

Effects of Additives and Storage Temperature on Staling Properties of Bagels

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ABSTRACT

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The effects of xanthan gum, Novamyl (a type II α -amylase), Instant Tender-Jel C starch (a modified starch), and GMS-90-SSK (a hydrated monoglyceride) on the staling properties of bagels stored at 4 and 22°C from 0–7 days were studied. Texture analysis and moisture determination were conducted on the bagels before lyophilization. Analysis of percent soluble starch, crumb pasting (Rapid Visco Analyser) and degree of amylopectin recrystallization (differential scanning calorimeter) were conducted on lyophilized bagel crumb. Novamyl-treated bagels appeared to be the most resistant to staling over time at both storage temperatures in relation to the enthalpy of gelatinization (ΔH). Bagels containing xanthan gum,

Instant Tender-Jel C starch, and GMS-90-SSK showed some improvements over the control bagels, although the effects of the additives on the characteristics of the bagels varied. Bagels made with xanthan gum or monoglyceride retained slightly higher crumb moisture percentages over most days of storage. The monoglyceride-treated bagels had higher enthalpy values, lower percentages of soluble starch, and a higher pasting profile but had the softest texture. The apparent onset of increased staling of the monoglyceride-treated bagels was attributed to complexes formed with the starch fractions.

The staling of bread products and baked goods has been reviewed by many researchers (Schoch and French 1947; Bechtel et al 1953; Bice and Geddes 1953; Collison 1968; Yasunaga et al 1968; Kim and D'Appolonia 1977; Leung et al 1983; Krog et al 1989; Stear 1990; Piazza and Masi 1995; Zobel and Kulp 1996). Similarly, various additives studied to discern the effects on staling properties of baked goods include monoglycerides (Strandine et al 1951), enzymes (Beck et al 1957; Pylar 1973; Martin and Hoseney 1991; Bowles 1996; Morgan et al 1997), dough improvers (Shkvarkina et al 1982), gums (Glicksman 1969; Dziezak 1991; Maier et al 1993; Ward et al 1993), modified starches (Tuschhoff 1986; Wurzburg 1995), and surfactants (Joensson and Toernaes 1987; Knightly 1996).

However, little research has been conducted on bagels in either of these areas. Thus, the objectives of this study were to evaluate the effects of various additives on the staling of bagels and to examine how different storage temperatures affect staling rate and keeping quality of bagels in comparison to untreated bagels.

MATERIALS AND METHODS

Flour

Dakota State High Gluten spring wheat flour (Food Services of America, Fargo, ND) was used for all bagel treatments because it was typical of commercial bagel flours. Farinograph tests were performed according to Approved Method 54-12 (AACC 2000). Wheat flour protein was determined using a nitrogen analyzer (FP-428, Leco Corp., St. Joseph, MI). Moisture and ash contents were determined by AACC Approved Methods 44-15A and 08-01, respectively.

Bagel Dough Formulas

Bagel dough ingredients (flour weight basis) were 3.0 % sugar, 2.0% salt, 1.0% shortening, 0.625% instant dry yeast, 51–52% water (depending on the additive used), and 60 ppm of ascorbic acid. Additive levels used for the various bagel treatments were 0.00025% Novamyl, 0.0005% xanthan gum, 4.0% Instant Tender-Jel C starch, and 0.001% GMS-90-SSK.

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Bagel Production and Storage Procedure

The bagel dough was mixed to optimum according to the method of Petrofsky (1986), taking care that the final dough temperature remained $\approx 26^\circ\text{C}$. Cold water and ice chips were used in the formula to control final mix temperature. After the dough rested briefly (≈ 1 min), the bagels were shaped manually by rolling the dough (75 g) into a ball. A slit was cut into the center of the dough ball with a small metal spatula and then the ball was rolled out so that all sides were uniformly shaped. During the shaping operation, the dough was covered with a damp towel to prevent it from drying out and forming a crust. The shaped bagels were placed on baking sheets lined with parchment paper. When filled, the sheets were put into large polyurethane bags and placed into a 4°C coldroom for 18 hr. Before boiling, the bagels were proofed for 20–30 min in a proofing cabinet at 22°C and 70% rh. After proofing, the bagels were boiled for 1 min on each side, briefly dried (30 sec), and then returned to the baking sheets and baked at 230°C for 17 min. The bagels were allowed to cool for 1 hr, then placed into plastic zip lock bags, and stored at 4 and 22°C for 0–7 days. For day 0, an additional 1.5 hr of storage time was allowed after cooling to ensure that the refrigerated bagels had reached a core temperature of 4°C before evaluation. Duplicate bagels for both storage temperatures were evaluated on days 0, 1, 3, and 7. After determining moisture and performing texture analysis on whole, intact bagels, they were individually frozen using liquid nitrogen and then immediately ground (low speed for 1 min) using a Waring blender equipped with a stainless steel pulverizer (model SS 110), according to the method of Whalen et al (1997). The frozen crumb was passed through a US #50 sieve using a small brush to assist the crumb through. The pulverized sample was collected on a paper plate, then transferred to a plastic specimen cup stored on dry ice until all the bagels were ground and could be transported to a freezer. The samples were lyophilized and stored in desiccators for further analysis.

Moisture Content

Moisture content of the bagel crumb was determined using Approved Method 44-15A (AACC 2000). Bagel crumb (2 g), taken from inside the crust (0.25 to 0.50 in.) of the bagel was evaluated.

Texture Analysis

The firmness of bagels stored 0–7 days at 4 and 22°C was measured using a texture analyzer (TA-XT2, Texture Technology Corp., Scarsdale, NY) equipped with a TA-52, 2-mm, stainless steel punch probe, according to the method of Johnson (1992). Six strokes of the probe were performed for each test, and an average curve was generated for each storage day at each temperature using an XTRAD computer program (Stable Micro Systems, Haslemere, Surrey, England). The probe entered the bagel at a speed of 1.5

mm/sec for a distance of 15 mm. The force required to pierce the crust of the bagel was recorded as peak 1 and the force required to travel through the crumb was recorded as peak 2. The data was saved to a spreadsheet and analyzed.

Differential Scanning Calorimetry

Recrystallization of amylopectin was determined on lyophilized bagel crumb using differential scanning calorimetry (DSC) (Perkin-Elmer Corp., Norwalk, CT) equipped with a digital DEC-425 thermal analysis data station. The instrument was calibrated using indium as a standard. Freeze-dried crumb (4.00 ± 0.05 mg) was weighed directly into aluminum DSC pans, followed by the addition of 8 μ L of deionized distilled water (1:2), according to the method of Zeleznak and Hosney (1986). The pans were hermetically sealed and allowed to equilibrate at room temperature (22°C) overnight. A sealed aluminum DSC pan containing 8 μ L of deionized distilled water was used as a reference. Samples were heated at 5–120°C at a scanning rate of 10°C/min. Enthalpy of gelatinization (ΔH , J/g), onset temperature (T_o , °C), and peak temperature (T_p , °C) were computed automatically. An average of three thermograms was used for each sample.

Soluble Starch

Water solubles were extracted from the lyophilized bagel crumb using the procedure of Kim and D'Appolonia (1977). A 1.25-g sample was mixed with 12.5 mL of deionized distilled water and shaken on a wrist-action shaker for 20 min. The slurry was centrifuged at $2,000 \times g$ for 5 min and filtered through filter paper (S&S 588, Schleicher and Schuell, Keene, NH). This procedure was repeated twice and the supernatants combined. Soluble starch was determined on the supernatant according to the method of Schoch and French (1947). Three volumes of methanol were added to the water solubles and heated gently for 1 hr. After standing overnight at 4°C, the flocculated soluble starch was collected by centrifugation at $16,300 \times g$ for 20 min. The precipitate was lyophilized upon collection and calculated for percentage soluble starch.

Crumb Pasting

Pasting properties of lyophilized bagel crumb were examined using a Rapid Visco Analyser (RVA 3D, Newport Scientific Pty. Ltd., Warriewood, Australia). Deionized distilled water (25 mL) was

weighed directly into a disposable RVA canister. Lyophilized bagel crumb (4.5 g) was added to the canister and agitated for 15 sec with a #11 rubber stopper in place to prevent spilling the sample. The paddle and canister were then attached to the instrument. The method utilized was modeled after that of Whalen et al (1997). The temperature profile program was equilibrate crumb slurry at 50°C for 1 min, raise temperature to 95°C over 3.75 min, hold the temperature at 95°C for 2.5 min, and finally lower the temperature to 50°C over 3.75 min for the remainder of the run. Total run time was 15 min. Peak, trough, and setback viscosities were calculated automatically. An average of two pasting profiles was used for each sample.

Statistical Analysis

Data were statistically analyzed using and the Statistical Analysis System (SAS Institute, Cary, NC). A randomized complete block design (RCBD) with three blocks (in time) was chosen. All comparisons were tested for least significant differences ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Chemical and Physical Characterization of Flour

Dakota State High Gluten wheat flour had protein, moisture and ash contents of 13.9 (14.0%, mb), 14.2, and 0.45% (14.0%, mb), respectively. Farinograph absorption was 63.2%. Peak time, stability, and mixing tolerance index were 6.5, 12.5, and 25 BU, respectively.

Moisture Content

Temperature and treatment effects on percent moisture of the bagel crumb is summarized in Table I. While all the bagels stored at 4°C had slightly higher moisture percentages, only day 1 showed a significant temperature effect. At 4°C, the vapor pressure of water is sufficiently low and, consequently, the moisture loss of products stored at that temperature is reduced (Meisner 1953). The observed differences on day 0 are possibly due to the short amount of time for a major difference in moisture to occur. By day 7, there were minimal changes in moisture, presumably because over time the remaining moisture would have reached equilibrium regardless of the storage temperature. Days 1 through 3 may be considered a typical time interval for the majority of moisture changes in bread-crumbs to occur. There were no significant differences observed for

TABLE I
Moisture (%) of Bagel Crumb^a

	Day 0	Day 1	Day 3	Day 7
Temperature (<i>n</i> = 15)				
22°C	36.4a	32.9a	31.0a	30.4a
4°C	36.9a	34.7b	31.9a	30.9a
Treatment (<i>n</i> = 6)				
Control	36.4a	33.4ab	31.3a	30.5a
Xanthan gum	36.9a	34.5a	31.5a	30.6a
Novamyl	35.3a	32.3b	31.4a	30.9a
Tender-Jel C	37.0a	33.8ab	31.2a	30.4a
GMS-90-SSK	37.4a	35.2a	31.9a	30.9a

^a Values followed by the same letter in the same column are not significantly different ($P < 0.05$).

TABLE III
Differential Scanning Calorimetry (DSC) Analysis of Bagel Crumb Pooled Across All Treatments^a

Storage Temp. (<i>n</i> = 15)	Day 0	Day 1	Day 3	Day 7
22°C				
Onset (T_o , °C)	47.0a	47.5a	48.1a	48.6a
Peak (T_p , °C)	52.2a	52.6a	53.3a	53.7a
Enthalpy (ΔH , J/g)	0.273a	0.992a	1.473a	2.080a
4°C				
Onset (T_o , °C)	46.0b	46.6b	47.2b	48.0b
Peak (T_p , °C)	51.1b	51.5b	52.2b	52.9b
Enthalpy (ΔH , J/g)	0.307b	1.185b	1.933b	2.353b

^a Values followed by the same letter in the same column are not significantly different ($P < 0.05$).

TABLE II
Peak Force (g) of Bagel Crust and Crumb Pooled Over Temperature^a

Treatment (<i>n</i> = 6)	Day 0		Day 1		Day 3		Day 7	
	Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2
Control	543a	445ab	434ab	338a	405ab	305bc	333b	213a
Xanthan gum	554a	463ab	448a	345a	417ab	328a	372a	218a
Novamyl	546a	474a	444a	351a	428a	321ab	375a	219a
Tender-Jel C	518a	388c	390c	260c	334c	236d	305c	202a
GMS-90-SSK	511a	432b	413bc	317b	393b	294c	338b	208a

^a Values followed by the same letter in the same column are not significantly different ($P < 0.05$).

moisture on day 0, 1, 3, or 7 between the control treatment and the other four treatments as indicated in Table I. Although the treatments were not significantly different from the control, there were significant differences between the additives xanthan gum, GMS-90-SSK, and Novamyl on day 1. The Novamyl-treated crumb probably had the lowest percent moisture because of the increase in the number of small dextrans, which could be attributed to the action of the enzyme. The small dextrans might account for the crumb's reduced ability to bind moisture.

Texture Analysis

The bagels stored at 4°C were maintained at a constant temperature by means of refrigeration during all the tests, including the texture evaluations, to ensure consistency throughout this study. Due to the inherent physical differences of products stored at different temperatures, a cold bagel would require more force to penetrate the crust and crumb than a bagel stored at room temperature. Therefore, the characteristics measured by the texture analyzer would be an indication of the effects caused not only by the firmness of the bagel, but also by temperature. For this reason, the effect of temperature was factored out for these tests. The results obtained from the texture analysis were indicative of the differences between treatments of the bagels stored at room temperature (22°C). Peak 1 represents the force (g) required to penetrate the crust of the bagel, and peak 2 represents the maximum internal hardness (g) of the crumb. In bread, it is typical for firmness values to increase with increased storage time (Baker et al 1986, 1987; Baruch and Atkins 1989). These tests commonly measure the force required to compress the crust and crumb. However, the texture characteristics of the bagels in this study were conducted by measuring the force required to puncture the crust and crumb using a 2-mm stainless steel probe. The observed trends (Table II) indicated a decrease in both peaks over increased storage time, rather than an increase in peak force (g) as would be expected with a compression measurement. These differences do not mean that the firmness phenomenon was not occurring, but they also may indicate that there was a decrease in the tough, chewy characteristics of the crust and crumb of the bagel,

permitting the probe to penetrate the bagel with less force. On day 0, no significant differences were observed between treatments for peak 1. Significant differences were found between the control and Instant Tender-Jel C starch on days 1 and 3. The bagels treated with Instant Tender-Jel C starch required less force (g) to penetrate the crust than the other treatments. Day 7 showed significant differences between the control and bagels treated with xanthan gum, Novamyl, and Instant Tender-Jel C starch (Table II). Bagels treated with Novamyl and xanthan gum had a tougher crust than the control and bagels treated with GMS-90-SSK.

For peak 2 (Table II), bagels treated with Instant Tender-Jel C starch (day 0) had a significantly lower maximum internal hardness (g) of the crumb than the control and all the other treatments. On day 1, bagels treated with both GMS-90-SSK and Instant Tender-Jel C had significantly lower maximum internal hardness of the crumb compared with the control and the other two treatments. Day 3 showed significant differences between the control, bagels treated with xanthan gum and Instant Tender-Jel C starch. The bagels treated with xanthan gum were significantly more firm internally than were the control and bagels treated with Novamyl and GMS-90-SSK. The bagels treated with Instant Tender-Jel C starch were significantly less firm internally than all the other treatments. On day 7 there were no significant differences observed between the treatments for peak 2. The treatments that maintained the toughest crust and crumb characteristics were xanthan gum and Novamyl. These two additives were the most beneficial for maintaining crust and crumb firmness closest to that of the control up to day 3. Figure 1A and B illustrates the differences obtained between tests on days 0 and 7, respectively, for the two additives and control.

Differential Scanning Calorimetry

With increased storage time, the starch in baked goods begins to retrograde. This phenomenon can be measured by differential scanning calorimetry (DSC), which measures the increase in enthalpy associated with amylopectin recrystallization. For each day of storage, there was a significant difference in the onset and peak temperature between the bagels stored at the two temperatures (Table III). The onset and peak temperature values decreased significantly for the bagels stored at 4°C compared with the bagels stored at 22°C. Zeleznak and Hosney (1986) explained similar differences as an indication that storage temperatures closer to the melting temperature of the crystals formed during starch retrogradation resulted in the formation of a more perfect crystalline structure (annealing of the crystals) and thus required a higher melting temperature.

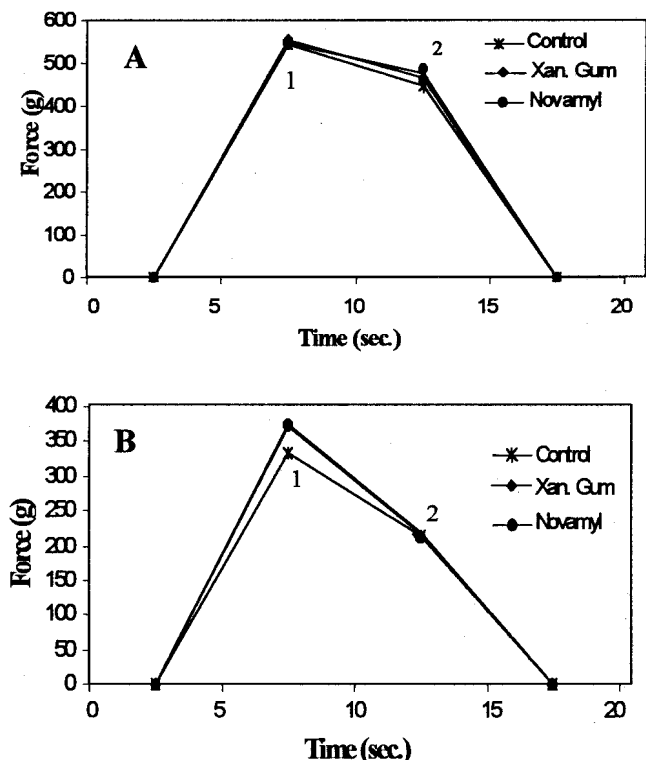


Fig. 1. Effect of xanthan gum and Novamyl on peak force (g) required to puncture the crust (1) and crumb (2) on storage day 0 (A) and 7 (B).

TABLE IV
Differential Scanning Calorimetry (DSC) Analysis of Bagel Crumb Pooled Across Temperature^a

Treatment (n = 6)	Day 0	Day 1	Day 3	Day 7
Onset (T_o , °C)				
Control	45.6d	46.3d	47.0d	47.7c
Xanthan gum	47.1b	47.6b	48.1b	49.1b
Novamyl	47.9a	48.3a	49.0a	49.5a
Tender-Jel C	46.8c	47.1c	47.5c	47.9c
GMS-90-SSK	45.5d	46.0e	46.7d	47.6c
Peak (T_p , °C)				
Control	51.1d	51.6d	52.2d	53.0d
Xanthan gum	52.2b	52.5b	53.0b	53.6b
Novamyl	52.9a	53.2a	53.9a	54.5a
Tender-Jel C	51.6c	52.1c	52.8c	53.3c
GMS-90-SSK	50.5e	51.0e	51.7e	52.2e
Enthalpy (ΔH , J/g)				
Control	0.295b	1.250b	2.117b	2.817b
Xanthan gum	0.278c	1.003c	1.500c	1.950d
Novamyl	0.238d	0.807d	1.113d	1.600e
Tender-Jel C	0.275c	1.048c	1.500c	2.117c
GMS-90-SSK	0.363a	1.333a	2.267a	3.100a

^a Values followed by the same letter in the same column are not significantly different ($P < 0.05$). Means pooled across all treatments.

TABLE V
Soluble Starch (%) of Bagel Crumb^a

	Day 0	Day 1	Day 3	Day 7 ^b
Temperature (<i>n</i> = 15)				
22°C	3.00a	2.72a	2.43a	2.03a
4°C	2.89b	2.63a	2.18b	1.81b
Treatment (<i>n</i> = 6)				
Control	2.83d	2.58c	2.15b	1.65d
Xanthan gum	3.15b	2.85b	2.33b	1.85c
Novamyl	3.40a	3.12a	3.03a	2.85a
Tender-Jel C	3.02c	2.78b	2.35b	2.05b
GMS-90-SSK	2.33e	2.05d	1.65c	1.18e

^a Values followed by the same letter in the same column are not significantly different ($P < 0.05$).

^b There was a significant treatment \times temperature interaction on day 7, but the individual means were not interpreted.

TABLE VI
Rapid Visco Analyser Measurements (RVU) of Bagel Crumb
Pooled Across All Treatments^a

Storage Temp. (<i>n</i> = 15)	Day 0	Day 1	Day 3	Day 7
22°C				
Peak viscosity	211.7a	205.4a	198.5a	193.1a
Trough viscosity	194.1a	187.7a	179.7a	172.7a
Setback viscosity	113.7a	109.8a	105.6a	101.5a
4°C				
Peak viscosity	215.9a	210.3a	206.5a	203.5b
Trough viscosity	197.9a	193.9a	190.7b	186.7b
Setback viscosity	116.6a	111.9a	108.3a	107.9a

^a Values followed by the same letter in the same column are not significantly different ($P < 0.05$).

The effect of temperature on the enthalpy of gelatinization was significant for each day of storage (Table III). Although the onset and peak temperature values increased with an increase in storage temperature, the opposite was observed for the effects of temperature on enthalpy of gelatinization. According to Zeleznak and Hosney (1986), an overall temperature dependence of recrystallization must contain contributions from crystal nucleation as well as from the propagation (growth) rate of crystals. The results (Table III) probably indicate a higher rate of crystal nucleation in bagels stored at 4°C but a faster rate of crystal propagation in bagels stored at 22°C. The bagels stored at 22°C had a lower enthalpy of gelatinization due to the lower rate of nucleation at this temperature, thus indicating a lower rate of retrogradation in bagels stored at 22°C. The effects of treatments on onset and peak temperature values (Table IV) were significant for each day of storage. Results indicated that the additives Novamyl, xanthan gum, and Instant Tender-Jel C starch required a higher melting temperature than the control and bagels treated with GMS-90-SSK on most days. It is possible that these additives allowed annealing of the starch crystals similar to that of the crystals formed at 22°C, as observed by Zeleznak and Hosney (1986). The onset and peak temperature values increased with increased storage time. The increase in onset and peak temperature values is presumably due to the extended time allowed for the amylopectin molecules to realign and become more crystalline. A larger number of crystals with increased strength would be formed with more time allotted. The effect of treatments on enthalpy (Table IV) was significant. All of the treatments differed from the control for all days of storage. Novamyl had the lowest enthalpy over all the other treatments. It was possible that Novamyl prevented large dextrins from forming, thus inhibiting a high degree of reassociation among amylopectin molecules. Xanthan gum and Instant Tender-Jel C starch had the next lowest enthalpy values, whereas bagels treated with GMS-90-SSK had the highest enthalpy of gelatinization. It is possible that some type of complex formed with the starch and hydrated monoglyceride, thus requiring a higher energy output to melt the crystals.

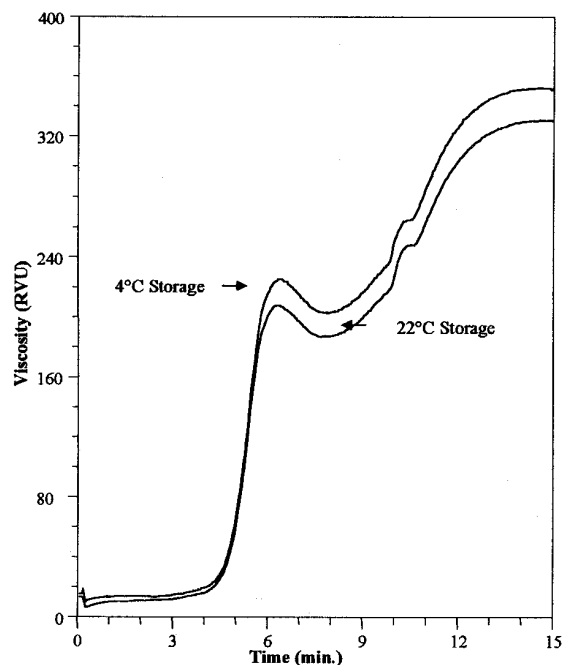


Fig. 2. Effect of temperature on the pasting profile of lyophilized bagel crumb on storage day 1.

Soluble Starch

The amount of soluble starch in bread products decreases with increased time in storage, indicating starch retrogradation. The effect of temperature was significant on days 0 and 3 (Table V). The bagels stored at 4°C showed a decrease in the amount of soluble starch extracted. Staling in bread has a negative temperature coefficient, as demonstrated by Meisner (1953). Our results were expected to be similar for trends observed in bagels. All bagel treatments were significantly different from the control on days 0 and 1 (Table V). On day 3, only the bagels treated with Novamyl and GMS-90-SSK were significantly different from the control. Novamyl increased the amount of soluble starch extracted, whereas GMS-90-SSK decreased the amount of soluble starch compared with the control. There was a significant TRT \times TEMP interaction on day 7, but not all treatments responded similarly to the effect of temperature on day 7. Bagel crumb treated with GMS-90-SSK showed a noticeable difference, while the other treatments were more uniform at the two temperatures. Bagels treated with Novamyl appeared to exhibit the greatest resistance to starch retrogradation. Significantly higher amounts of soluble starch were extracted from these bagels over the control and the other treatments on each day (Table V).

Pasting Properties (RVA)

Peak viscosity showed a significant temperature effect only for day 7 (Table VI). Trough viscosity showed a significant temperature effect for days 3 and 7. While the other days did not show a significant temperature effect, overall, the 4°C stored bagels showed slightly increased viscosity profiles (Fig. 2). Because bread staling occurs more rapidly at lower temperatures, based on the viscosity profile, a higher degree of staling could contribute to a more viscous pasting profile, except for GMS-90-SSK treatment because of its starch complexing capabilities. As indicated in Table VI, none of the days showed significance on setback viscosity due to the high degree of variability within one repetition of the data. The setback (final viscosity – trough), however, was higher for the bagels stored at 4°C. Setback is the common measurement indicative of staling in baked products measured by the RVA.

The additives Novamyl, Instant Tender-Jel C starch, and GMS-90-SSK influenced peak viscosity significantly compared with the control on days 0 and 1 (Table VII). Novamyl and Instant Tender-

TABLE VII
Differential Scanning Calorimetry (DSC) Analysis of Bagel Crumb
Pooled Across Temperature^a

Treatment (n = 6)	Day 0	Day 1	Day 3	Day 7
Onset (T_o , °C)				
Control	237.2b	231.8b	228.7a	223.3ab
Xanthan gum	229.7b	223.2b	291.3ab	216.2bc
Novamyl	136.5d	127.8d	123.0c	117.2d
Tender-Jel C	210.8c	207.3c	205.2b	200.8c
GMS-90-SSK	254.8a	249.0a	236.2a	233.8a
Peak (T_p , °C)				
Control	227.5a	221.8a	216.3a	210.3a
Xanthan gum	212.7b	206.7b	202.2b	198.3a
Novamyl	113.5d	107.2d	102.7d	96.0c
Tender-Jel C	195.5c	192.2c	189.3c	183.0b
GMS-90-SSK	230.7a	226.3a	215.7a	210.8a
Enthalpy (ΔH , J/g)				
Control	132.0a	128.3a	121.9a	118.8a
Xanthan gum	130.3a	126.3a	121.2a	115.8a
Novamyl	102.7a	95.7a	93.2a	93.3a
Tender-Jel C	118.8a	115.8a	112.3a	112.0a
GMS-90-SSK	134.8a	130.2a	122.0a	120.3a

^a Values followed by the same letter in the same column are not significantly different ($P < 0.05$).

Jel C starch were significantly less viscous than the control and xanthan gum. Significant differences were observed between the control, Instant Tender-Jel C starch, and Novamyl on days 3 and 7. On these days, Instant Tender-Jel C starch and Novamyl were less viscous than the other treatments at a significant level. Bagel crumb treated with xanthan gum, Instant Tender-Jel C starch, and Novamyl was significantly different from the control bagel crumb for trough viscosity on days 0, 1, and 3 (Table VII). All three additives lowered the viscosity significantly from the control on those days. On day 7, only bagel crumb treated with Instant Tender-Jel C starch and Novamyl had significantly lower trough viscosities than the control crumb and the other treated crumb. The effect of the additives was not significant for setback viscosity (Table VII), however the additives seemed to follow a general trend. Bagels treated with GMS-90-SSK had the highest setback; the control and bagel crumb treated with xanthan gum had the next highest setback; bagels treated with Instant Tender-Jel C starch had the second lowest setback; and bagels treated with Novamyl had the lowest setback. Novamyl appeared the most effective at preventing a high setback and viscous pasting profile, presumably because the amylase prevented large dextrans from forming during storage, thus resulting in less aggregation of the starch molecules upon heating and cooling. GMS-90-SSK treatment seemed to have an adverse effect by raising both the viscosity profile and the setback compared with the control. This apparent effect was due however, to the complex the monoglyceride formed with the starch fractions. Figure 3 shows the effects of the additive on the pasting profiles. Another point of interest shown in Figs. 2 and 3 is the bump that formed during the cooling process. Similar bumplike patterns have been reported earlier (Xu et al 1992; Bhattacharya and Corke 1996). It is similar to the amylose-lipid complex commonly observed at ≈ 85 – 100°C with DSC analysis.

CONCLUSIONS

The additives Novamyl, xanthan gum, Instant Tender-Jel C starch, and GMS-90-SSK all extended shelf-life of bagels to some degree over that of the control bagels. Bagels treated with Novamyl appeared to retard staling to the highest degree at both temperatures, based on the results of DSC, soluble starch, and RVA analyses. However, bagels treated with Xanthan gum and GMS-90-SSK typically retained higher crumb moisture percentages throughout their shelf-life. Overall, the test of greatest importance would be whether the product gained in consumer acceptance. Due to the length of the storage period,

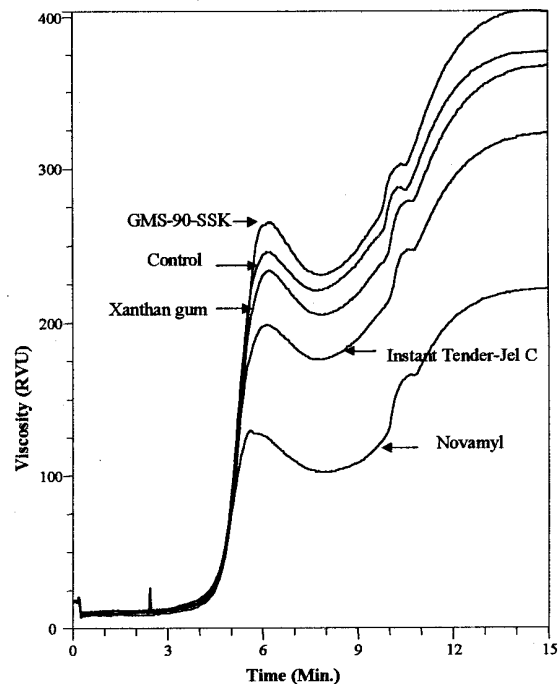


Fig. 3. Effect of additives on the pasting profiles of lyophilized bagel crumb on storage day 1 at 22°C .

sensory evaluation was not feasible. However, instrumental texture analysis showed that the bagels treated with xanthan gum and Novamyl retained the toughest crust and crumb characteristics, while the bagels treated with Instant Tender-Jel C starch caused the crust and crumb to soften considerably. For bagels, a tough and chewy crust and crumb are desirable, which is dissimilar for bread, where a soft texture is preferred. Possibly a combination of the additives such as Novamyl and xanthan gum, or Novamyl and GMS-90-SSK would yield a more desirable crust and crumb texture while extending the shelflife of the bagels. Instant Tender-Jel C starch was not superior to any of the additives used for this study and, thus, would not be recommended as an additive for further studies in this application due to its chemical modification.

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