Effect of native and gelatinized starches from various sources on sponge cake making characteristics of wheat flour

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Abstract Effect of addition of native and gelatinized starches from various sources (CS, corn; WCS, waxy corn starch; WS, wheat; PS, potato starch; KB, kidney bean SP, sweet potato; and RS, rice starch) on viscoelasticity and sponge-making properties of wheat flour (WF) was investigated. Sponge cakes prepared using native and gelatinized starches were compared to those prepared with 100% WF. The addition of gelatinized starches from various botanical sources led to increase in batter viscosity (increased storage and loss modulus and decreased $\tan \delta$) of batter. Sponge cakes made with addition of native and gelatinized starches from different botanical sources showed higher springiness, specific volume and cohesiveness. Firmness of sponge cakes showed variation among botanical sources and type (native or gelatinized) of starch. Sponge cakes prepared from gelatinized RS showed firmer texture. The crust color became more reddish brown on addition of gelatinized starch from all sources, however, crumb color varied with the source. Overall, it was observed that addition of gelatinized starches resulted in sponge cakes with softer texture and better organoleptic properties as compared to those made from WF.

Keywords Sponge cakes · Gelatinized starch · Rheological characteristics · Textural properties · Sensory

Abbreviations

CS Corn starch
WCS Waxy corn starch

WS Wheat starch
RS Rice starch
PS Potato starch
KB Kidney bean
SP Sweet potato

Introduction

Demand for low-fat products has increased but development of such products with reduced fat is challenge as it adversely affects organoleptic properties like appearance, odor, taste, texture and mouth feel (Pareyt et al. 2009; Zoulias et al. 2002). Starch generally served as important carbohydrate source in most of cereal-based products, and contributed to important properties such as retention of moisture, viscosity, improved texture and mouth-feel, increased shelf-life of products during processing and storage (Wang and Copeland 2013). Native starches showed narrow applications in food industries due to their limited solubility in water. Modification techniques help to overcome these limitations by inducing structural changes in starch molecules which showed stronger ability of starches to hydrolyze into smaller molecules. Quality attributes of many products which were found mainly due to some desirable properties like pasting, gelatinization and retrogradation properties of starch were influenced by the use of additives (Copeland et al. 2009). Functional attributes of starches as swelling capacity, pasting behavior, viscosity, solubility, binding and bulking capacities, waxy and non-waxy characteristics are employed during various food formulations by the food processing industries (Khatkar et al. 2009). Ebrahimi et al. (2016) studied about the problem of early staling of cakes and aimed at improving the quality and increased shelf life of cakes by

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utilizing modified starches. Thus, modified starches were utilized as additives to improve their quality.

Keeping in view the above considerations, starches from different botanical sources were used for the preparation of sponge cakes aiming for better consumer acceptability and longer shelf life as compared to those prepared those prepared using WF.

Materials and methods

Materials

Refined wheat flour (maida), baking powder, eggs, ground sugar were procured from local market for cake making. Starches used for preparation were extracted from commercial varieties using laboratory methods as described by Bajaj et al. (2018).

Preparation of sponge cakes

The method used for sponge cakes preparation was flour (50 g), sugar (50 g), whole egg contents (50 g), baking powder (3.33 g). Eggs and sugar were beaten using hand blender for 2 min (speed 4) and then (speed 2) for next 2 min until stiff peak is attained. Starch (30%) both native and gelatinized, refined wheat flour and baking powder were mixed using cut fold method until smooth batter was achieved. The batter was then poured into moulds and baked (160 °C) for 15–18 min in baking oven (National Manufacturing Company, Lincoln, NE, USA). After baking, sponge cakes were cooled to room temperature before further analysis.

Rheological properties

Dynamic viscoelasticity was measured using dynamic rheometer (Haake RS 6000 mfg. by Thermo Electron, Karlsruhe, Germany) as illustrated by Shevkani and Singh (2014). Briefly, batter was equilibrated for 300 s at 25 °C between parallel plates of rheometer, stress (0.1 Pa) and frequency (1 rad/s) was set as instrument parameters respectively. Storage modulus (G'), loss modulus (G'') and $\tan \delta$ ($\tan \delta = G''/G'$) was measured at 25 °C.

Hunter color characteristics

Hunter color characteristics (L^* , a^* , b^* and dE) of sponge cakes for both crust and crumb of sponge cakes were measured using Ultra Scan VIS Hunter Lab (Hunter Associates Laboratory Inc., Reston, VA, USA). Overall color change (ΔE) was calculated according to the equation

$$\Delta E = \sqrt{[(L^* - L^*_n)^2 + (a^* - a^*_n)^2 + (b^* - b^*_n)^2]}.$$

Textural properties

Texture profile analysis of sponge cakes prepared using native and gelatinized starches was performed using texture analyzer (TA/TX2-plus; Stable Micro systems, Surrey, UK) equipped with load cell (5 kg). 1 cm³ cubes of crumb were placed on platform (HD P/90) using 75-mm probe (P/75) and were subjected to compression (50%) at test speed of 1 mm/s. Textural characteristics were calculated from using formulae as given by Bourne (1978).

Sensory characteristics

Sensory evaluation of sponge cakes prepared using native and gelatinized starches from different botanical sources was completed as discussed by Singh et al. (2015). Ten semi-trained panelists were randomly presented with sponge cake samples and were evaluated for various textural parameters (color, texture, taste, and overall acceptability) using a 9-point hedonic scale.

Statistical analysis

The data was reported as the average of triplicate observations. Data was then subjected to two way analysis of variance (ANOVA) using Minitab Statistical Software (MINITAB 14.12.0, State College, PA).

Results and discussion

Rheological characteristics of cake batter

Rheological characteristics (G' , G'' and $\tan \delta$) of sponge cake batters prepared using native and gelatinized starches from different botanical sources are shown in Table 1. Rheological spectra are illustrated in Fig. 1. G' (storage modulus) was found greater than G'' (loss modulus) for batter prepared with both native and gelatinized starches which indicated typical liquid like behavior. Cake batter with 100% wheat flour (control) showed G' and G'' with 6909 and 6240 Pa respectively while $\tan \delta$ was 0.90. On addition of native and gelatinized starches, G' and G'' decreased in comparison with the control with minimum value observed 2617 Pa and 1644 Pa respectively for batter with gelatinized WS while the maximum 16,280 Pa and 6924 Pa respectively was observed for gelatinized PS batter. $\tan \delta$, which is ratio of G'' and G' . WF showed the highest $\tan \delta$, indicating more liquid than solid like behavior (Ronda et al. 2011). Incorporation of gelatinized

Table 1 Effect of blending native and gelatinized starches (30%) from different botanical sources with wheat flour on cake batter rheology

Botanical source	Type	G'	G''	Tan δ
Wheat flour (70%)	–	6909	6240	0.9
Corn starch	Native	5756	4422	0.77
	Gelatinized	4226	3080	0.72
Potato starch	Native	5174	3428	0.66
	Gelatinized	16,280	6924	0.42
Wheat starch	Native	4551	3717	0.81
	Gelatinized	2617	1644	0.62
Rice starch	Native	4792	3172	0.66
	Gelatinized	1423	1121	0.78
Kidney bean starch	Native	5030	2581	0.51
	Gelatinized	10,616	2076	0.19
Waxy corn starch	Native	12,535	5275	0.42
	Gelatinized	17,512	3819	0.21
Sweet potato starch	Native	7179	4133	0.57
	Gelatinized	7388	2288	0.3

*Values represent mean $\pm$ standard deviation. Means with different superscripts in the same column are significantly different ($P \leq 0.05$); the number of replications (n), $n \geq 3$

starch showed significant decrease in viscoelasticity of cake batter. Viscoelasticity played an important role that determined the quality of end products. The sponge cake batter showed enough viscosity for gas bubbles to trap during mixing and should retain during baking. Batter with lower or higher viscosity resulted in cakes with lower volume (Gomez et al. 2010; Wilderjans et al. 2008). Frequency sweeps illustrated effect of shear or stress on viscoelastic behavior of batter while amplitude was kept constant (Steffe 1996). All cake batters prepared using both native and gelatinized starches showed shear-dependent behavior as represented by increase in G' and G'' with increase in frequency (Fig. 2). Cake batter prepared with gelatinized starches showed higher moduli compared to those prepared using native starches which showed enhancement in batter viscoelasticity which seemed to be due to water absorption by starches upon cooking (Wilderjans et al. 2010). The increase in water absorption during cooking of starches showed reduced free water availability and hence increased the viscoelastic behaviour compared to cake batter prepared using 100% wheat flour (Anastasiades et al. 2002).

Hunter color characteristics of crust and crumb of sponge cakes

The appearance of crust and crumb of sponge cakes are illustrated in Fig. 2. Hunter color parameters of sponge

cakes are shown in Table 2. Color characteristics showed significant variation with addition of both native and gelatinized starches. The cakes prepared using native starches were lighter in color compared to those prepared using gelatinized starches which showed development of attractive reddish brown color with glossy surface. The development of crust color has been reported to depend upon duration and temperature of baking because of caramelization of sugars and milliard reactions (Rochers et al. 2004). These reactions not only help in development of color but also improve the texture and flavor of sponge cakes. The crust of cakes prepared using native starches showed higher L^* values and lower a^* values as compared to those prepared using gelatinized starches. The increase in redness (a^*) values in crust of cakes prepared using gelatinized starches may be due to accelerated Milliard reaction by exposing more sugars for reaction to produce reddish brown color and glossy texture. The incorporation of gelatinized starches also significantly affected the color of crumb. The crumb of cakes prepared using gelatinized starches significantly higher a^* values compared to cakes prepared using native starches. Crumb of cakes prepared using PS showed the highest L^* value while those prepared using gelatinized starch from WS and SP showed the highest a^* value. The differences in crumb color in sponge cakes prepared using starches from different botanical sources may be due to composition and color of starch source. Surface glossiness showed higher value with increased level of substitution. a^* and b^* values affected significantly by replacing WF with both native and gelatinized starches. Muffins prepared using resistant starch showed lighter color than those prepared without resistant starch due to diluting effect on the pigmented ingredients in the recipe (Baixauli et al. 2008). Furthermore, significant differences were observed in porosity and appearance of crumb among the cakes made with native or gelatinized starches. Cakes prepared using gelatinized starches showed less porous structure with lesser number of air cells as compared to cakes prepared using native starches. The sponge cakes prepared using gelatinized starches was glossy with shrinkage of outer surface. Baixauli et al. (2008) also reported lesser air cells in muffins prepared with resistant starch as compared to those made without resistant starch.

Textural characteristics of sponge cakes

Textural characteristics (firmness, springiness, cohesiveness and resilience) are of prime importance for preparation of cakes as they specify consumer acceptance. The textural characteristics of cakes prepared using native and gelatinized starches are compared in Table 3. Firmness is the maximum force required to compress the crumb of cake

under a constant deformation. It ranged from 1.40 N for WCS to 3.62 N for KB. Firmness decreased with addition of gelatinized starches as compared to native starches. Cohesiveness determines internal resistance of food when under compression (Baeva et al. 2000). Product with higher cohesion showed greater resistance to manufacturing,

packaging and delivery stresses, and thus reached consumers in its expected state. It was observed that cohesiveness increased with addition of gelatinized starches as compared to those prepared using native starches. Springiness which is addressed as indicator of elasticity is a desirable property associated with elastic and fresh aerated

Fig. 1 Effect of blending of native and gelatinized starches (at level of 30%) from different botanical sources with wheat flour on cake batter rheology

product (Shevkani and Singh 2014). Springiness decreased for sponge cakes prepared using of gelatinized starches compared to those with native starches. Springiness was observed the lowest for cake prepared using gelatinized SP starch (0.56) followed by WCS (0.69) while it was observed the highest for cakes prepared using gelatinized CS. Lu et al. (2010) also reported increase in firmness which ranged from 1.73 N to 3.72 N and decrease in springiness of sponge cakes from 0.92 to 0.71 N s for

sponge cakes incorporated with varying level of green tea powder. These results were found consistent with our results for sponge cakes when prepared using native and gelatinized starches. Resilience represented by the ratio of recoverable energy with first compression is relieved. It increased with the addition of gelatinized starches. It was observed that textural properties for sponge cakes were positively correlated with one another, while they were found to be negatively correlated with rheological parameters (Mastakidou et al. 2010). Similar results were observed for sponge cakes prepared using native and gelatinized starches.

Fig. 1 continued

Fig. 2 Images of crust and crumb of sponge cakes prepared using native and gelatinized starches from different botanical sources

Fig. 2 continued

Table 2 Hunter color characteristics of crust and crumb of sponge cakes prepared using native and gelatinized starches (30%) from different botanical sources

Botanical source	Type	Crust			Crumb		
		<i>L</i> *	<i>A</i> *	<i>B</i> *	<i>L</i> *	<i>A</i> *	<i>B</i> *
Wheat flour (70%)	Control						
	Native	60.46 ± 2.54 ^a	7.57 ± 0.25 ^{cd}	31.32 ± 1.05 ^a	68.50 ± 2.76 ^b	0.61 ± 0.09 ^b	33.03 ± 0.06 ^f
Corn starch	Native	72.37 ± 0.06 ^c	7.79 ± 0.02 ^{cd}	38.84 ± 0.01 ^f	82.51 ± 0.04 ^g	0.22 ± 0.00 ^a	26.80 ± 0.12 ^a
	Gelatinized	61.57 ± 0.05 ^b	5.53 ± 0.01 ^a	31.91 ± 0.02 ^a	69.57 ± 0.05 ^c	1.02 ± 0.01 ^e	29.91 ± 0.03 ^d
Potato starch	Native	74.32 ± 0.22 ^e	9.70 ± 0.01 ^f	36.54 ± 0.08 ^d	83.38 ± 0.22 ^h	0.84 ± 0.00 ^d	28.43 ± 0.57 ^c
	Gelatinized	70.28 ± 0.03 ^d	9.08 ± 0.01 ^e	38.94 ± 0.01 ^f	80.85 ± 0.03 ^f	1.01 ± 0.01 ^e	28.76 ± 0.03 ^c
Rice starch	Native	72.86 ± 2.89 ^e	7.36 ± 0.17 ^c	37.43 ± 1.22 ^e	82.24 ± 3.13 ^g	0.33 ± 0.00 ^a	32.17 ± 0.00 ^f
	Gelatinized	59.92 ± 0.05 ^a	6.85 ± 0.01 ^b	34.45 ± 0.01 ^b	69.45 ± 0.05 ^c	1.12 ± 0.00 ^e	29.13 ± 0.00 ^d
Wheat starch	Native	63.44 ± 0.50 ^c	8.77 ± 0.59 ^e	38.21 ± 0.27 ^f	74.59 ± 0.49 ^e	0.54 ± 0.01 ^b	29.41 ± 0.05 ^d
	Gelatinized	61.84 ± 0.08 ^b	10.94 ± 0.01 ^g	35.44 ± 0.02 ^c	72.11 ± 0.07 ^e	2.90 ± 0.02 ^g	27.65 ± 0.01 ^b
Waxy corn	Native	63.63 ± 0.07 ^c	11.01 ± 0.00 ^h	35.01 ± 0.02 ^c	73.46 ± 0.07 ^e	0.30 ± 0.01 ^a	30.95 ± 0.01 ^e
	Gelatinized	70.36 ± 0.06 ^d	9.54 ± 0.01 ^f	35.01 ± 0.03 ^c	79.17 ± 0.06 ^f	1.68 ± 0.01 ^f	28.87 ± 0.05 ^c
Sweet potato	Native	74.29 ± 0.09 ^f	8.30 ± 0.00 ^e	31.41 ± 0.04 ^a	80.66 ± 0.10 ^f	4.21 ± 0.01 ^h	29.38 ± 0.03 ^d
	Gelatinized	71.18 ± 0.12 ^d	8.61 ± 0.02 ^e	38.10 ± 0.06 ^f	72.52 ± 0.17 ^c	0.15 ± 0.03 ^a	26.44 ± 0.02 ^a
Kidney bean starch	Native	61.21 ± 0.11 ^b	11.07 ± 0.01 ^h	35.95 ± 0.07 ^{cd}	71.85 ± 0.13 ^d	0.75 ± 0.01 ^c	29.95 ± 0.00 ^d
	Gelatinized						

*Values represent mean ± standard deviation. Means with different superscripts in the same column are significantly different ($P \leq 0.05$); the number of replications (n), $n \geq 3$

Table 3 Textural characteristics of sponge cakes prepared using native and gelatinized starches (30%) from different botanical sources

Botanical source	Type	Firmness (N)	Springiness	Cohesiveness	Gumminess	Resilience
Wheat flour (70%)						
Control	–	2.67 ± 0.03 ^{cd}	0.83 ± 0.01 ^d	0.62 ± 0.03 ^a	1.55 ± 0.03 ^c	0.21 ± 0.01 ^a
Corn starch	Native	1.97 ± 0.05 ^b	0.82 ± 0.16 ^d	0.68 ± 0.01 ^a	1.22 ± 0.01 ^d	0.34 ± 0.02 ^b
	Gelatinized	1.36 ± 0.12 ^a	0.89 ± 0.24 ^f	0.75 ± 0.05 ^b	1.27 ± 0.15 ^d	0.38 ± 0.12 ^c
Wheat starch	Native	2.79 ± 0.01 ^d	0.83 ± 0.18 ^d	0.62 ± 0.10 ^a	1.84 ± 0.10 ^f	0.23 ± 0.05 ^a
	Gelatinized	1.29 ± 0.15 ^a	0.86 ± 0.12 ^e	0.74 ± 0.13 ^b	0.68 ± 0.06 ^b	0.37 ± 0.07 ^c
Waxy corn starch	Native	1.40 ± 0.03 ^a	0.69 ± 0.26 ^c	0.74 ± 0.20 ^b	1.43 ± 0.01 ^e	0.35 ± 0.12 ^b
	Gelatinized	1.56 ± 0.01 ^{ab}	0.84 ± 0.01 ^d	0.85 ± 0.05 ^d	0.82 ± 0.09 ^c	0.32 ± 0.14 ^b
Potato starch	Native	1.98 ± 0.06 ^b	0.86 ± 0.05 ^e	0.75 ± 0.02 ^b	0.79 ± 0.13 ^c	0.37 ± 0.08 ^c
	Gelatinized	2.16 ± 0.011 ^c	0.84 ± 0.04 ^d	0.70 ± 0.13 ^a	1.53 ± 0.23 ^e	0.32 ± 0.06 ^b
Sweet potato starch	Native	1.93 ± 0.15 ^b	0.56 ± 0.07 ^b	0.81 ± 0.08 ^d	2.59 ± 0.04 ^g	0.49 ± 0.12 ^d
	Gelatinized	2.04 ± 0.20 ^b	0.32 ± 0.13 ^a	0.87 ± 0.12 ^d	5.27 ± 0.01 ⁱ	0.42 ± 0.18 ^d
Rice starch	Native	1.65 ± 0.04 ^{ab}	0.84 ± 0.10 ^d	0.79 ± 0.01 ^c	0.34 ± 0.06 ^a	0.43 ± 0.21 ^d
	Gelatinized	3.62 ± 0.16 ^c	0.83 ± 0.08 ^d	0.68 ± 0.15 ^a	0.34 ± 0.12 ^a	0.43 ± 0.02 ^d
Kidney bean starch	Native	2.24 ± 0.24 ^c	0.84 ± 0.02 ^d	0.77 ± 0.07 ^c	4.35 ± 0.05 ^h	0.42 ± 0.04 ^d
	Gelatinized	3.28 ± 0.14 ^c	0.75 ± 0.18 ^{cd}	0.78 ± 0.20 ^c	4.25 ± 0.16 ^h	0.46 ± 0.13 ^d

*Values represent mean ± standard deviation. Means with different superscripts in the same column are significantly different ($P \leq 0.05$); the number of replications (n), n ≥ 3

Table 4 Sensory characteristics of sponge cakes prepared using native and gelatinized starches (30%) from different botanical sources

Botanical source	Type	Colour	Aroma	Taste	Texture	Overall acceptability
Wheat flour (70%)						
Control	–	9.20 ^c ± 0.06	8.60 ^d ± 0.05	8.75 ^f ± 0.12	8.42 ^d ± 0.06	8.25 ^b ± 0.10
Corn starch	Native	9.56 ⁱ ± 0.12	7.42 ^a ± 0.02	8.43 ^e ± 0.11	9.26 ^h ± 0.03	9.75 ^h ± 0.25
	Gelatinized	9.42 ^h ± 0.14	9.25 ^g ± 0.12	9.12 ^h ± 0.18	9.86 ^j ± 0.12	9.43 ^f ± 0.06
Wheat starch	Native	9.04 ^c ± 0.03	9.01 ^f ± 0.10	9.34 ^j ± 0.01	8.75 ^e ± 0.12	8.35 ^c ± 0.14
	Gelatinized	9.24 ^f ± 0.12	9.06 ^f ± 0.12	9.32 ^j ± 0.16	8.95 ^f ± 0.08	8.33 ^c ± 0.10
Waxy corn starch	Native	8.26 ^a ± 0.06	7.32 ^a ± 0.14	7.25 ^c ± 0.12	7.68 ^b ± 0.14	6.65 ^a ± 0.08
	Gelatinized	8.62 ^b ± 0.14	8.50 ^c ± 0.06	6.34 ^a ± 0.03	6.40 ^a ± 0.06	6.79 ^a ± 0.16
Potato starch	Native	9.36 ^g ± 0.10	8.78 ^e ± 0.12	8.92 ^g ± 0.13	9.58 ⁱ ± 0.03	9.05 ^d ± 0.12
	Gelatinized	9.20 ^c ± 0.06	8.25 ^b ± 0.10	8.25 ^d ± 0.10	8.25 ^c ± 0.10	8.25 ^b ± 0.10
Sweet potato starch	Native	9.20 ^c ± 0.12	9.55 ^h ± 0.25	6.75 ^b ± 0.25	8.52 ^d ± 0.25	8.26 ^b ± 0.25
	Gelatinized	9.42 ^g ± 0.14	9.32 ^g ± 0.06	9.22 ⁱ ± 0.06	9.12 ^g ± 0.06	9.08 ^d ± 0.06
Rice starch	Native	9.04 ^c ± 0.03	8.35 ^c ± 0.14	9.35 ^j ± 0.14	9.24 ^h ± 0.14	9.61 ^g ± 0.14
	Gelatinized	9.24 ^f ± 0.12	9.13 ^f ± 0.10	9.23 ⁱ ± 0.10	9.13 ^g ± 0.10	9.21 ^e ± 0.10
Kidney bean starch	Native	9.16 ^d ± 0.06	8.65 ^d ± 0.08	8.23 ^d ± 0.08	8.21 ^c ± 0.08	8.28 ^b ± 0.08
	Gelatinized	9.22 ^f ± 0.14	8.23 ^b ± 0.16	8.79 ^e ± 0.16	8.18 ^c ± 0.16	8.20 ^b ± 0.16

*Values represent mean ± standard deviation. Means with different superscripts in the same column are significantly different ($P \leq 0.05$); the number of replications (n), n ≥ 3

Sensory characteristics

The sensory scores for starch based sponge cakes are shown in Table 4. Sensory characteristics (color, taste, odor, texture and overall acceptability) for both native and

gelatinized starch based sponge cakes ranged from 6.65 for WCS to 9.75 for CS, 8.26 to 9.56, 6.34 to 9.34 and 6.40 to 9.86 respectively. Sponge cakes prepared using native CS showed the highest score while those prepared from WCS scored the lowest for all sensory parameters. The results

indicated that sponge cakes can be prepared using both native and gelatinized starches with good overall consumer acceptability comparable to those prepared using WF.

Conclusion

The study revealed that sponge cakes prepared using native and gelatinized starches from various sources were found comparable to those prepared using 100% WF. The incorporation of native and gelatinized starches in sponge cakes showed positive attributes on the batter and sponge cake characteristics. Starches (native and gelatinized) incorporated showed significant increase in viscoelasticity of cake batters. More viscous batters as in case of PS and SP retained more air bubbles and thus resulted in sponge cakes with softer texture and better volume. Thus, it was concluded that incorporation of gelatinized starches in sponge cakes showed better color and overall acceptability.

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