with tamarind seed gum also offered a moister crust and crumb after baking, as well as after being stored for 6 days. The shelf life of gluten-free cakes with 0.4% tamarind seed gum was 2 days longer than that of cakes made with 100% rice flour and wheat flour. The gluten-free layer cakes with 0.4% tamarind gum received a more favorable sensory assessment than cakes made with 100% rice flour, and a similar assessment to cakes made with wheat flour. Therefore, it is recommended that tamarind seed gum be used as a food additive for improving qualities of gluten-free layer cakes.

Author Contributions: Conceptualization, W.-C.S. and S.-C.W.; writing—original draft preparation, S.-C.W. and W-C.S.; writing—review and editing, Y.-S.S., methodology, W.-C.S. and Y.-W.T.; formal analysis, Y.-W.T.; investigation, W.-C.S. and S.-C.W.; resources, S.-C.W. and Y.-S.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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