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HYDROPHILIC COLLOIDS AS ADDITIVES IN WHITE LAYER CAKES[1]

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ABSTRACT

Certain hydrophilic colloids which were superimposed upon a standard high-ratio formula improved the quality of white layer cakes when they were relatively fresh and after storage. Cakes were stored unwrapped to accelerate the staling process and were scored after 16 and 48 hr. of storage. The use of 0.1% 7HP CMC produced the highest scores at both periods. Also, 0.2% gum tragacanth, 0.2% gum arabic, 0.1% Irish moss, 0.1% ammonium alginate, and 0.1% 7LP CMC produced better cakes than the control (no additive). Agar, 0.1%, scored lower than the control at the 16-hr. period, but scored about the same after 48 hr. of storage. 7HP CMC, 0.6%, and 0.1% guar gum produced gumminess and were detrimental to cake quality.

An attempt to establish an objective method as a replacement for organoleptic scoring was unsuccessful, since the correlation between the objective determinations (volumes, crumbliness, and batter resistance to shearing force) and the eating-quality score was small.

To establish repeat sales and increase sales volume, the wholesale cake baker of today must produce a product that will compare favorably with that produced by the housewife. To do so, his product must be of good quality and must retain these characteristics throughout the distribution process.

A great deal of work has been devoted to studies dealing with changes which take place in baked goods. Loss of moisture and firming of the crumb are associated with these changes which result in decreased consumer acceptance of the product and are commonly referred to as staling (11). Bread staling has been investigated extensively, and excellent reviews have been given (4,8,12); however, the literature contains only a few reports of studies of the changes in cake properties during storage.

Kulp, Ponte, and Bechtel (11) found that moisture loss from cakes

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was interpreted by a panel to cause rapid staling, and during a 27-day test period, one-half of the total firming, and between one-third and one-half of the staling, observed by a sensory panel occurred in the first 4 days. Bechtel and Meisner (5) found that both sensory panel and laboratory tests over a 6-day period showed that the highest-moisture bread rated highest for freshness.

Various workers have attempted to retard staling by adding substances which are hydrophilic in nature. Bayfield (2) stated that hydrophilic colloids as additives in white bread, especially cellulose-derived sodium carboxymethylcellulose (CMC), do enhance the shelf-life of bread as measured by softness. However, Krustalev and Muserskii (10) tried agar as a staling reducer in bread and obtained negative results. Glabe, Goldman, and Anderson (9) stated that Irish moss extractive (carrageenin) in white layer cakes produced notable effects, particularly an improved texture. Bayfield (3) found that potential customers, who randomly sampled white layer cakes both with and without CMC, were almost unanimous in their preference for cake containing the CMC. In addition to the improved eating characteristic or mouth-feel, the CMC also improved the shelf-life of the cakes.

It appears that certain hydrophilic colloids have shown beneficial results as cake additives; however, it is evident that no extensive studies have been made. Therefore, the object of this investigation was to determine the effects of some of the more common types of hydrophilic colloids as cake additives. Also, it was hoped that as a result of this study an objective method might be obtained to replace organoleptic scoring through the correlation of objective measures of the cake batters and the cakes.

Materials and Methods

All ingredients used in the study were obtained from commercial sources and all from original lots. The various additives were obtained either on the open market or directly from the manufacturer. All the additives were finely ground powders and were added dry to the flour, sugar, and other dry ingredients, and mixed thoroughly. Preliminary experiments were performed to determine the optimum percentage of each additive and amount of additional water needed to produce the best cake. All combinations of 0, 0.1, 0.2, and 0.3% of each additive and 0, 5, and 10% additional water were used. The additive and additional water percentages were based on the flour weight. It was found that 5% additional water was needed with all the additives.

An extra short or fancy patent cake flour, bleached to a suitable pH and containing 7.5% protein, 0.32% ash, and 12.1% moisture, was used. Other ingredients used were: medium granulated sugar (sucrose); spray-dried nonfat dry milk; double-action phosphate baking powder; frozen egg whites; and an all-vegetable, emulsified-type shortening. Refrigerated tapwater was adjusted to produce batters at 72°F.

The hydrophilic colloids included in the study and the percentage of each used follows: 1) the seaweed colloids; 0.1% agar, 0.1% Irish moss extractive (SeaKem Type 402), and 0.1% ammonium alginate; 2) seed extracts: 0.1% guar gum; 3) exudates or saps of trees: 0.2% gum tragacanth and 0.2% gum arabic; 4) synthetic colloids: sodium salt of carboxymethylcellulose (CMC) – 0.1% 7LP, 0.1% 7HP, and 0.6% 7HP. The 0.6% 7HP CMC was included to study the effects of larger amounts of this additive.

Design of Experiment. The study was conducted employing a Latin square experimental design. The treatments were arranged and the experiment performed so that the differences among rows represented the variation in replicates and the column differences represented the variation in treatment positions. One experiment was performed each day with treatments scheduled at 15-min. intervals and the experiment was repeated ten times. The study was conducted in an air-conditioned laboratory with temperature maintained at 76°F. and approximate r.h. of 71%.

The formula used which produced a standard high-ratio cake of good qualities is given below. The flour was weighed on 14% moisture basis (1), and dry mixes were prepared by sifting and blending all the dry ingredients. The batters were mixed using a flat paddle on a C-100 Hobart mixer equipped with a 3-qt. bowl.

Ingredient	*Amount*	*Basis Flour*	*Batch Weight*
	g.	%	%
Flour	222.0	100.0	22.2
Sugar	280.0	126.1	28.0
NFDM	27.0	12.2	2.7
Salt	5.0	2.3	.5
Baking powder	15.0	6.8	1.5
Egg whites	140.0	63.1	14.0
Shortening	100.0	45.0	10.0
Water (1st stage)	150.0	67.6	15.0
(2nd stage)	61.0	27.5	6.1

Two 370-g. batters, designated A and B, were scaled from each mix into 7-in. aluminum baking pans with paper bottom liners and greased sides. These were baked for 24 min. at 350°F. in a gas-fired, reel-type oven. Immediately after the batters were scaled and placed in the oven to bake, the batter's resistance to shearing force was determined upon another portion of the batter using a MacMichael Viscosimeter.

The baked cakes were weighed immediately out of the oven to determine the bake-out loss. After cooling 10 min., the cakes were removed from the pans, weighed, and stored unwrapped on a wire rack at room temperature (76°F.).

After 16 hr. the cakes were weighed to determine the loss in moisture for the period. The "A" cakes were scored by the experimenter and the volume, compressibility, and crumbliness determined. After 48 hr. the "B" cakes were weighed again and scored, and volume, compressibility, and crumbliness determined.

In order to perform the various tests, a miter-box was constructed so that similar sections of the cake could be obtained for each test. For scoring, the cake was cut vertically 1/4 in. off center and the smaller section used. To determine eating qualities, this section was cut into smaller pieces after it was scored for the other characteristics. A slice 1/2 in. thick, which was the center of the cake, was taken from the second section for the compressibility determination. The remaining part was used for the crumbliness determination.

Scoring. The following point values were established for each of the cake characteristics: volume, 10; grain, 10; texture, 10; softness, 10; and eating qualities, 12 points. Eating qualities may be considered the sensations received in biting, chewing, and swallowing. In evaluating eating qualities, two additional judges were employed. Since all the cakes were similar in crust and crumb color, these characteristics were omitted. Also, no specific consideration was given to flavor, taste, or aroma, and no flavoring was used in the cakes. In scoring the volume, 900 cc. was considered standard and 1/2 point was deducted for each 25 cc. or fraction thereof below 900 cc.

Resistance to Shearing Force Determination. To obtain relative values of the viscous properties of the batters, the MacMichael Viscosimeter with the cylindrical plunger, small inner cup, and No. 30 torsion wire was used, following the method described by Glabau[3] but without his modification of the plunger. The procedure is as follows: After the scaled batters were placed in the oven to bake, 33 g. of the remaining batter were scaled into the small inner cup of the MacMichael Viscosimeter and this in turn was inserted into the large chamber. The cylindrical plunger was inserted into the batter with the spindle and disk at the upper end suspended with the torsion wire. The motor was then started, the cup rotated at 5 r.p.m., and the

[3] Glabau, C. A. Bakers Weekly modification of the MacMichael Viscosimeter to be used for cake batters, fillings, jellies, etc. Personal communication (May 1961).

resistance to shearing force in MacMichael degrees was read off directly on the upper graduated disk. The rotation continued over a 5-min. period of time and readings were taken at ½-min. intervals. The second reading (1 min.) is the one reported.

Compressibility. Compressibility or relative firmness values were obtained with the Baker Compressimeter (1). Using the miter-box, a slice ½ in. thick was taken exactly out of the center of the cake and one reading was taken in the center of the slice. The compressimeter was operated to 1.5 mm. compression using the round plunger. Thus, firmness values are expressed as g. of pressure required to apply 1.5 mm. of stress.

Crumbliness. The crumbliness of the cakes was determined following the procedure used by Kulp, Ponte, and Bechtel (11) using the Ro-Tap Testing Sieve Shaker. Eight 1-in. cubes, free of crust, were obtained from the last section of the cake. The cubes were placed in a U.S. No. 4 sieve equipped with a catch pan and lid, which was inserted in the shaker. After 10 min. of shaking, the remaining cake and sifted crumbs were weighed and the percentage of crumbs calculated.

Results and Discussion

Analysis of variance tables were prepared for all determinations. Examples are Tables IV and V. When the effects were significant, the treatment means were compared using Duncan's (7) multiple range test.

Table I gives the summary of all treatment means for the determinations made in the study. Table II and Table III give the comparisons of all treatments using Duncan's test, at the 5% and 1% level of significance, respectively. The letters in Table II and Table III represent the treatments and corresponding numerical values in Table I. The discussion is based on the comparisons made at the 5% level of significance (Table II). For comparisons at the 1% level, the reader may consult Table III.

Batter Resistance to Shearing Force. From Table I, it can be observed that the different treatments affected the resistance to shearing force of the batters. The analysis of variance given in Table IV shows that the treatment effects were highly significant and the replicate and position effects were insignificant.

The 0.6% 7HP CMC (D) gave the highest viscosity. Tragacanth (J) was higher than 0.1% 7HP CMC (C), Irish moss (G), 7LP CMC (B), gum arabic (I), and agar (F). There were no significant differences

TABLE I
SUMMARY OF ALL TREATMENT MEANS
(Average 10 Determinations)

STORAGE TIME	TREATMENTS[a]									
	A	B	C	D	E	F	G	H	I	J
hr.										
	Batter resistance to shearing force — °MacM.									
	83	76	78	108	80	74	76	84	75	85
	Bake-out loss — g.									
	21.2	21.4	21.8	21.4	22.0	21.9	21.9	21.1	21.9	21.7
	Air loss — g.									
16	12.0	12.0	12.3	11.7	12.1	12.2	11.5	12.4	12.4	11.9
32	14.5	14.9	15.0	14.3	14.9	14.5	14.7	14.8	14.8	14.8
48	26.5	26.9	27.3	26.0	27.0	26.7	26.2	27.2	27.2	26.7
	Cake volume — cc.									
16	862	850	840	843	850	847	855	850	844	849
48	828	820	821	813	825	814	824	815	818	821
	Total score									
16	46.3	46.8	49.7	43.6	43.8	45.7	47.5	47.4	47.5	48.4
48	41.8	43.6	45.8	39.7	40.6	42.0	42.9	42.4	43.1	44.1
	Eating-quality score									
16	8.1	9.3	11.7	7.4	7.2	8.6	9.1	9.5	9.7	10.3
48	4.9	6.3	8.2	5.0	4.7	5.7	6.0	6.0	6.0	6.8
	Compressibility of cakes									
16	20.6	20.9	20.9	20.4	21.2	21.5	20.7	20.5	20.9	20.8
48	28.5	28.4	28.4	27.3	28.0	29.1	28.4	28.1	28.2	27.8
	Crumbliness — %									
16	40.4	38.2	37.6	40.8	38.3	38.0	37.8	38.8	39.0	39.0
48	37.9	37.2	36.5	39.4	38.6	36.2	36.3	36.5	39.1	38.2

[a] A — Control
B — 0.1% 7LP CMC
C — 0.1% 7HP CMC
D — 0.6% 7HP CMC
E — 0.1% guar gum
F — 0.1% agar
G — 0.1% Irish moss
H — 0.1% ammonium alginate
I — 0.2% gum arabic
J — 0.2% gum tragacanth

between agar (F), gum arabic (I), 7LP CMC (B), Irish moss (G), 0.1% 7HP CMC (C), or guar (E).

Bake-out Loss. The cakes were weighed immediately out of the oven to determine the loss in weight due to baking. The treatment effects were not significant at the 5% level. It is interesting to note that the treatments with the additional water did not lose more weight than the control in baking.

Air Loss. Air loss data are reported as 16-hr. air loss, 32-hr. air loss, and the 48-hr. air loss (16 hr. plus 32 hr.) and are expressed in grams.

TABLE II
COMPARISON OF TREATMENTS ACCORDING TO EACH DETERMINATION PRODUCING SIGNIFICANT RESULTS (5% SIGNIFICANCE LEVEL)[a]
(Treatments underscored by the same line are not significantly different. Treatments not underscored by the same line are significantly different.)

hr.										
	Resistance to shearing force									
	F	I	B	G	C	E	A	H	J	D
	Air loss									
16	G	D	J	A	B	E	F	C	H	I
	Volume									
16	C	D	I	F	J	H	B	E	G	A
48	D	F	H	I	B	C	J	G	E	A
	Total score									
16	D	E	F	A	B	H	G	I	J	C
48	D	E	A	F	H	G	I	B	J	C
	Eating-quality score									
16	E	D	A	F	G	B	H	I	J	C
48	E	A	D	F	G	H	I	B	J	C
	Crumbliness									
16	C	G	F	B	E	H	I	J	A	D
48	F	G	H	C	B	A	J	E	I	D

[a] A — Control
B — 0.1% 7LP CMC
C — 0.1% 7HP CMC
D — 0.6% 7HP CMC
E — 0.1% guar gum
F — 0.1% agar
G — 0.1% Irish moss
H — 0.1% ammonium alginate
I — 0.2% gum arabic
J — 0.2% gum tragacanth

The air loss was significant at the 5% level for only the 16-hr. period. The Irish moss (G) was lower than agar (F), 0.1% 7HP CMC (C), ammonium alginate (H), and gum arabic (I). The 0.6% 7HP CMC (D) was lower than either ammonium alginate or gum arabic. Although the loss in moisture was significantly different, it is doubtful that these differences would have any commercial value owing to their size.

Cake Volume. The volumes of the cakes were determined after 16 and 48 hr. using the rapeseed displacement method. The treatment effects were significant after both 16 and 48 hr. of storage. After 16

TABLE III

COMPARISON OF TREATMENTS ACCORDING TO EACH DETERMINATION PRODUCING SIGNIFICANT RESULTS (1% SIGNIFICANCE LEVEL)[a]

(Treatments underscored by the same line are not significantly different. Treatments not underscored by the same line are significantly different.)

hr.										
	Resistance to shearing force									
	F	I	B	G	C	E	A	H	J	D
	Air loss									
16	G	D	J	A	B	E	F	C	H	I
	Volume									
16	C	D	I	F	J	H	B	E	G	A
48	D	F	H	I	B	C	J	G	E	A
	Total score									
16	D	E	F	A	B	H	G	I	J	C
48	D	E	A	F	H	G	I	B	J	C
	Eating-quality score									
16	E	D	A	F	G	B	H	I	J	C
48	E	A	D	F	G	H	I	B	J	C
	Crumbliness									
16	C	G	F	B	E	H	I	J	A	D
48	F	G	H	C	B	A	J	E	I	D

[a] A — Control
B — 0.1% 7LP CMC
C — 0.1% 7HP CMC
D — 0.6% 7HP CMC
E — 0.1% guar gum
F — 0.1% agar
G — 0.1% Irish moss
H — 0.1% ammonium alginate
I — 0.2% gum arabic
J — 0.2% gum tragacanth

hr., the control (A) produced the largest volume which was different from all treatments except Irish moss (G). The 0.1% 7HP CMC (C) and 0.6% 7HP CMC (D) gave the smallest volumes.

After 48 hr. of storage the volumes became smaller, owing to drying and shrinking. Some of the cakes decreased in volume less than others. The control (A) was larger than the ammonium alginate (H), agar (F), and the 0.6% 7HP CMC. Guar was larger than agar or 0.6% 7HP CMC, whereas Irish moss was larger than the 0.6% 7HP CMC.

In order to study the effects of time between the 16- and 48-hr. periods, the data for the two periods were compared (6). The effects

TABLE IV

ANALYSIS OF VARIANCE OF THE RESISTANCE TO SHEARING FORCE DETERMINATION (°MacMichael)

SOURCE OF VARIATION	d. f.	m. s.	F
Replicates	9	49.84	1.470
Positions	9	24.02	0.708
Treatments	9	1017.60	30.010**
Error	72	33.91	

F (9, 72): 2.01*, 2.67**

of time include all of the factors such as drying out and staling which contribute to the changes in the cakes. The analysis of variance for volume comparison between the storage times is given in Table V. Time, replicate, position, and treatment effects were highly significant. Only the replicates × times interaction was significant.

TABLE V

ANALYSIS OF VARIANCE FOR VOLUME COMPARISON BETWEEN STORAGE TIMES

SOURCE OF VARIATION	d. f.	m. s.	F
Times	1	42,486.00	510.50**
Replicates	9	6,587.00	79.15**
Positions	9	4,913.11	59.04**
Treatments	9	5,393.56	64.81**
Replicates × times	9	256.78	3.09**
Positions × times	9	19.56	.24
Treatments × times	9	133.33	1.60
Error (pooled)	144	83.22	

F (1,144): 3.92*, 6.84**; F (9,144): 1.95*, 2.56**

Since the effect of storage times was significant, the prime interest in this analysis was to compare the means of the 16- and 48-hr. periods (Table I) for each treatment. The least difference (6) which was required for significance was 8 cc. at the 5% level. The smallest decrease in volume was 19 cc. (0.1% 7HP CMC); therefore, all of the treatments were definitely smaller after 48 hr. of storage.

Total Score. The total score may be considered the most complete evaluation of the treatments and the most important factor in determining the best treatment. The treatment effects for both periods were significant.

The 16-hr. total score means reveal that 0.1% 7HP CMC (C) scored higher than all other treatments. The gum tragacanth (J) scored second highest, but it was not higher than gum arabic (I), Irish moss (G), or ammonium alginate (H). Gum arabic (I) did not differ from the control (A). The 0.6% 7HP CMC (D) and guar (E) scored lower than the other treatments. Agar (F) was higher than 0.6% 7HP CMC (D), and guar (E), but it was lower than ammonium alginate (H), Irish moss (G), gum arabic (I), gum tragacanth (J), and 0.1% 7HP CMC (C).

After 48 hr. of storage, the 0.1% 7HP CMC again scored highest. Gum tragacanth was second highest but did not differ from 7LP CMC (B), gum arabic (I), and Irish moss (G). The 7LP CMC (B) was higher than the 0.6% 7HP CMC (D), guar (E), control (A), or agar (F). Guar (E) and 0.6% 7HP CMC (D) scored lowest.

The above observations for both the 16- and 48-hr. periods show that the 0.1% 7HP CMC and gum tragacanth were the most effective in increasing the total score. Also, the 0.6% 7HP CMC and guar were detrimental to cake quality.

From the analysis of storage-time effects, it was observed that times, replicates, positions, and treatments were highly significant, but the interactions were insignificant. In comparing each treatment mean for the two periods the least difference for significance was 1.2. Since the smallest decrease in total score was 3.2, all of the treatments scored lower after 48 hr. of storage. Of the higher-scoring treatments, the 7LP CMC (B) decreased the least (3.2) and the ammonium alginate (H) decreased the most (5.0).

Eating-Quality Score. Many of the additives had a definite effect on eating quality. Both dryness and gumminess produced a lower score.

Eating-quality scores for the 16-hr. period show that the 0.1% 7HP CMC (C) was highest. Gum tragacanth (J) was second highest and was different from the remaining treatments excepting gum arabic (I). Guar (E) ranked the lowest but was not different from 0.6% 7HP CMC (D). The control (A) and 0.6% 7HP CMC (D) were different, but the control and agar (F) were not.

After the 48-hr. period, all of the treatments decreased in eating quality. The 0.1% 7HP CMC (C) was again highest. Gum tragacanth (J) was second highest but it was not different from 7LP CMC (B); however, it was higher than gum arabic (I), ammonium alginate (H), and Irish moss (G). The 7LP CMC was not different from gum arabic (I), ammonium alginate (H), Irish moss (G), and agar (F). Guar (E) scored the lowest and was different from agar (F). The control and 0.6% 7HP CMC were not different from guar.

It may be concluded from the above observations that the 0.1% 7HP CMC, gum tragacanth, gum arabic, ammonium alginate, 7LP CMC, and Irish moss improved the eating quality.

The effects of time on eating quality were highly significant. The least significant difference was 0.5 at the 5% level. The smallest decrease in eating quality was 2.4 which was well above the 5% level. Thus all treatments decreased significantly. There was a tendency for the higher-scoring treatments to decrease more than those having a lower initial score. It may be noted that the gum arabic (I) decreased the most (3.7 points) and the 0.6% 7HP CMC (D) decreased the least (2.4 points) in eating-quality score.

The treatments × times interaction was highly significant. This is probably due to the fact that some additives tended to produce gumminess in the fresh cakes and the gumminess disappeared as the cakes dried out.

Cake Compressibility. Compressibility or relative firmness values were obtained after each storage period. The treatment effects were insignificant for both the 16- and 48-hr. determinations. The replicate effects for both periods were highly significant, which denotes a large day-to-day variation.

Cake Crumbliness. The crumbliness of the cakes, which was affected by both dryness and grain structure, was determined for the two periods.

After 16 hr. of storage, the 0.6% 7HP CMC (D) was highest in percentage crumbliness, but it was not different from the control (A), gum tragacanth (J), gum arabic (I), or ammonium alginate (H). The control was higher than 0.1% 7HP CMC (C), Irish moss, agar, and 7LP CMC. There were no significant differences between the 0.1% 7HP CMC (C), Irish moss (G), agar (F), 7LP CMC (B), guar (E), ammonium alginate (H), arabic (I), and tragacanth (J).

After 48 hr., the 0.6% 7HP CMC (D) was the most crumbly and was different from agar (F), Irish moss (G), ammonium alginate (H), and 0.1% 7HP CMC (C). Guar (E) was higher than agar (F) or Irish moss (G).

The effects of time between the periods were significant. The least significant difference in comparing the two means of each treatment was 1.8 at the 5% level. The control (A) and ammonium alginate (H) decreased 2.5 and 2.3 in crumbliness, respectively, and were significant.

Correlation Study. Originally it was hoped that one result of this investigation would be an objective measure which could be substituted for organoleptic scoring. Scatter diagrams were made by plotting all the values for volume, resistance to shearing force, and crumbliness against the eating-quality score for the 16- and 48-hr. periods. Of these tests, the 16-hr. crumbliness looked the most promising. The correlation coefficient of the 16-hr. crumbliness and eating quality score was computed and found to be −0.50. It was concluded that none of the above measures were of value in determining the eating quality.

Summary and Conclusions

During the investigation it was established that certain hydrophilic colloids improved the quality of white layer cakes when some additional water was added. The cakes were scored when relatively fresh (16 hr.) and again after 48 hr. of storage. To accelerate the staling process, the cakes were stored unwrapped.

These hydrocolloids increased the total score and eating-quality score compared to the control at both periods. The use of 0.1% 7HP CMC produced the most outstanding cake. Other additives, producing better cakes than the control at the 16-hr. period, ranked as follows: gum tragacanth, gum arabic, Irish moss, ammonium alginate, and 7LP CMC. After 48 hr. of storage, the 7LP CMC increased in rank.

At the 16-hr. period, the agar scored lower than the control; however, after 48 hr. of storage they were about the same. The 0.6% 7HP CMC and guar produced gumminess and were detrimental to the cake quality.

The loss in weight due to baking (bake-out) was not significantly different between the treatments. In air loss, the Irish moss and 0.6% 7HP CMC were significantly lower after 16 hr. of storage; however, the total air loss during storage did not differ significantly between the treatments. The bake-out loss and air loss were of particular interest, since the cakes containing the additives had 5% additional water.

The control produced the largest volume at both periods. Although the additives produced slightly smaller volumes, they shrank less during storage.

There were no significant differences in compressibility, as measured by the Baker Compressimeter, between the treatments at either the 16- or 48-hr. period; however, the compressibility of the cakes decreased with an increase in storage.

The 0.6% 7HP CMC produced the highest crumbliness at either period, and did not decrease significantly with an increase in storage time. The control gave the second highest crumbliness at the 16-hr. period and decreased significantly with an increase in storage time.

The 0.6% 7HP CMC increased the resistance to the shearing force of the batters. Agar, gum arabic, 7LP CMC, and Irish moss were significantly lower than the control in resistance to shearing force.

An attempt to establish an objective method as a replacement for organoleptic scoring was unsuccessful, since the correlation between the objective measures (volumes, crumbliness, resistance to shearing force) and eating quality was small.

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