Effect of Pre-gelatinized Wheat Starch on Physical and Rheological Properties of Shortened Cake Batter and Cake Texture

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***Abstract*—The focus of this study was the effect of 1.5%, 3% and 4.5% pre-gelatinized wheat starch (based on the total weight of cake batter) on improving the qualitative properties of shortened cake batter. Specific volume and viscosity of the shortened cake batter were measured for controls, 1.5%, 3% and 4.5% gelatinized starch; some important properties such as texture and sensory evaluation were examined. By increasing pre-gelatinized wheat starch used in the batter, a significant difference was observed in the rheological properties of the batter. Cake batter properties were found improved compared to the control samples. The sample with 3% pre-gelatinized starch had a lower viscosity than other treatments. The treatment with 4.5% pre-gelatinized starch had the lowest specific volume compared to other treatments. The overall results showed that the shortened cake with 3% pre-gelatinized starch was the best treatment in terms of texture and sensory evaluation factors.**

Keywords-pre-gelatinized wheat starch; rheological properties; shortened cake batter; viscosity

I. INTRODUCTION

Currently, there are many producers of baking products such as breads, cakes, muffins and biscuits in Iran. According to the Association of Iranian Confectionery Manufacturing Companies, over 240,000 tons of cake is produced annually for use in domestic and foreign markets [1]. One of the important problems with cakes is that they stale fast. They quickly lose their freshness within a few days and become leathery and hardly chewable. Economically, it is important to keep cakes fresh. Flat cakes have generally very short shelf life; thus, additives such as modified starch can improve their quality [2, 3]. The main ingredients of cake are flour, sugar, eggs and fat, each of which has an important role in the structure and quality of the product [4]. Extensive research has been conducted on the material and process conditions of cake products. Variety, quality and shelf life of cakes are always a concern of researchers. The improved cooking methods, storage at certain temperature and additives improve texture, strengthen the gluten network, provide softness and smoothness and postpone staling.

Instant starches or hydro-colloids added to baked goods can increase moisture survival [5, 6]. Moisture content is an important parameter for staling, because retro gradation of the starch is reduced with increasing moisture content [5, 6]. In [7], wheat starch was replaced by 3, 5 and 7% retrograded waxy corn starch to produce bread and evaluated rheological properties of the batter and sensory properties of the breads by farinograph and extensographic after 24, 48 and 72 hrs. Results of the rheological tests showed that this starch increase water absorption. In general, the replaced starch quickly increased viscosity; however, it was not able to keep its stability. The batter made by the replaced starch was weaker and less stable than the batter made by wheat starch. Results of sensory evaluation showed higher acceptability for these breads; addition of 5-7% starch considerably improved shelf life of the bread. The breads remained softer and more humid during 6 days of storage time [7]. In [8], it was shown that that moisture content increase shelf life of the product by 2%. Therefore, high moisture lost in bakery products is one of the reasons for accelerated staling of these types of products [8]. In [9], authors evaluated the effect of different types of starch (corn, potato, waxy maize and pre-gelatinized) added to cake formulation in order to delay staling of the cake and found that pre-gelatinized starch contributes to reduced moisture loss during cooking and storage and cakes containing pre-gelatinized starch are softer than the control cake. In [10], it was reported that the overall stiffness of cakes consists of two separate factors: 1) stiffness effects caused by moisture transfer to the crust and 2) internal stiffness of the cell wall matter associated with starch retro gradation during storage. In [11], authors studied the effect of rice starch on rheological properties of the batter at different temperatures. Rice starch was gelatinized at 20, 40, 60 and 90 minutes. The results showed that gelatinization temperature increased by increasing the time to 60 minutes. The rice starch batter had higher viscosity and lower moisture content for a longer period of time. This is probably due to lower amylose and protein content of the modified starch batter.

II. MATERIALS AND METHODS

Materials used to produce shortened cake batter included wheat starch, sugar, water, eggs, inverted sugar, oil, emulsifier, vanilla and baking powder as well as pre-gelatinized starch. Materials and equipment used for production of pre-gelatinized wheat starch included wheat starch, water and extruder. Materials used for physicochemical tests included buffer, petroleum ether, 2% boric acid, 0.1 N hydrochloric acid, 50%NaOH, concentrated sulfuric acid, catalyst, reagent solution (methyl red + ethanol + methylene blue).

A. Production of Pre-Gelatinized Wheat Starch

To produce the pre-gelatinized wheat starch, wheat starch and water were mixed and pre-gelatinized in an extruder at 70-100 °C and 30-80 rpm. Then, the water was evaporated in a dryer. The mixture was crushed to smaller pieces by a mill [12].

B. Production of Shortened Cake Batter

To produce shortened cake batter, eggs, sugar and emulsifier were mixed by a mixer at high speed for 3 minutes (Table I). Then, oil and water were added to the mixture and stirredbya stirrerat high speed. Next, starch, vanilla, baking powder, inverted syrup, pre-gelatinized starch and salt were added and the mixture was stirred at medium speed for 3 minutes [13]. To produce batter with the pre-gelatinized starch, three units of water per unit of pre-gelatinized starch minus the same amount of null flour were added to the mixture.

TABLE I. FORMULATION OF THE CONTROL AND SAMPLE CAKES

Raw material	Control	1.5% pre-gelatinized starch	3% pre-gelatinized starch	4.5% pre-gelatinized starch
Starch	36	34.5	33	31.5
Oil	10	10	10	10
Sugar	20	20	20	20
Baking powder	1	1	1	1
Emulsifier	1.5	1.5	1.5	1.5
Egg	11	11	11	11
Water	19.5	24	28.5	23
Invert syrup	3	3	3	3
Vanilla	0.1	0.1	0.1	0.1
Pre-gelatinized flour	0	1.5	3	4.5

C. Tests for Pre-gelatinized Starch and Starch Used in the Formulation

Moisture, ash and protein content of the starch were calculated by AACC 08-01, AACC 44-15 and AACC 46-13, respectively. Starch fat was evaluated according to the national standard of Iran.

D. Tests for Batter

Determination of Specific Volume

Specific weight of the batter was calculated by measuring the weight ratio of 240 ml batter to 240 ml water [14]. Specific volume was calculated by the following formula:

$$\text{Batter specific volume} = \frac{\text{weight of 240ml batter}}{\text{weight of 240ml distilled water}}$$

Determination of Batter Viscosity

Viscosity of cake batter was measured by the Brookfield model, DV-II + programmable. Since Brookfield viscometer cannot easily measure viscosity of the cake batter, viscosity of batters was measured under certain conditions using a particular spindle. Viscosity of the samples was measured using spindle 64, 1 RPM and 73 torque at 30 s [15].

E. Tests for Cake

Cake Texture Assessment

Texture analysis test was performed by texture profile analyzer with AACC 74-04 in days 15 and 30 of storage on controls and the samples treated with 1.5%, 3% and 4.5% pre-gelatinized starch. For the compression test, the samples were first cut into 2.5 cm cubes; then, the cubes were compressed by a plate probe by 50% at 1 mm/s. The compressive force applied to the samples was reported in Newton. Maximum force applied to the samples indicated higher stiffness of the samples. Moreover, sensory properties of the cakes such as color, flavor and texture was tested by 8 trained evaluators using a 9-point hedonic method. In this test, number 1 represented the lowest score given by the evaluators and number 9 the highest [16]. All physical and chemical tests were performed 3 times on 3 different days. Data obtained was analyzed using a completely randomized design (CRD) by the SPSS software, version 19. The mean of treatments was compared by Duncan's multiple range test to the average level of error 5%. Moreover, the data obtained from sensory evaluation was analyzed by the Friedman test.

III. RESULTS

A. Starch

The results related to flour and pre-gelatinized starch are shown in Table II. The results are significantly different ($p<0.05$).

TABLE II. RESULTS OF THE TESTS ON NULL FLOUR AND THE PRE-GELATINIZED STARCH (EACH NUMBER INDICATES 3 ITERATIONS)

Test	Null flour		Pre-gelatinized starch
Protein (%)	11.89		13.91
Ash (%)	0.5		0.5
Moisture (%)	14.71		3.34
Fat (%)	0.86		0.18
Wet gluten	28.35		Not measurable
Gluten index (%)	87.3		Not measurable
Falling number	614.5		115
Sedimentation number	25		32
Particle size	Pan	77.43	17.13
	Sieve 125	20.80	13.69
	Sieve 180	1.05	45.34
	Sieve 475	1.08	24.28
pH	5.75		5.81

B. Specific Volume of Batter

The results related to the effect of pre-gelatinized starch on specific volume of batter are shown in Figure 1 and Table III. Statistically, there was no significant difference in specific volume of 1.5% and 3% treatments, while controls and 4.5% treatments were significantly different from each other and other treatments. Specific volume of cake batter as a factor for assessing overall ability of the batter to maintain air provides limited information regarding the size and extent of the gas cells [16].

According to [17], higher specific volume of cake batter reflects lower volume of the cake. This report is consistent with the current study, where the increased amount of pre-gelatinized starch used reduced the specific volume of cake batter. Eventually, an increase was observed in volume of the cakes containing more pre-gelatinized starch. According to observations, the increase in pre-gelatinized starch softened the batter texture which made the mixing easier. Since mechanical factors (mixing) are one of the factors effective in increasing cake volume, the increase in pre-gelatinized starch and water content and a reduction in the amount of null flour used in the cake batter influenced aeration and thus the amount of air in the batter and reduced the specific volume.

C. Viscosity of Batter

As shown in Figure 2, there is a significant difference in viscosity of all treatments. The 3% treatment had the lowest viscosity while the 1.5% treatment was the most viscose sample. According to the results, the pre-gelatinized starch added to the batter formulation reduced viscosity by 3%, while 4.5% pre-gelatinized starch added to the cake batter increased viscosity by3% compared to the sample. The results showed that the 3% treatment had the highest reduced viscosity compared to the control treatment.

Pre-gelatinized starch changes the elasticity of the batter and increases gas storage capacity, reducing the consistency of the batter. This means that the batter is softer, that is, its viscosity is reduced compared to the control sample. Thus, the increased softness is followed by reduced viscosity of the batter. Pre-gelatinized starch has a very high water holding capacity. Therefore, addition of certain amounts of pre-gelatinized starch will result in increased residual moisture and reduced viscosity of the batter. The results indicate that the 3% treatment had the lowest viscosity compared to controls and other treatments. In [18] it was stated that the flour boiling happens simultaneously with partial drying of the starch molecular structure under heat, which is also true for the pre-gelatinized starch. The increased solubility of the pre-gelatinized starch can be due to partial breaking and increased mobility of the molecules by absorbing water as well as physical porous structure of this type of starch [19].

D. Cake Texture

The cake samples produced were tested for F(max) which is a measure of the force on the cake samples. The changes related to maximum force were tested for all samples in three different days of storage (1, 15 and 30). It was observed that a larger increase in the pre-gelatinized starch used in the product structure and reduced amount of flour was followed by reduced stiffness of texture. Therefore, 4.5% treatment had the softest tissues compared to other treatments. This can be attributed to water absorption of the pre-gelatinized starch. In addition, there is a direct relationship between moisture and stiffness. Water absorption and thus moisture content will have a direct effect on textural properties of bakery products. Pre-gelatinized starch changes elasticity of the batter and increases gas storage capacity. The increased gas storage capacity and consequently reduced consistency of the batter will soften the cake texture. Thus, the pre-gelatinized starch plays an important role in reducing stiffness of the cake texture by reducing elasticity. Moreover, texture analysis showed that the cake had higher stiffness in day 30 compared to day 1 and 15.

E. Sensory Evaluation

According to the results of the sensory evaluation test, 3% treatment obtained higher score for flavor, color and general acceptance compared to other treatments. In contrast, acceptance of texture was higher for 4.5% treatment compared to other treatments. The pre-gelatinized starch will improve taste, color and texture of the final product.

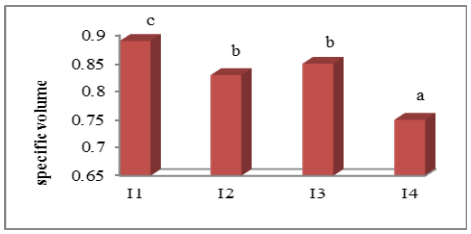

Fig. 1. Effect of pre-gelatinized starch on specific volume of cake batters. Letters indicate significant mean of treatments at 0.05

TABLE III. RESULTS RELATED TO BATTER SPECIFIC VOLUME

Treatment	Specific volume
Control sample	0.93c
1.5% treatment	0.83b
3% treatment	0.85b
4.5% treatment	0.70a

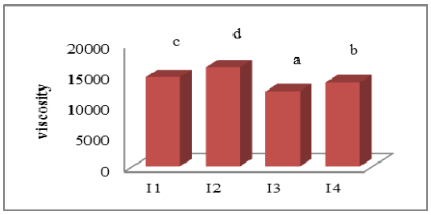

Fig. 2. Effect of pre-gelatinized starch on viscosity of cake batters. Letters indicate significant mean of treatments at 0.05

TABLE IV. RESULTS RELATED TO SPECIFIC VISCOSITY OF BATTER

Treatment	Viscosity
Control sample	14.42c
1.5% treatment	15.97d
3% treatment	12.15a
4.5% treatment	13.58b

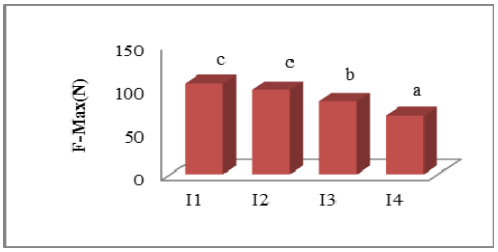

Fig. 3. Comparison of means of three days F-Max (N)

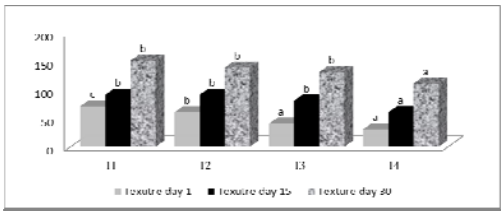

Fig. 4. Comparison of the effect of day on OF-Max (N) * letters indicate significant mean of treatments in 0.05.

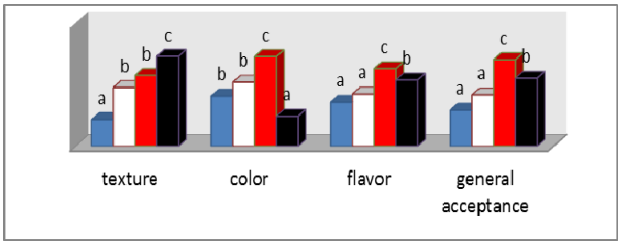

Fig. 5. Comparison of mean of sensory evaluation

IV. Discussion

A significant difference was observed in specific volume of the 4.5% treatment and the control. Due to its higher water absorption capacity, the 3% treatment had the lowest viscosity than other treatments. Physicochemical tests on the cake samples indicated no significant difference in moisture, aw, volume, color and stiffness of the 1.5% treatment and the control ($P>0.05$), while a significant difference was observed in the results of physicochemical tests as the amount of pre-gelatinized starch was increased in the formulation ($P<0.05$); the increase in the amount of 3% pre-gelatinized starch was associated with an increase in moisture, aw and volume of the treatment. This led to an increase in quality of the 3% sample. Results of cake texture assessment which were evaluated for the effect of various amounts of the pre-gelatinized starch on the cake texture showed that the increase in the pre-gelatinized starch used in the structure as well as the reduction in the amount of the used null flour was associated with a decrease in stiffness of the cake samples; the 4.5% treatment had the softest texture compared to other treatments. Moreover, cake texture assessment for various amounts of the pre-gelatinized starch in days 1, 15 and 30 indicated no significant difference in stiffness ($P>0.05$). Cake texture assessment showed that the control and treatments were more stiff in day 30 compared to day 1 ($P<0.05$). Moisture of the null flour is higher than that of pre-gelatinized starch, because the pre-gelatinized starch is exposed to a combination of moisture, pressure, temperature and mechanical cuts during its production using extrusion process which is a special process in short time and high temperature and the pre-gelatinized starch loses its moisture [20].

V. Conclusion

The pre-gelatinized starch, as an improver, has a positive effect on nutritional value and leads to changes in physicochemical properties of the finished product. battersMixes with different percentages of pre-gelatinized wheat starch were investigated in this paper. The results presented in this paper showed that the increased amount of pre-gelatinized starch reduced the specific volume of cakes. The best results derived from a 3% pre-gelatinized starch. Sensory evaluation of the cake samples, performed by trained sensory evaluators, showed that the cake produced by 3% pre-gelatinized starch had the highest score on flavor, color and general acceptance compared to other treatments. A better texture however was achieved with a 4.5% mix. As higher amount of pre-gelatinized starch replaced the null flour, some properties of the cake such as texture and general acceptance also improved.

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