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EFFECTS OF DIFFERENT STARCH TYPES ON RETARDATION OF STALING OF MICROWAVE-BAKED CAKES

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Different types of starches (corn, potato, waxy corn, amylomaize and pregelatinized starches) were added to cake formulations to retard staling of microwave-baked cakes. As a control, cake formulated without any starch addition was used. Weight loss, firmness, volume index, specific gravity, soluble starch and amylose content of cakes were used as the indicators of staling and/or quality criteria. Variation of staling parameters during storage of cakes followed zero-order kinetics. Cakes were baked in a microwave oven for 1.5 min at 100% power. Control cakes were also baked in a conventional oven at 175°C for 25 min. Pregelatinized starch helped to decrease moisture loss during baking and storage. Cakes containing amylomaize starch were firmer than the control cake. Starches, except amylomaize, were effective in reducing firmness during storage. The most effective starch type, in terms of retarding the staling of microwave-baked cakes, was chosen as pregelatinized starch. More amylose was leached in control cakes during microwave baking than conventionally baked cakes.

Keywords: cake; starch; microwave baking; staling.

INTRODUCTION

After baking, all bakery products undergo a series of chemical and physical changes which are referred to as staling (Cauvain, 1998). Staling results in loss of freshness and quality of the baked product. The most important change associated with staling is the gradual increase in the firmness of the baked product. The term firmness refers to the force necessary to attain a given deformation (Gil *et al.*, 1999). It is known that starch retrogradation implies hardening of the starch gel, therefore it is supposed to be responsible for the increased firmness of the stale product. Starch retrogradation is mostly influenced by three factors: temperature, specific volume of the baked product and moisture content (Stauffer, 2000).

Guy (1983) reported that the overall firming of cakes consisted of two separate processes: a firming effect caused by moisture transfer from crumb to crust, and an intrinsic firming of cell wall material which was associated with starch retrogradation during storage. Functionality of the ingredients is important for cake staling. Ingredients such as sugar and fat have softening effects on cakes, but eggs have firming effects (Hodge, 1977).

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One of the problems in microwave-baked cakes is accelerated staling. Although various studies investigated the effects of ingredients and processing conditions on the quality of microwave baked cakes (Baker *et al.*, 1990; Sumnu *et al.*, 2000), they did not consider their staling. The staling mechanism of microwave-baked cakes is therefore still unclear. Another problem in microwave baking is the higher moisture loss with respect to conventional baking methods. It was shown that microwave baked cakes and breads lost more moisture than conventionally baked ones (Sumnu *et al.*, 1999). When a food material is heated in a microwave oven, relatively larger amounts of interior heating result in increased moisture vapour generation inside of a solid food material, which creates significant interior pressure and concentration gradients. Positive pressures generated inside a food material increase the flow of the vapour and liquid through the food material to the boundary (Datta, 1990). Using instant starches or adding hydrocolloids can be used to increase moisture retention (Bell and Steinke, 1991; Zallie, 1988).

Moisture content is an important parameter for staling since starch retrogradation slows when the moisture content is high. Studies showed that increasing the moisture content of bread by 2% increased its shelf life by one day (Stauffer, 2000). Therefore, high moisture loss in microwave-baked goods was thought as a reason for rapid staling in microwave baking.

Usage of different ingredients having different physical properties become significant in order to retard staling of microwave baked cakes and to give insights to the staling mechanism in a microwave oven. The main objective of this study was to retard staling of microwave-baked cakes by using different starches so that the quality of microwave-baked cakes during storage could be comparable to that of conventionally baked cakes.

MATERIALS AND METHODS

Materials

Five different types of starches; potato starch (Çapamarka, Turkey), corn starch (Çapamarka, Turkey), waxy corn starch (Novation™ 4600, National Starch and Chemical Company, USA), amylomaize starch (Hylon™ VII, National Starch and Chemical Company, USA), and pregelatinized tapioca starch (Ultra-Tex™ 3, National Starch and Chemical Company, USA) were used to compare their effects on cake staling. Cake flour (untreated) was supplied by Özkaşıkçı, Turkey. Flour contains 27% wet gluten, 13% moisture and 0.65% ash. Plain shortening containing soybean lecithin was used as fat. All other ingredients used for cake baking were supplied from the commercial markets.

The basic control cake was a classical white-layer cake formulation. It contained 100% cake flour, 100% sugar, 50% fat, 125% water, 12% milk powder, 9% egg white, 3% salt and 5% baking powder (all percentages were given in flour weight basis).

Preparation of Cakes

Egg white and sugar were mixed in a mixer (Arçelik ARK55 MS, Turkey) at its lowest speed, for one minute. Fat was added and mixed. All the dry ingredients (cake flour, milk powder, salt and baking powder) and water were added simultaneously and mixed for two minutes until the cake batter was obtained. Cake batter of 100 g was weighed in a greased glass baking pan (8 cm in diameter) lined with waxy paper. The baking pan was placed in the centre of the microwave oven (Arçelik, Turkey) and baked at 100% power for 1.5 min. The power of the microwave oven used in this study was determined by the IMPI 2-L test (Buffler, 1993) as 785 W. The control cake formulation was also baked in a forced conventional electrical oven (Arçelik, Turkey) for 25 min at 175°C.

After baking, the cakes were cooled to room temperature (20 ± 2°C) for one hour. Then, the cakes were wrapped with stretch film, and stored at 20 ± 2°C for five days.

Five different starches were used to compare their effects on the staling of microwave-baked cakes. The basic control cake formulation was used by adding 5% starch (5 g of cake flour is replaced with starch in 100 g cake flour). As a control, no starch was added to the cake formulation.

Quality Measurements

Water binding capacity was determined for starches by using the method of Medcalf and Gilles (1965).

In order to measure the staling and quality of microwave-baked cakes, volume index, specific gravity, weight loss, firmness, soluble starch and amylose content of the cakes were determined. All measurements were done each day during five-day storage of the cakes, except volume index and specific gravity. Volume indices of the cakes were measured only after baking. Specific gravities of the cake batters were measured before baking.

Volume index of the cake was determined by using the AACC template method 10-91 (AACC, 1991), but this chart was modified with respect to the cake diameter used in this study (8 cm). The amount of air incorporated into a batter was determined by measuring the specific gravity of batter using a pycnometer. The cake was weighed before baking, just after the baking, and each day during storage to determine weight loss.

Firmness of the cake was measured using a universal testing machine (Lloyd Instruments LR30K, UK). A load cell of 5 N was used with a compression of 25% and a speed of 55 mm/s. A cylindrical probe of 2.5 cm in diameter was used. Cake samples were prepared according to the method of AACC (1988).

Soluble starch was determined colorimetrically by adding iodine solution to the water extract of cake (Giovanelli *et al.*, 1997). The amylose content in soluble starch was determined by using the method of Morad and D'Appolonia (1980).

Statistical Analysis

Analysis of variance (ANOVA) was used to determine the significant differences between the effects of starches on the retardation of staling of microwave-baked cakes. If significant difference was found, the treatments were compared by Duncan's Multiple Range test ($P \leq 0.05$). Three replications from different bakes were used for each treatment in all of the quality measurements.

RESULTS AND DISCUSSION

Figures 1 and 2 show the effects of starch types on percent weight loss after baking and during one hour of cooling, respectively. As can be seen in these figures, microwave baked cakes lost more moisture than

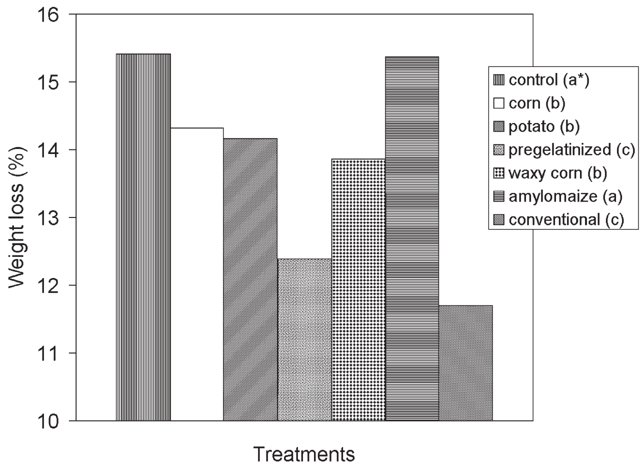

Figure 1. Effects of different starch types on weight loss of microwave-baked cakes during baking. *Bars with different letters (a, b, etc.) are significantly different ($P \leq 0.05$).

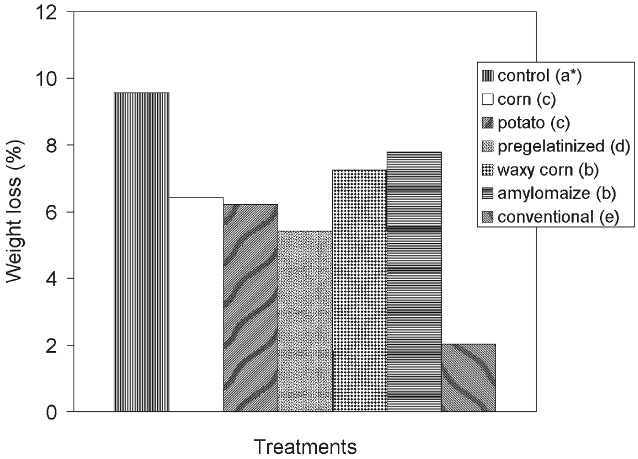

Figure 2. Effects of different starch types on weight loss of microwave-baked cakes during one hour of cooling. *Bars with different letters (a, b, etc.) are significantly different ($P \leq 0.05$).

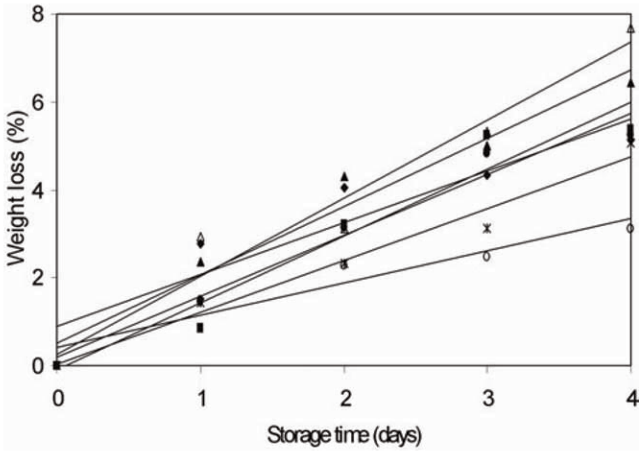

Figure 3. Effects of different starch types on weight loss of microwave-baked cakes during storage. (△) control[a*]; (▲) corn[a]; (◆) potato[ab]; (∗) pregelatinized[bc]; (■) waxy corn[ab]; (●) amylomaize[ab], (○) conventional[c]. *Starch types with different letters (a, b, etc.) are significantly different ($P \leq 0.05$).

conventionally baked cakes. It was previously shown that microwave-baked cakes lost more moisture than conventionally baked ones (Sumnu *et al.*, 1999). Relatively larger amount of interior heating during microwave baking result in significant internal pressure which increases the loss of moisture from the baked product (Datta, 1990).

Control cakes containing no added starch and amylomaize starch added cakes lost more weight, in other words more moisture during baking (Figure 1). Pregelatinized starch was the most effective starch on reducing the weight loss. The amount of moisture that microwave-baked cakes containing pregelatinized starch and conventionally baked cakes lost are not significantly different. This may be explained by very high water binding capacity of pregelatinized starch (Table 1). Since pregelatinized starches bind a significantly greater amount of water, they are recommended to be used for moisture retention in baked goods (Zallie, 1988).

In Figure 2, it can be seen that all the cakes baked in the microwave oven lost more moisture than conventionally baked cake during cooling. Adding any type of starch decreased the weight loss of cakes as compared to control cakes. This can be explained by the higher water binding capacities of starches compared to that of flour (Table 1). Pregelatinized starch is again the most effective starch to reduce weight loss of microwave cakes one hour after baking.

The variation of weight loss during the storage of cakes can be seen in Figure 3. Cakes baked with pregelatinized starch lost a similar amount of moisture as conventionally baked cakes during storage (Figure 3). The loss of moisture is an important consideration in cake staling (Willhoft, 1973). During storage, weight loss of the cakes increased linearly therefore a zero-order kinetic model was proposed:

$$\frac{dY}{dt} = k$$

where Y was the dependent variable (weight loss), t was storage time in days and k was the kinetic rate constant.

Rate constants and regression coefficients are given in Table 2. Control cake had the highest rate of weight loss, and it was significantly different from all other cakes, except amylomaize starch added cakes. Slow rate constants of starch added cakes showed that starches were effective to reduce weight loss not only during baking but also during storage.

Firmness of the baked goods is a good indicator of staling, because staling causes an increase in the firmness of both breads and cakes. The effects of different starch types (except amylomaize starch) on firmness of microwave-baked cakes can be seen in Figure 4. When amylomaize starch was shown in this graph, it became significantly different from all other starches because of its very high

Table 1. Water binding capacities (WBC) of different starches.

	WBC (w/w)
Flour	0.63
Corn	0.68
Potato	0.70
Waxy corn	1.18
Amylomaize	0.92
Pregelatinized	4.80

Table 2. Effects of different starch types on the rate constants of different staling indicators.

	Weight loss		Firmness		Soluble starch		Amylose	
	k	r^2	k	r^2	k	r^2	k	r^2
Control	1.77	0.95	0.26	0.89	0.30	0.93	0.18	0.99
Conventional	0.73	0.91	0.18	0.99	0.22	0.99	0.07	0.98
Corn	1.55	0.96	0.22	0.96	0.34	0.90	0.18	0.95
Potato	1.52	0.94	0.17	0.97	0.16	0.87	0.08	0.98
Waxy corn	1.18	0.87	0.11	0.93	0.09	0.99	0.01	0.80
Amylomaize	1.39	0.97	1.64	0.96	0.48	0.99	0.26	0.95
Pregelatinized	1.18	0.98	0.13	0.94	0.28	0.98	0.08	0.90

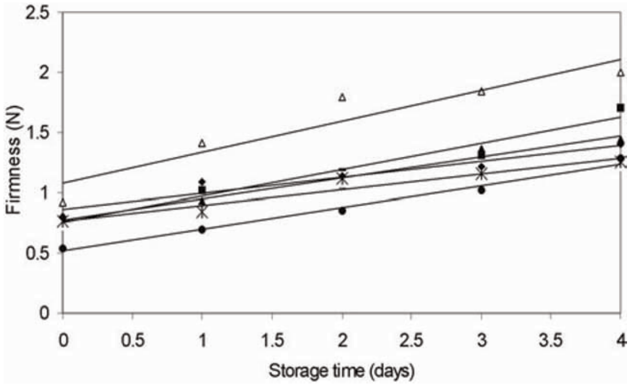

Figure 4. Effects of different starch types on firmness of microwave-baked cakes during storage. (△) control[a*]; (■) corn[b]; (▲) potato[bc]; (∗) pregelatinized[c]; (◆) waxy corn[bc]; (●) conventional[d]. *Starch types with different letters (a, b, etc.) are significantly different ($P \leq 0.05$).

Table 3. Volume indices and specific gravities of cake formulations containing different starch types.

	Volume index (cm)				Specific gravity
	L	C	R		
Control	28	30	28	86	0.96
Corn	28	30	28	86	0.95
Potato	30	32	30	92	0.92
Waxy corn	30	28	30	88	0.94
Pregelatinized	32	34	32	98	0.90
Amylomaize	28	30	28	86	0.94
Conventional	30	32	30	92	

L, left; C, centre; R, right.

rate constant (Table 2) and the effects of other starches on firmness of microwave-baked cakes could not be seen clearly in the same graph. Therefore, firmness variation of microwave-baked cakes containing amylomaize starch was given separately in Figure 5.

When baked goods stale, their firmness values increase. In microwave baking, this increase was faster than the conventional baking (Figure 4 and Table 2). This might be related with the high amount of amylose leached during microwave heating (Higo *et al.*, 1983). As can be seen from Figure 4, all starches were effective on slowing down the firmness change, in other words, retardation of staling of microwave-baked cakes when compared to the control cake. The effects of pregelatinized starch, waxy corn starch, and potato starch on the firmness of microwave-baked cakes were not significantly different. Cakes containing amylomaize starch were firmer than the control cake (Figures 4 and 5). Amylomaize contains the highest amylose content (70%) as compared to the other starches. This may show that staling of microwave-baked cakes mainly comes from amylose retrogradation.

Volume indices of microwave-baked cakes and specific gravities of cake batters with different starches are shown in Table 3. Specific gravity is a measurement of air incorporated into a cake batter during mixing. This air (along with baking powder gasses released during baking) determines the cake texture and volume. The low volume of microwave-baked cakes was known to be due to the insufficient starch gelatinization (Yin and Walker, 1995). An inverse relationship between batter specific gravity and cake volume were observed (Table 3). This might indicate that different starches had the ability to retain a greater amount of air into the batter (less specific gravity) and maintained more air during the final stage of baking (larger cake volume). As can be seen in the table, volume index of pregelatinized starch added microwave baked cake (with the least specific gravity) was the highest. Since pregelatinized starch is already gelatinized, development of structure and volume of the cakes can easily be completed during microwave baking. The waxy corn starch added cakes collapsed in the oven. This can be explained by the highest gelatinization enthalpy and lower dielectric loss factor of waxy corn starch than the other starches (Sumnu, 1997; Ndife *et al.*, 1998). High gelatinization enthalpy and low dielectric loss factor indicate slow heating and slow gelatinization. Therefore, the short time of microwave baking might not be enough for the gelatinization and structure development of waxy corn added cakes.

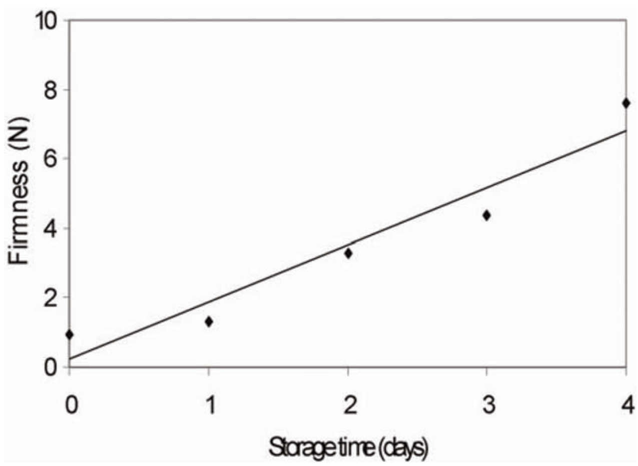

Figure 5. Effect of amylomaize starch on firmness of microwave-baked cake during storage.

Soluble starch and amylose is released to the environment during the gelatinization process and the amount of both soluble starch and amylose decreases with the staling process because they tend to reassociate during retrogradation (Zallie, 1988). Therefore, the amount of soluble starch and amylose is used as an indicator of staling. Table 4 shows the effect of starch types on soluble starch and amylose contents of microwave baked cakes. Amount of both soluble starch and amylose decreased during storage. Amylomaize starch added cakes had the highest rate of leaching of soluble starch (Table 2). High amylose content (70%) of amylomaize starch might be the reason for the highest rate of soluble starch leached in the cake.

It can be seen that more amylose was leached in control cakes during microwave baking than conventionally baked cakes (Table 4). The amount and rate of variation of amylose content for the waxy corn added cakes were very low compared to the other treatments, due to the very low amylose content of waxy corn starch (3%). Amylomaize starch, having the highest amylose content, had the highest amylose variation rate (Table 2). These results also explained the highest firming rate of amylomaize added cakes.

Table 4. Soluble starch and amylose contents of cake formulations containing different starch types.

	Soluble starch (%) in days					Amylose (%) in days				
	0	1	2	3	4	0	1	2	3	4
Control	2.427	2.263	2.033	1.775	1.187	1.151	1.007	0.814	0.604	0.499
Corn	2.857	2.119	1.754	1.658	1.383	0.959	0.672	0.456	0.418	0.192
Potato	1.783	1.37	1.331	1.149	1.091	0.371	0.293	0.247	0.127	0.079
Waxy corn	1.207	1.12	1.005	0.938	0.861	0.037	0.017	0.007	0.005	0.003
Pregelatinized	2.675	2.57	2.157	1.944	1.59	0.329	0.227	0.068	0.014	0.009
Amylomaize	1.965	1.556	1.04	0.433	0.102	1.382	1.022	0.649	0.454	0.343
Conventional	2.486	2.26	2.011	1.768	1.645	0.341	0.307	0.198	0.118	0.067

CONCLUSIONS

Pregelatinized starch, waxy corn starch and potato starch were significantly effective in retarding staling according to the firmness of cakes. The highest volume indexes were obtained in cakes formulated with pregelatinized starch. The moisture that pregelatinized starch added microwave cake and the conventionally baked cake lost during baking were not significantly different. The final quality of the cakes baked with pregelatinized starch was close to the conventionally baked cakes. As a result, pregelatinized starch can be recommended to be used in microwave cake formulations to retard staling.

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