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Effects of Corn Resistant Starch on the Physicochemical Properties of Cake

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ABSTRACT

Promotion of the dietary fiber of foods can enhance human health by reducing the risk of many serious diseases. Cakes are among the highly consumed foods but sadly of low fiber content. Therefore, increasing the fiber content in them is of great importance, and this was the aim followed in this study. Wheat flour was partially replaced at 0, 10, 20 and 30% (w/w) with corn Resistant Starch (RS), as a source of dietary fiber, and used in the production of sponge cake. Obtained results indicated that batter consistency increased while its density reduced with an increase in the level of RS. Increasing the level of RS caused an increase in cake density but a decrease in volume. Cakes became softer but their cohesiveness, springiness and chewiness reduced. They also became whiter, less reddish and less yellowish. Addition of less than 30% RS had no significant effect on the sensory attributes of the cakes. In total, it was concluded that a maximum level of RS in the sponge cake recipe to produce an acceptable product amounted to 20%.

Keywords: Corn resistant starch, Dietary fiber, Sponge cake.

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INTRODUCTION

The concept of Resistant Starch (RS) includes starch and starch degradation products which withstand digestion in the small intestine of healthy individuals (Asp and Björk, 1992). RS has been categorized into four types according to its resistance properties: RS1= Enzyme inaccessible starch; RS2= Ungelatinized starch granules; RS3= Retrograded gelatinized starch, RS4= Chemically modified starch (Haralampu 2000).

RS as a source of dietary fiber has attracted considerable attention during the last two decades due to its physiological functions (Sajilata *et al.,* 2006). Resistant starch helps in decreasing the risk of colon cancer, improves cardio-vascular health, prevents diabetes type II, lowers plasma triglyceride and cholesterol level, positively influences the operating of the gastrointestinal tract, and assists in the control of obesity. In addition to its beneficial impacts on human health, RS benefits from functional advantages over traditional fiber sources. It has somehow lower effects on the sensory properties of food, offers good water-binding capacity, viscosity, swelling power and gel formation, which makes it find applications in a variety of foods (Sajilata *et al.,* 2006; Fuentes-Zaragoza *et al.,* 2010; DeVries, 2004).

The use of resistant starch in bakery products has been studied in breads, spaghetti, cakes, muffins, biscuits and battered fried products (Brites *et al.,* 2011; Korus *et al.,* 2009; Lin *et al.,* 1994; Sozer *et al.,* 2007; Baixauli *et al.,* 2008b; Sanz *et al.,* 2008b; Ktenioudaki and Gallagher, 2012).

There has been extensive research carried out on addition of such different fiber sources to cakes as oat and rice bran (Lebesi and Tzia, 2011; Majzoobi *et al*., 2013), corn

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bran (Singh *et al.,* 2012), wheat bran, microcrystalline cellulose (Gómez *et al.,* 2010) and apple pomace (Sudha *et al.,* 2007). However, there are few researches that have studied RS supplementation in cakes, and besides, incorporation of relatively low levels of RS has been taken into account in these studies.

The objective followed in this study was to incorporate high levels of RS in cakes and investigate the physicochemical and sensory changes taken place when flour is replaced by RS.

MATERIALS AND METHODS

Wheat flour, fresh whole eggs, low fat milk, white fine sugar, sunflower oil, baking powder and vanilla were purchased from the local market; gluten powder was obtained from Fars-Glucosin Co., Marvdasht, Iran and corn resistant starch (type RS1) supplied by Karen Nutrilife Co., Tehran, Iran. The basic control cake included: 100 g flour, 62.5 g low fat milk, 56g whole eggs, 75 g sucrose, 31.5 g oil, 3.1 g baking powder and 0.45 g vanilla. As for RS supplemented cakes, 10, 20, and 30% of wheat flour were replaced by RS.

Batter Preparation

Sugar, egg and vanilla were whipped at medium speed using a kitchen mixer (Moulinex, Model HM 1010, Beijing, China) for 2 minutes; milk was then added and mixed for another 5 minutes, baking powder was mixed well with wheat flour and passed through a stainless steel screen (ASTME:11, Iran) and then added to the mixture. Finally sunflower oil was incorporated into the formulation and gently mixed.

Batter Consistency

A 100 g sample of the cake batter was poured in the container of a Bostwick consistometer when at ambient temperature (20±0.5ºC) and allowed to stand for 2 minutes. It was then released to run along the leveled channel. The results were reported as the distance (cm) the front moved during a 30 second period. Higher values would indicate lower batter consistencies (Baeva *et al.,* 2000).

Batter Density

Batter density was measured by dividing the weight of a standard container filled with batter to the weight of the container filled with an equal volume of distilled water (Majzoobi *et al.* 2012).

Baking of cake

A 250 g sample of cake batter was placed into rectangular metallic pans (80 mm width, 175 mm length and 50 mm depth), and baked at 180ºC in an electric oven (Nanerazavi Co., Mashhad, Iran) for 35 minutes. Cakes were removed from the pans and left at room temperature for 1 hour. The cakes were then sealed in polyethylene bags to be prevented from becoming dry.

Cake Height and Volume

A digital caliper was an made use of for cake height determination. Cake volume was determined according to rapeseed displacement method one hour after being removed from the oven as described by the Approved Methods of the AACC (2000) (Method No. 10-10-B).

Color Assessement

An assessment of color parameters of the cakes' crust and crumb was carried out according to the method described by Afshari-Jouybari and Farahnaky (2011) based upon a quantitative analysis of *L, a,* and *b* values of samples using Photoshop Software. *L*-value shows lightness, *a* indicates greenness-redness while *b* representing blueness-yellowness of the samples. A digital camera (Canon, model IXUS 230 HS, 14.0 Megapixels, Japan) was employed to take high resolution pictures of the samples. Lightness, contrast and resolution of all images were set at 60%, 60% and 300 dots per inch (dpi), respectively. To determine the crust color, pictures were taken from the whole crust, while to determine the crumb color pictures were taken from cross sections of cakes and saved as JPEG files. The color parameters of cakes were determined in the "*Lab*" mode of Adobe Photoshop 8 Software.

Texture Analysis

Crumb texture was studied using a Texture Analyser (TA-XT2, Stable Micro System Ltd., Surrey, UK) which was interfaced with a computer to control the instruments and analyze the data. The analyzer was equipped with the software ''Texture Exponent Lite''. Cake slices (30× 30×30 mm), were cut from the center before being placed on the platform of the Texture Analyser. An Aluminum cylindrical probe of the diameter of 80 mm was made use of in a ''Texture Profile Analysis'' (TPA) test to compress the samples to 25% depth, at a pretest speed of 5 mm s^{-1}, test speed of 0.25 mm s^{-1}, time interval of 10 seconds. Hardness (peak force of first compression cycle), cohesiveness (ratio of positive areas of second cycle to area of the first cycle), springiness (the distance that the cake recovered in its height during the time that elapsed between the end of the first bite and the start of the second bite), the slope (gradient) of force-deformation curve and maximum force of the first bite of TPA test were estimated from the TPA curve and taken as indications of the crumb texture.

Sensory Evaluation

The organoleptic characteristics of cakes were evaluated through the judgement of 12 panelists (6 males and 6 females, ages between 20-30 years). The panelists were asked to evaluate the cakes on the basis of approval of the color, texture, taste and overall quality on a 5-point hedonic scale. The value scales' ranged from 5 (like, extremely) to 1 (extreme dislike) for each organoleptic attribute. Samples were served on white plastic dishes and presented in random. For rinsing between samples, drinking water was available to the assessors.

Statistical Analysis

To evaluate the impact of RS on batter and cakes' properties the experiments were done in a completely randomized design and performed at least in triplicate. Analysis of Variance (ANOVA) was used to made use of the differences between samples. To determine the significances within treatments at $P< 0.05$, Duncan's Multiple Range Test was employed. The results were statistically analysed using SPSS software (SPSS, Inc., USA).

RESULTS AND DISCUSSION

Batter Consistency

Bostwick number determines consistency through an estimation of the distance which batter flows in 30 seconds. Thus a larger number recorded means a lower batter consistency. As observed from Table 1, batters incorporating RS showed lower consistencies as compared with the control. By an increase in RS content a progressive decrease in Bostwick number from 8.6 cm (for the control) to 10.1 cm (for 30% RS) was observed. Similar results have been reported for muffins (containing RS) by Baixauli *et al.* (2008b), associated with a dilution of the gluten in the system. Gluten is of a much higher water holding capacity than RS. Therefore, when the gluten concentration is reduced, the RS starch cannot fully compensate for the functioning

Table 1. Effect of different levels of Resistant Starch (RS) on the physical properties of batter and cake.[a]

RS (%)	Bostwick number (cm)	Batter density (g/cm^3)	Cake density ($g\ cm^{-3}$)	Cake volume (cm^3)	Cake height (cm)
0	8.6±0.10[d]	1.017±0.001[a]	0.376±0.006[b]	552.70±2.50[a]	4.71±0.04[a]
10	8.9±0.10[c]	0.937±0.002[b]	0.390±0.009[a]	550.66±1.50[a]	4.60±0.10[a]
20	9.4±0.10[b]	0.847±0.001[c]	0.394±0.003[a]	542.33±2.50[b]	4.33±0.06[b]
30	10.1±0.10[a]	0.773±0.001[d]	0.406±0.003[a]	512.10±3.00[c]	3.96±0.06[c]

[a] Mean values±standard deviation. Values followed by different letters in the same column are significantly different ($P< 0.05$).

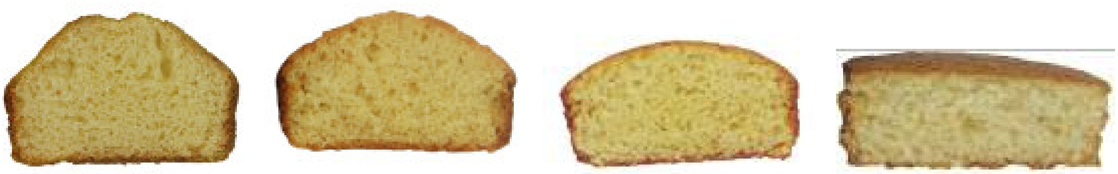
of the gluten. Consequently, the free water can reduce batter consistency. However, Gómez *et al.* (2010) reported that inclusion of other fibers such as sources wheat and oat bran as well as microcrystalline cellulose increased batter consistency. Apparently, the molecular structure of the fiber and its ability to interact with water greatly influence the batter consistency. Either too high or too low consistency results in an inferior cake quality. If the batter consistency is too low, it cannot preserve air bubbles during baking and would adversely affect cake volume. Too high consistency also averts the needed expansion from the cake.

Table 1 gives the density of the batter containing different levels of RS. Density presents the quantity of air bubble incorporation into the batter. The addition of RS to the batter reduced the density. In general, the changes were more pronounced with larger substitution percentages. The same results have already been reported by Sanz *et al.* (2008a) and Baixauli *et al.* (2008b) after the incorporation of RS to muffin batter. Batter density is an indicator of total air holding capacity but does not determine the bubble dispersion or size (Zhou *et al.,* 2011). Thus RS may have caused large bubble size in the batter that may burst in the oven causing the collapse of the cake (Allais *et al.,* 2006).

Cake Properties

Cake Volume, Density and Height

Table 1 shows the results of replacing flour with RS. Replacement of flour with RS caused an increase in cake density from 0.376 to 0.406 $g\ cm^{-3}$ and a decrease in the volume from 552.70 to 512.10 cm^3. The extent of the influence was correlated with the wheat flour replacement level. Early gelatinization of starch is the key factor in cake volume and quality (Wilderjans *et al.*, 2010). RS is not only resistant to digestion but also to gelatinization in most food processing conditions and plays the role of a filler and will not gelatinize readily during baking (Korus *et al.*, 2009; Wilderjans *et al.,* 2010). Thus, inclusion of RS in cake formulation may cause a decrease in cake volume. The decrease in the cake volume is also related to the decrease in batter density and consistency as discussed earlier. Figure 1 shows the cross-section of the cakes



0% 10% 20% 30%

Figure 1. Cross-section of the cakes containing different levels of resistant starch.

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produced in this study. It can be clearly observed that the height of the cakes decreased with the cakes becoming flatter and losing their symmetrical shape with an increase in RS level. The data obtained from Table 1, shows a significant reduction of cake height from 4.71 cm for the control to 3.96 cm for the 30% RS added cake.

Cake Texture

The textural parameters assessed from TPA test curves are presented in Table 2. A marked decrease in hardness from 0.430 to 0.107 kg was observed. On the other hand, the cake became softer with increasing RS level. A similar trend was observed for gradient as it is also an indication of cake hardness. Previous results have revealed a positive correlation between cake volume and softness (Gómez *et al.,* 2010). This was not the case in this study since addition of RS resulted in lower cake volume (Table 1) but softer texture. Cake softness is related to many factors such as the internal structure and moisture content of the cake. Throughout the present study, dilution of gluten and a lack of gel formation by RS during the baking process resulted in a lower mechanical energy accompanied by a formation of an undeveloped gluten network (Sanz *et al*., 2009). Cohesiveness, springiness, and chewiness of the cakes all decreased significantly with an increase in the level of RS. This may be attributed to the denser matrix of the cakes and therefore the samples being less able to recover after deformation. The results were in conformity with those in the study by Baixauli *et al.* (2008 a) for RS containing muffins.

Cake Color

The effects of RS addition on cake color are shown in Table 3. Significant differences were observed between the crust and crumb of the control cakes *vs.* the cakes baked from RS enriched batters. In terms of crumb, replacement of flour with RS resulted in a significant increase in *L* while decrease in *b*-value, indicating lighter *vs.* less yellowish crumb. Crumb color is affected by the

Table 2. Effect of different levels of Resistant Starch (RS) on textural properties of cake.[a]

RS level (%)	Hardness (kg)	Gradient (g s^{-1})	Cohesiveness	Springiness	Chewiness (kg)
0	0.430±0.002[a]	0.073±0.010[a]	0.860±0.010[a]	0.958±0.002[a]	0.305±0.002[a]
10	0.310±0.002[b]	0.057±0.003[b]	0.830±0.003[b]	0.948±0.001[b]	0.204±0.002[b]
20	0.236±0.001[c]	0.036±0.001[c]	0.826±0.001[b]	0.939±0.002[c]	0.151±0.001[c]
30	0.107±0.002[d]	0.016±0.001[d]	0.727±0.001[c]	0.868±0.002[d]	0.049±0.002[d]

[a] Mean values±standard deviation. Values followed by different letters in the same column are significantly different (P< 0.05).

Table 3. Effect of different levels of Resistant Starch (RS) on color of crust and crumb of the cakes.[a]

RS level (%)	Crust (L)	Crust (a)	Crust (b)	Crumb (L)	Crumb (a)	Crumb (b)
0	40.3±0.6[c]	9.7±0.6[a]	26.6±1.0[a]	68.0±2.0[d]	-4.7±0.6[a]	42.0±1.0[a]
10	40.0± 0.6[c]	8.3± 0.6[b]	24.0±1.0[b]	71.6±1.2[c]	-6.3±0.6[b]	40.3±0.6[a]
20	42.0±1. 0.[b]	7.0±1. 0.[c]	21.7±1.2[c]	74.3±0.6[b]	-6.6±1.2[b]	37.3±0.6[b]
30	47.7± 0.6[a]	5.3± 0.6[d]	14.7±1.2[d]	78.0±1.0[a]	-8.3±0.6[c]	30.3±1.0[c]

[a] Mean values±standard deviation. Values followed by different letters in the same column are significantly different (P< 0.05).

constituents in the formulation (Majzoobi *et al.,* 2012). RS is of white color and hence acts in diluting the pigmented components of the cake formulation. Therefore, the lightness of the samples increased with an increase in the RS level. Furthermore, increasing the level of RS reduces the sugar and amino acid content of the cakes, preventing Millard and caramelization reactions as the key reactions in crust color. Increasing the amount of RS resulted in lighter and less reddish crust. Baixauli *et al.* (2008 a) have also reported similar results for the RS containing muffins.

Sensory Evaluation

Results pertaining to sensory evaluation are presented in Figure 2. Textural properties are critical parameters in the cake quality. It was observed that incorporation of RS imparts softness and tenderness to cake texture, a phenomenon favorable to consumers. However, inclusion of RS by 30% significantly decreased the texture score. Samples containing different levels of RS were similar in taste, crust and crumb color to those of the control. However, possibly because of the negative effects of RS on the texture of the samples, the overall acceptance of the samples was reduced as the level of RS content was increased to 30%.

CONCLUSIONS

Based upon the results obtained, it may be concluded that RS can be used as a dietary fiber in cake formulation due to its positive physiological impacts on human health and at the same time lower impact on cake functional properties as compared with other sources of fiber. However, addition of higher levels of RS (more than 20%) can have some undesirable effects on physicochemical properties of cakes. The main undesirable effects of RS on the cakes were comprised of the reduction in the cake volume and textural properties in terms of appropriate softness, integrity of the crumb structure, springiness as well as chewiness. These changes were also reported by the panelists when a 30% of RS was used. Therefore, it can be suggested that RS may be used in the production of sponge cake at maximum level of 20% without any significant undesirable effects on the cake overall sensory properties. Further works are

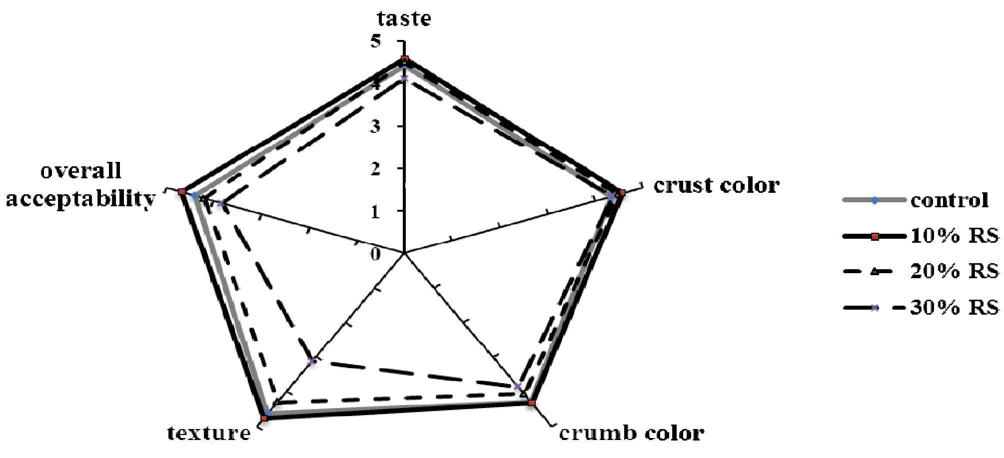

Figure 2. Sensory evaluation results obtained from the cakes containing different levels of Resistant Starch (RS).

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needed to address the probable undesirable effects of higher levels of RS on the cake quality.

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تاثیرات نشاسته مقاوم ذرت بر خصوصیات فیزیکوشیمیایی کیک

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چکیده

افزایش فیبر غذایی در غذاها می تواند خطر بسیاری از بیماریهای مهم را کاهش دهد و سلامتی انسان را تقویت نماید. کیک جزء غذاهای پرمصرفی به شمار می آید که مقدار فیبر کمی دارد. بنابراین افزایش مقدار فیبر کیک دارای اهمیت بسیاری است که در این تحقیق دنبال شد. آرد گندم به طور نسبی با نشاسته مقاوم ذرت به عنوان منبع فیبر غذایی در سطوح ۰، ۱۰، ۲۰ و ۳۰٪ (وزنی/وزنی) جایگزین شد و در تولید کیک اسفنجی به کار رفت. نتایج بدست آمده نشان داد که با افزایش درصد نشاسته مقاوم قوام خمیر کیک افزایش یافت در حالی که دانسیته آن کاهش پیدا کرد. بافت کیک نرمتر شد ولی پیوستگی، فنریت، صمغی بودن و قابلیت جویدن آن کاهش یافت. همچنین رنگ کیک ها روشنتر شد ولی قرمزی و زردی آن کاهش یافت. افزودن کمتر از ۳۰٪ نشاسته مقاوم تاثیر معنی داری بر خصوصیات حسی-چشایی کیک نداشت. در مجموع نتیجه گیری شد که بیشترین سطح نشاسته مقاوم درفرمول کیک اسفنجی ۲۰٪ می باشد که محصول قابل قبولی را تولید نماید.

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