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CHANGES IN TOMATO PASTE DURING STORAGE AND THE EFFECTS OF HEATING ON CONSISTENCY OF RECONSTITUTED TOMATO PASTE

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ABSTRACT

Bostwick consistencies of reconstituted tomato pastes were measured both immediately after paste production and after storage times of up to 9 months. Bostwick values measured after storage were more than twice those measured on the day of paste production. This increase in Bostwick developed over the first month of paste storage at room temperature and could be slowed down but not prevented if the paste was stored at 4C. Heating the reconstituted paste for 30 min at 90C or 15 min at 100C restored the original consistency. Serum viscosities also decreased during paste storage, but the change in serum viscosity was smaller than the changes in Bostwick. As with the Bostwick, heating the reconstituted juice restored the serum viscosity. For a reproducible evaluation of the consistency of stored tomato paste, it is essential that the reconstituted paste be heated to 90C or above.

PRACTICAL APPLICATIONS

Consistency is an important quality consideration in products prepared from reconstituted tomato paste. During storage, changes occur in tomato paste, which affect the consistency after reconstitution. The results presented here show that for stored tomato paste, heating after reconstitution restores consistency to the same level as measured before storage. This knowledge will help in the formulation of products made from stored tomato paste.

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KEYWORDS

Bostwick, consistency, paste, storage, tomato, viscosity

INTRODUCTION

Of the approximately 10–12 million tons of processing tomatoes grown annually in California, the majority are thermally processed and concentrated into tomato paste. In hot-break tomato paste production, the tomatoes are disintegrated and rapidly heated to approximately 95C to inactivate endogenous enzymes. This juice is then finished by passing through screens with mesh sizes between 1.1 and 6.3 mm (0.045–0.25 in.) to remove seeds and skin fragments. The finished juice then moves through a series of evaporators that remove the water from the juice at elevated temperatures and reduced atmospheric pressure. The finished paste typically has a final soluble solids or degrees Brix (°Brix) content of 28–31°Brix, roughly a factor of 6 concentration over the approximately 5°Brix hot-break juice. Concentrated paste is typically stored for 1 year or more, and this stable material is diluted for production of sauces, salsas and other value-added products. Many variations in the quality of the paste can be obtained depending on factors such as the cultivar of tomatoes used, the finisher screen size and the break temperature.

The rheological properties of fluid tomato products like sauces and ketchup are important quality parameters. The flow properties of the whole juice, referred to as the gross viscosity or the consistency, are typically evaluated using a Bostwick consistometer. In this measurement, the distance the juice flows in a trough in 30 s is measured. More viscous juices flow shorter distances; thus, a higher Bostwick value indicates a lower consistency. Other devices such as efflux pipettes and rheometers have also been used to measure the apparent viscosity of whole juice. Apparent viscosities and Bostwick values of tomato juices can be directly related to each other (Milczarek and McCarthy 2006). There is a great deal of evidence that the flow properties of the whole juice are determined primarily by the insoluble material in the juice (Marsh *et al.* 1980; Tanglertpaibul and Rao 1987). The viscosity of the serum, the soluble fraction of the tomato juice after removal of insoluble material by centrifugation, can be determined using a Cannon-Fenske-type viscometer. This serum viscosity is the result of the solutes present, particularly the polymeric material, which in tomato juice consists mostly of pectin. Both serum viscosity and Bostwick values are routinely determined in quality control evaluations during tomato paste production.

Concentrating tomato juice to paste during the tomato season allows for preservation and long-term storage, but subsequent dilution for formulation of value-added products is known to result in a loss of consistency. This consistency loss occurs when paste is produced in small benchtop evaporators (Kotte *et al*. 2006), pilot plant evaporators (Marsh *et al*. 1978; Apaiah and Barringer 2001; Den Ouden and Van Vliet 2002) or large-scale commercial processing plants (Anthon *et al*. 2008). When samples have been collected at various levels of concentration, the greatest loss of consistency occurs in the early stages of concentration, as the juice is concentrated from 5 to 10°Brix with further concentration to 20°Brix or higher causing only small additional losses. Several explanations for this loss of consistency have been proposed, including chemical hydrolysis of pectins due to high temperatures in the process (Hurtado *et al*. 2002), irreversible polymer dehydration by the high solute concentrations in the paste (Marsh *et al*. 1978; Kotte *et al*. 2006) and mechanical shear of the juice particles as they are pumped through the system (Beresovsky *et al*. 1995; Mizrahi 1997). Our previous work (Anthon *et al*. 2008) provided evidence that the first two of these explanations are unlikely to account for the consistency loss during paste production.

During tomato paste production, Bostwick values for each batch of tomato paste are routinely determined on the day the paste is produced. End users rely on this value in deciding whether a particular paste will be suitable to produce the desired consistency in their final product. Whether the Bostwick value determined on the day of paste manufacture accurately reflects the consistency of the paste at the time of use can be a point of dispute between these end users and paste producers. Although the loss of consistency during paste production has been well characterized, possible changes in consistency occurring during subsequent paste storage have received less attention. Marsh *et al*. (1978) reported that the Bostwick values of pastes stored for 3 months were higher than those recorded on the day of manufacture. Here, we have investigated the changes in consistency that occur during tomato paste storage and show how they differ from the changes that occur during paste production.

MATERIALS AND METHODS

Tomato Juice and Paste

Tomato products were sampled on three different days over two seasons at the Morning Star processing plant in Williams, California. Hot-break juice was collected after passing through the finishers, but prior to any concentration and an 11°Brix, concentrate was taken from the second effect evaporator. These samples were immediately cooled on ice then transported to Davis, CA for analysis on the day of production. For storage of these samples beyond the day of production, sodium azide was added to a final concentration of 0.2 g/L

TABLE 1.
DESCRIPTION OF TOMATO PASTES

	Finisher screen size	Soluble solids
	mm (in)	°Brix
Paste 1	1.14 (0.045)	31
Paste 2	1.52 (0.060)	28
Paste 3	2.29 (0.090)	28

to act as a preservative. Tomato paste was obtained in sealed sample bags. Multiple bags were collected on each of 3 different days of production and opened as needed during paste storage. Descriptions of these pastes are given in Table 1.

Paste Reconstitution and Heating

Approximately 200 g of paste was accurately weighed into a 4L double zipper "Ziplock" polyethylene bag, and 600 g of distilled water was added. The paste and water were blended by manually kneading the bag until a uniform suspension was obtained. Soluble solids content was determined with an Atago PR32 digital refractometer (Bellevue, WA), then additional water was added to dilute the suspension to 5°Brix. Subsequent dilutions of this same paste during storage were all done with this same final water-to-paste ratio. Dilution to other °Brix values followed a similar procedure.

Heating of reconstituted paste was done by weighing 200 g of reconstituted paste or juice into a 1 L double zipper "Ziplock" polyethylene bag. These bags were heated in either a temperature-controlled circulating water bath or, in some cases, a boiling water bath.

Juice Characterization

Bostwick consistency was determined with a special extra long (50 cm) Bostwick consistometer constructed from plexiglass as described (Marsh *et al.* 1980). All determinations were done in triplicate.

Tomato serum was prepared by centrifuging 20 mL of 5°Brix tomato juice or reconstituted paste for 10 min at 11,000 × g in a Sorvall RC4B centrifuge. The supernatant was collected and 7 mL was transferred to a #100 Cannon-Fenske viscometer in a 30C water bath. Flow times for the serum between the two demarcation lines were determined relative to the flow time for distilled water in the same viscometer. As is typical in the tomato industry, this relative flow rate was then multiplied by 60 s to give a viscosity in units of seconds. Duplicate determinations were done for each serum. In no case did these duplicates differ by more than 1 s.

The precipitate weight ratio (Takada and Nelson 1983) was determined by pipetting 1.0 mL of 5°Brix tomato juice or reconstituted paste into pre-weighed 1.5 mL Eppendorf centrifuge tubes. The tubes were re-weighed then centrifuged for 5 min at 16,300 × g in an Eppendorf 5415D centrifuge. The supernatant was aspirated off and the tubes were again weighed. All determinations were done in triplicate.

Serum separation was determined by placing 10 mL of 5°Brix juice in 15 mL plastic centrifuge tubes. A small volume (20 μL) of 100 g/L of sodium azide was added to each tube to act as a preservative. After 21 days of standing at room temperature, the height of clear serum on the top of the juice as well as the total height of the juice in the tube were measured. Serum separation is expressed as the percent of the total juice height occupied by the clear serum.

RESULTS

Consistency Loss in Tomato Paste

A sample of unconcentrated 5°Brix hot-break juice, a partially concentrated (11°Brix) processing intermediate and 28°Brix paste, collected on the same day from a commercial processing plant, were analyzed for Bostwick consistency. The latter two samples were diluted with water to 5°Brix, then Bostwick values for all three samples were determined. As has been observed before, 5°Brix dilutions of 11 and 28°Brix concentrates both had higher Bostwick values than that of the unconcentrated 5°Brix juice (Fig. 1A). The loss in consistency occurred early in the process as the juice was concentrated from 5 to 11°Brix, with no further loss occurring as the juice was concentrated to 28°Brix. The hot-break juice, 11°Brix concentrate and 28°Brix paste were then stored at room temperature. Fresh dilutions of the paste and 11°Brix concentrate were prepared after 35 days of storage and the Bostwick values again determined. Both the unconcentrated juice and the fresh dilution of the 11°Brix concentrate gave the same Bostwick values as measured prior to storage. In contrast, the Bostwick value of the diluted paste was 2.2 times greater than that measured previously (Fig. 1A). Results similar to those in Fig. 1 were obtained with pastes collected on 2 additional days of production at this same processing plant. For the pastes collected on these two additional days, the Bostwick values measured after 35 days of storage were 2.05 and 2.66 times higher than the Bostwick values measured on the day of production.

The precipitate weight ratio, defined as the weight ratio of the pellet formed by centrifugation to the weight of juice centrifuged, has been shown to

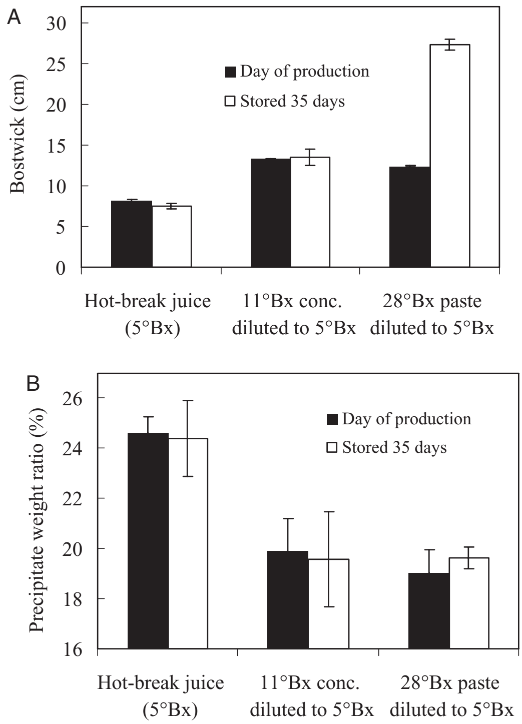

FIG. 1. (A) BOSTWICK CONSISTENCY AND (B) PRECIPITATE WEIGHT RATIOS OF 5°BRIX TOMATO JUICE, 11°BRIX CONCENTRATE AND 28°BRIX PASTE AFTER DILUTION TO 5°BRIX, MEASURED ON THE DAY OF PASTE PRODUCTION AND AFTER 35 DAYS OF STORAGE

Data are the means of three determinations; error bars indicate two standard deviations.

be well correlated with Bostwick values in tomato juice. Juices with higher consistency (lower Bostwick values) have higher precipitate weight ratios. In agreement with this, the precipitate weight ratio of the unconcentrated juice was higher than that of either the diluted 11°Brix concentrate or 28°Brix paste when measured on the day of manufacture (Fig. 1B). Storing either the juice or the concentrates for 35 days led to no significant changes in precipitate weight ratio. This is in spite of the fact that this storage period caused the Bostwick value of the 28°Brix paste to more than double. Thus, unlike the change in consistency that occurred during juice concentration, the change in consistency that occurred during storage was not accompanied by changes in precipitate weight ratio.

The change in 28°Brix paste that caused the higher Bostwick values upon dilution occurred rapidly, during the first 21 days of storage. A change in

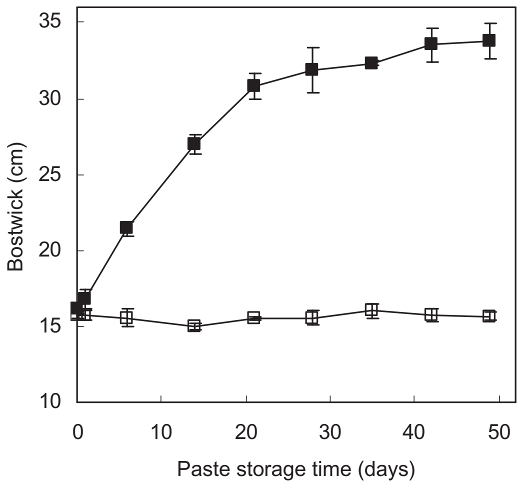

FIG. 2. CHANGE IN BOSTWICK DURING PASTE STORAGE
Paste was reconstituted with water to 5°Brix either on the day of production or after the number of storage days indicated. Bostwick values were determined with the reconstituted juice either with no heat treatment (■) or after heating at 90C for 1 h (□). Data are the means of three determinations; error bars indicate two standard deviations.

consistency could be detected after as little as 1 day of storage (Fig. 2). Longer storage times (up to 9 months) caused little additional change beyond that seen in the first 3 weeks (Figs. 2 and 3). Storing the paste at 4C rather than at room temperature slowed the change but did not prevent it. By 3 months of storage, there was very little difference in consistency between paste stored at 4C and room temperature (Fig. 3).

Heating Effects

Heating diluted pastes reversed the loss of consistency that occurred during paste storage. When stored pastes were diluted then heated for 1 h at 90C, Bostwick values of the reconstituted juices were close to those observed on the day of production (Figs. 2 and 3). For the three pastes examined and all storage times up to 9 months, the Bostwick values of the heated dilutions were within 20%, and in most cases within 10%, of the Bostwick values measured for the dilution prepared on the day of manufacture. Brix values measured before and after heating were not different, indicating that these heat treatments did not alter the soluble solids content (data not shown). Heating was much less effective in reversing the loss of consistency that occurred during paste manufacture. Heating of the dilutions prepared on the day of manufacture caused a small but significant ($P < 0.05$) decrease in Bostwick, ranging

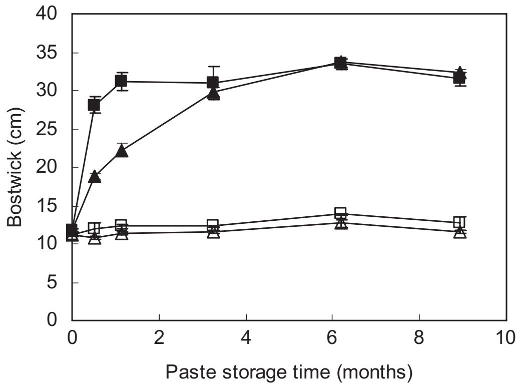

FIG. 3. EFFECT OF STORAGE TEMPERATURE ON THE CHANGE IN BOSTWICK DURING PASTE STORAGE

Paste was stored either at room temperature (■,□) or at 4C (▲,△). Paste was reconstituted with water to 5°Brix either on the day of production or after the storage times indicated. Bostwick values were determined with the reconstituted juice either with no heat treatment (■,▲) or after heating at 90C for 1 h (□,△). Data are the means of three determinations; error bars indicate two standard deviations.

from 3 to 9% for the three pastes examined. In all three cases, the Bostwick values of the heated dilutions were still substantially higher than the Bostwick values of the original unconcentrated juice (Fig. 4).

The heat requirement for restoring the consistency of stored paste was examined by heating 5°Brix dilutions for 1 h at different temperatures. Temperatures below 90C were not effective in fully restoring the Bostwick in 1 h of heating (Fig. 5A). As would be expected, the decrease in Bostwick occurred more rapidly with heating at 100C than at 90C (Fig. 5B). After 20 min at 100C, the Bostwick value had returned to the same value as measured on the day of manufacture. Longer heating times (up to an hour) caused little additional change.

Effect of Different Dilutions

The 28°Brix paste diluted to 5°Brix allowed for a direct comparison between the paste and the 5°Brix juice from which it was manufactured. The standard practice for evaluating paste consistency in the processing industry is to dilute the paste to 12°Brix. Bostwick values obtained from 12°Brix dilutions of paste showed the same loss of consistency during storage and the same reversal by heating as observed with the 5°Brix dilution (data not shown). The effect of heating on the Bostwick value of stored paste was determined for a range of dilutions between 5 and 12°Brix. A plot of the

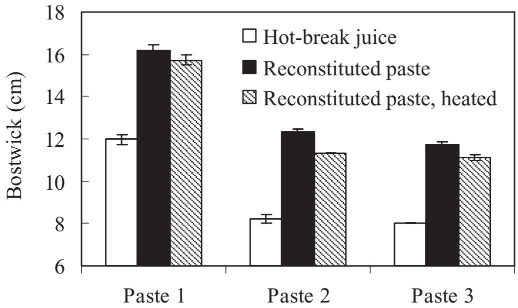

FIG. 4. CONSISTENCY LOSS DURING PASTE PRODUCTION AND THE EFFECT OF HEATING AFTER PASTE RECONSTITUTION

Bostwick values for hot-break juice, paste reconstituted to 5°Brix, and paste reconstituted to 5°Brix then heated for 1 h at 90C were measured on the day of paste production. Results from three different pastes collected on 3 separate days of paste production are shown. Data are the means of three determinations; error bars indicate two standard deviations.

Bostwick values on a log scale versus °Brix values after dilution gave a straight line (Fig. 6), in agreement with earlier results that the Bostwick value decreases logarithmically with the degree of paste concentration (Marsh *et al.* 1978). Heated dilutions also gave a straight line with a similar slope, showing that the effect of heating on the Bostwick is proportionally the same at all levels of paste dilution.

Serum Viscosity

Serum viscosity is a second parameter used along with the Bostwick value to evaluate tomato paste consistency. Serum viscosity changed rapidly during paste storage. The decrease in serum viscosity occurred almost entirely on the first day of storage as opposed to the 3 weeks of storage required for the change in Bostwick to occur (Fig. 7). However, the relative change in serum viscosity during storage was much smaller than the change in Bostwick. For the three pastes examined, the percent changes in serum viscosities during storage ranged from 16 to 25%, whereas the increases in Bostwick values were all more than 100%. This decrease in serum viscosity during storage was smaller than the decrease that occurred during paste manufacture. For the three pastes examined, the serum viscosities of the 5°Brix dilutions prepared on the day of manufacture were 32–40% lower than the serum viscosities of the hot-break juices from which they were prepared. This is in line with our previous measurements made at this same processing plant where the concentration of hot-break juice to paste resulted in serum viscosity losses between 31 and 37% (Anthon *et al.* 2008).

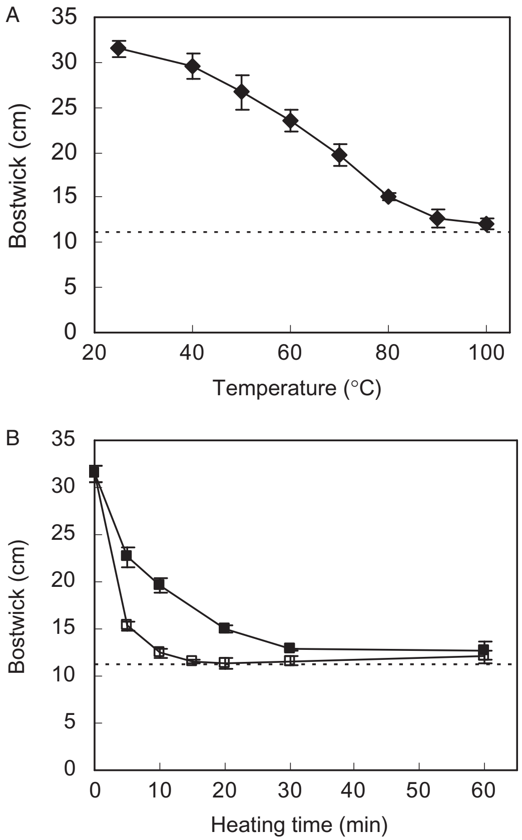

FIG. 5. EFFECT OF HEATING ON THE BOSTWICK VALUE OF RECONSTITUTED PASTE
A 28°Brix paste was stored for 9 months then reconstituted to 5°Brix and heated at the times and temperatures indicated. (A) Heating was for 1 h at the temperatures indicated. (B) Heating was at 90C (■) or 100C (□) for the times indicated. Dashed lines indicate the Bostwick value for this paste measured on the day of paste production. Data are the means of three determinations; error bars indicate two standard deviations.

Heating the reconstituted paste for 1 h at 90C increased the serum viscosity but did not completely restore it to the level observed on the day of manufacture (Fig. 7). Just as the decrease in serum viscosity during storage was much more rapid than the increase in Bostwick, the heating times required to restore the serum viscosity were also shorter. The greatest increase in serum viscosity occurred in the first 5 min of heating at either 90 or 100C (Fig. 8). Short time heating at 100C resulted in higher serum viscosities than were observed by heating at 90C; however, prolonged heating at 100C caused serum viscosity to decrease, while additional heating at 90C did not.

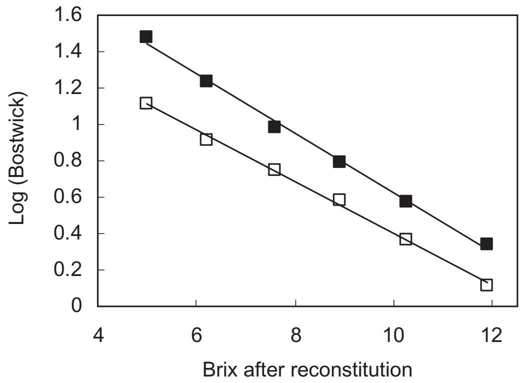

FIG. 6. EFFECT OF HEATING ON BOSTWICK OF STORED PASTE RECONSTITUTED TO DIFFERENT °BRIX LEVELS
A 28°Brix paste was reconstituted with water to the °Brix levels indicated after 22 days of storage. This reconstituted paste was either heated to 90C for 1 h (☐) or not heated (■) before Bostwick values were determined.

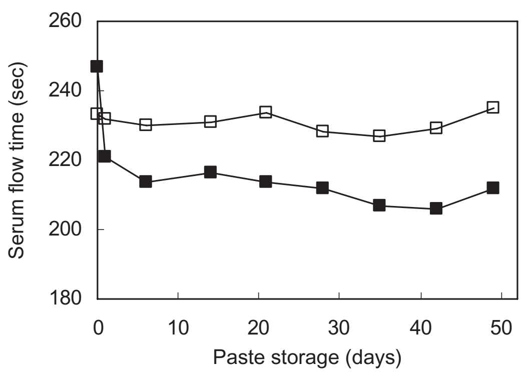

FIG. 7. CHANGE IN SERUM VISCOSITY DURING TOMATO PASTE STORAGE
Paste was reconstituted with water to 5°Brix after different storage times. This reconstituted paste was then either heated to 90C for 1 h (☐) or not heated (■) before the serum viscosity was determined.

Serum Separation

Serum separation, the formation of a layer of clear serum on the top of the juice upon standing, was much greater in juices prepared from stored pastes. With the 5°Brix juice reconstituted on the day of paste manufacture, the height of clear serum formed after 21 days of standing at room temperature was only

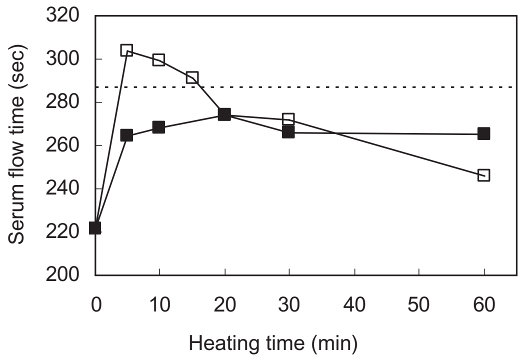

FIG. 8. EFFECT OF HEATING TIME ON SERUM VISCOSITY OF STORED PASTE
Paste was stored for 9 months then reconstituted to 5°Brix and heated at 90C (■) or 100C (□) for the times indicated. The dashed line indicates the serum viscosity for this paste measured on the day of paste production.

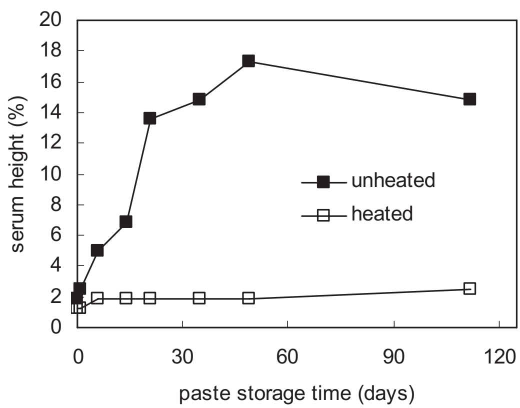

FIG. 9. EFFECT OF PASTE STORAGE ON SERUM SEPARATION
Paste was reconstituted with water to 5°Brix after different storage times. This reconstituted paste was either heated at 90C for 1 h (□) or not heated (■) then evaluated for the degree of serum separation. Serum separation is expressed as the % of the total juice height occupied by clear serum after 21 days of standing at room temperature.

1.8% of the total juice height (Fig. 9). With juice prepared from stored paste, this clear serum layer was 15% or more of the total juice height. This increase in serum separation occurred during the first few weeks of paste storage, a time course similar to that seen for the increase in Bostwick. As with the increase in Bostwick, the increased serum separation was reversed if the reconstituted paste was heated.

DISCUSSION

It is well known that reconstituted tomato pastes will have lower consistencies than the juice from which the paste was prepared. Here, we show that in addition to the loss of consistency that occurs during paste production, there is a further change in consistency during paste storage. This change takes place in the first month of storage and results in more than a doubling of the Bostwick value. However, unlike the consistency loss during paste production, this storage loss can be reversed by heating the reconstituted juice. This and other differences between the two effects strongly suggest that the mechanisms responsible for the consistency losses during production and those during storage are different.

One proposed mechanism for consistency loss in tomato paste is that the high osmotic and ionic strength in the paste causes changes in the polymeric materials in juice particles, altering the interactions between these particles and changing rheological properties of the juice when reconstituted with water. In this mechanism, consistency loss is a direct and unavoidable consequence of juice concentration. This mechanism appears to be inadequate for explaining the consistency loss during paste manufacture because on a laboratory scale, juice can be concentrated to double strength then re-diluted without any change in consistency (Anthon *et al.* 2008). However, this mechanism may be a reasonable explanation for the consistency changes during paste storage. A requirement for high solute concentrations could explain why consistency changes during storage were observed with the 28 or 31°Brix pastes but not with the 11°Brix concentrate (Fig. 1A). Serum viscosities changed more rapidly during storage and showed a faster response to heating after reconstitution than did the Bostwick consistencies. Serum viscosities are determined by the properties of the soluble polymers (primarily pectin) in the tomato juice, while the Bostwick consistencies are affected mostly by the insoluble material. The faster onset of changes in the serum viscosity during both storage and reconstitution indicates that the soluble pectin polymers respond more quickly than the insoluble material to changes in solute concentration.

The results presented here imply that any changes in the polymeric material induced by high solute concentration are readily reversed by heating after dilution. One well-known effect of heat on tomato juice is to cause the degradation of pectins by acid hydrolysis and β-elimination reactions (Diaz *et al.* 2007). It is unlikely, however, that pectin degradation is involved in the restoration of consistency by heating because rates of pectin breakdown at 90C are low (Diaz *et al.* 2007), and degradation of pectin polymers results in consistency and serum viscosity losses. The decline in serum viscosity occurring with longer heating times at 100C (Fig. 8) could well be the result of such pectin hydrolysis. A decrease in serum viscosity by heating tomato juice to temperatures above 100C has been noted previously (Caradec and Nelson 1985).

It has previously been shown that Bostwick consistency is well correlated with the precipitate weight ratio (Takada and Nelson 1983). This relationship appears to be quite close for the changes in Bostwick occurring during paste production (Anthon *et al.* 2008). It was thus surprising that the large change in Bostwick during paste storage was not accompanied by a change in the precipitate weight ratio (Fig. 1A,B). This is a further indication that the mechanisms for consistency loss during paste production and paste storage are different. The fact that under some conditions a large change in Bostwick value can occur with no change in precipitate weight ratio shows that the precipitate weight ratio is not a generally applicable predictor of consistency. The irreversible consistency loss during paste production has been shown to be paralleled by a reduction in juice particle size (Den Ouden and Van Vliet 2002; Kotte *et al.* 2006). It is possible that the reversible changes during storage involve changes in the interactions between juice particles instead.

Serum separation and Bostwick value increased in parallel during paste storage, and both changes were completely reversed by heating. This would indicate that these two attributes are closely related. This is in agreement with Stoforos and Reid (1992), who also reported a correlation between the Bostwick value and serum separation, and Den Ouden and Van Vliet (2002), who developed a model that successfully predicted serum separation based on the consistency measured with a rheometer.

In most previous studies on consistency loss, it was not specified if the reconstitution of the paste occurred on the day the paste was prepared or after some period of storage. It is thus not clear if the consistency losses reported previously represent only the losses that occurred during production or whether they include that loss plus a storage effect. Likewise, in previous studies on the consistency of reconstituted paste, a variety of different heat treatments have been applied. Reconstituted pastes have variously been either not heated (Beresovsky *et al.* 1995; Basim *et al.* 2004; Bayod *et al.* 2007, 2008) or heated to 50C (Kotte *et al.* 2006), 88C (Marsh *et al.* 1979), 90C (Den Ouden and Van Vliet 2002) or 100C (Marsh *et al.* 1978). In all but one case where heat was applied, the duration of the heat treatment was not given so it is not clear whether the heating was sufficient. In only one case (Marsh *et al.* 1978) was a clear distinction made between the consistency loss that occurred immediately on the day of paste manufacture and that which occurred during subsequent paste storage. These authors noted an increase in Bostwick during paste production and a further increase during paste storage; however, the storage increase was far smaller than what was found here. They also showed that heating the reconstituted paste for 30 min at 100C caused a small reduction in Bostwick if applied to paste on the day of production, similar to what was found here (Fig. 4). They did not test the effect of heating on restoring consistency with stored paste.

For nearly complete recovery of both the Bostwick consistency and serum viscosity to the values obtained on the day of manufacture, heating for 15 min at 100C or 30 min at 90C appears adequate. Longer heating times (up to an hour) at 90C caused no additional changes, but at 100C, these longer heating times led to a decrease in serum viscosity and a small increase in Bostwick. Effects of heating at temperatures higher than 100C were not tested, but it is likely that these higher temperatures would allow for the use of even shorter heating times to restore consistency but with an increased possibility of undesirable changes from excess heating. The heating times given here are the total heating times used in our experiments. They are thus overestimates of the actual minimum times at these temperatures required to restore consistency because they do not account for the come-up time during heating.

Production of formulated products with tomato paste (ketchup, sauces, etc.) almost invariably involves heating the final product. This could explain why the reversible consistency changes occurring during storage have not been widely recognized before. The current practice in the California tomato industry during paste production is to take a paste sample every few hours, reconstitute it with water to 12°Brix (without heating) then measure the Bostwick value. This appears to be an adequate procedure for characterizing a particular paste, as long as it is recognized by end users that subsequent evaluations of the paste after storage require that the paste be heated after reconstitution to obtain this same Bostwick value. During formulation of products using tomato paste, it is thus essential that the formulation being evaluated receive the same heat treatment that will eventually be applied during production.

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