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The contribution of water removal to the phenomenon of "consistency loss" associated with juice concentrate products

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Abstract

A recurring problem with juice concentrates is that, on reconstitution of the original strength juice, there is a loss in consistency (Marsh et al 1978). This is reflected in a lower product yield for products produced from concentrate as compared to products prepared directly from the original juice. It is commonly held that this loss in consistency is in part due to the thermal effects of the concentration/ evaporation process (Ilker and Szczesniak, 1990), or the mechanical changes induced by the shear effects during fluid flow within the process (Mannheim and Koperlan, 1964; Berovsky et al, 1995). This paper demonstrates that a further, important, cause is irreversible molecular associations induced by the existence of high solute concentrations in the final concentrate. Using tomato juice concentrates we demonstrate that the particle sizes of the dispersed hydrocolloid materials is reduced as a consequence of being having the water concentration in the system reduced, then returned to the original level. This size change, corresponding to an approximately 10% decrease in phase volume under the conditions investigated, correlates well with the changed flow rheology characterization of the initial and final system.
Further confirmation of the importance of concentration induced aggregation as a source of consistency loss is provided by comparing the loss accompanying a tradition evaporation-redilution process with the change in consistency accompanying a freeze thaw cycle. There is an important correlation between the changes in consistency accompanying these very different processes. The referenced patent (Reid 2004) applies this correlation to allow for prediction of potential consistency loss in evaporative paste production by merely freezing some of the original juice material, and evaluating the change in consistency of the thawed material in contrast to the original..

Keywords:

Introduction

For a variety of reasons, not least the economic costs of transporting water, juice concentrates are in frequent use as intermediate products reconstituted in the final application. A recurring problem with these concentrates is that on reconstitution to the original juice strength there is a loss in consistency. This consistency loss is reflected in a lower product yield for products produced from concentrate as compared to product prepared directly from the original juice. The source of this loss in consistency has long been debated, with the most commonly held view being that the loss is due in part to the thermal degradation of polymers during the evaporation process, and also due to mechanically induced polymer degradation consequent upon the high shear forces experienced during fluid flow While clearly significant, these do not appear to be the sole causes of consistency loss. Another potential mechanism for loss in consistency may be found in the possibilities for irreversible biopolymer cross-linking induced under the conditions of high solute concentration in the final concentrate. This study seeks to demonstrate that the cross-linking mechanism is a significant contributor to the observed consistency loss.

In order to demonstrate the contribution from polymer aggregation/cross-linking we have evaluated the change in particle size of the dispersed hydrocolloid particles of a tomato paste produced from tomato juice by evaporative methods as a function of final paste concentration. This information has been correlated to the consistency loss observed when these pastes are diluted back to lower concentrations. We have also evaluated, using a freezing protocol whereby the original juice is held frozen for a period of time prior to being thawed, any consistency loss consequent upon the "freeze concentration" experienced by the unfrozen matrix and compared this to the consistency loss observed associated with evaporative concentration..

Materials and methods

Production of concentrates

Tomato juices are produced by standard methods, both large scale and bench scale, using a range of tomato varieties. .Aliquots of the juices are then used to prepare pastes of a range of concentrations from 12Bx to 30Bx are then produced using a bench scale scraped surface, evaporative concentrator which requires only 3-4 l of starting juice. Prior studies have shown that the pastes produced have characteristics similar to those of commercial pastes produced from the same feedstock juice. By using the small scale bench process, characteristic pastes can be conveniently produced from many different varieties. Further aliquots of the juice, in sealed containers, are placed in frozen storage (-8^o, -30^o, -196^{o}C)

Reconstitution methods

Evaporative pastes are reconstituted with deionized water to the required final concentration. Care is taken not to introduce air bubbles, as these would interfere with rheological evaluation. The diluted pastes are equilibrated for 24 hours at 4^{o}C, then heated, in a sealed container, by microwave to 50^{o}C prior to cooling to 20^{o}C prior to evaluation.

Frozen juices are thawed by microwave, hearing only to 50^{o}C, and then equilibrated at 20^{o}C.

Viscosity

A Rotovisco RV20 controlled strain rate rheometer (Haake Buchler Instruments) fitted with a M5/MVII sensor system was used to measure viscosities of original juices, reconstituted evaporative pastes, and thawed frozen juices. Samples were equilibrated at 20.0^o$\underline{+}$0.1C. The shear rate was programmed to cycle from 3.5s^{-1} to 450s^{-1}.Where appropriate, apparent viscosity is reported for shear rates 50s^{-1} and 100s^{-1}.

Particle size analysis

The size distribution of the hydrocolloid containing particles in tomato juices was determined using Malvern Mastersizer MS20 and Coulter LS-200 and LS-230 Particle size analyzers. Measurement requires dilution of the juice. To prevent osmotically induced size changes, the diluting solutions were sucrose solutions of the same ° Bx as the sample under study. Standard particle sizing routines were followed.

Results and Discussion

Concentration by evaporation

Concentration by evaporation causes a marked consistency loss. Figure 1 shows typical viscosity curves for single strength tomato juice samples reconstituted from pastes of varying degrees of concentration produced from the same original juice. The higher the initial Brix of the paste, the greater is the loss in consistency. Figure 2 shows typical flow curves for another set of reconstituted single strength juices prepared from a different set of pastes. These results can be reconciled with the particle size information summarized in figures 3 and 4, which show that the manufacture of paste, followed by redilution is, indeed, accompanied by a particle size reduction. The proposed cross-linking effect of increased solute concentration as a result of the reduction of water content would be expected to result in such a size decrease. The decreases seen are equivalent to a volume reduction of around 10%. A decrease in particle phase volume of 10% is sufficient to account for the observed viscosity reductions

Effect of “freeze concentration”

A series of thawed juice samples were evaluated after frozen storage at -8^{o}C, -30^{o}C or -196^{o}C. Figure 5 shows the comparison of the flow proerties with the original juice. The greatest reduction in consistency is seen for storage at -8^{o}C, with no reduction in consistency for the sample frozen in liquid nitrogen (-196^{o}C). These results can be explaned as a consequence of freeze concentration, assuming that rapid cooling to -196^{o}C gives no opportunity for osmotic dehydration of the particles, and that cooling to -30^{o}C limits the amount of osmotic dehydration, as this would be expected to be slow at -30^{o}C. The effects of freeze concentration and the associated osmotic dehydration are most evident after storage at -8^{o}C.

Correlation between evaporative concentration and freeze concentration

In order to correlate the effects of evaporative concentration, and freeze concentration, a range of juices were used to prepare 30Bx pastes by evaporative concentration. Samples of these same juices were also held in frozen storage at -8^{o}C. The evaporative pastes were then rediluted to single strength, and the apparent viscosity at 100s^{-1} determined. The corresponding frozen juices were thawed, and the apparent viscosity at 100s^{-1} determined. The results of this study are summarized in figure 6, which plots the apparent viscosities for both evaporative and frozen samples for each juice studied. Each point represents a different juice, and each juice was from a different tomato cultivar. The results indicate that there is a correlation between the consistencies of diluted evaporative pastes and frozen thawed juice. It is possible to use this correlation in a predictive fashion. Figure 7 shows a comparison between predicted and measured consistency loss, using the freeze concentration consistency loss to predict the expected consistency losses of conventionally produced pastes. This observation is utilized in a patent which enables the prediction of potential consistency loss of a processed paste from simple measurements made of frozen juice samples. Reid 2004. This can be an important tool for cultivar screening.

Conclusions

This study clearly shows that the increased solute concentration accompanying from water removal in juice concentrates results in polymer cross-linking within the particulate phase, reducing the phase volume, and hence lowering the resulting flow viscosity. This is an important contributor to consistency loss additional to any thermal degradation, or mechanical damage.

Acknowledgements.

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Figures

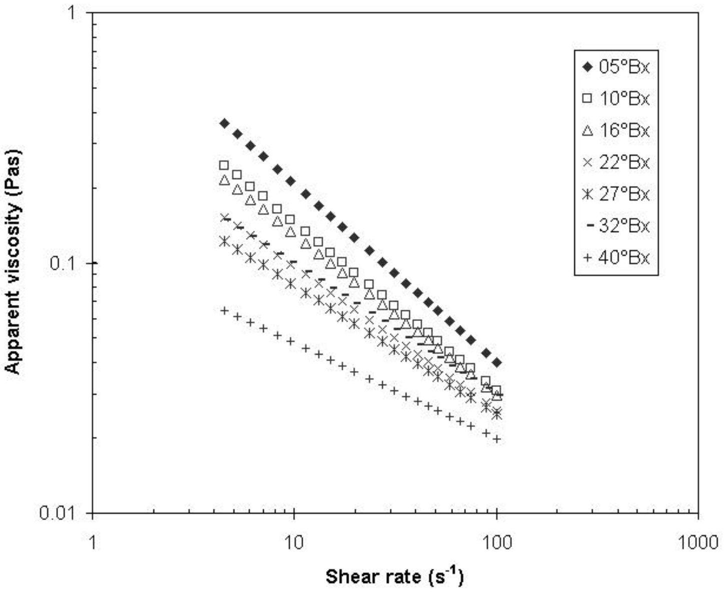

Figure 1. Viscosity curves for single strength (5.0°Bx) tomato juice samples reconstituted from pastes of varying °Bx produced from a common original juice.

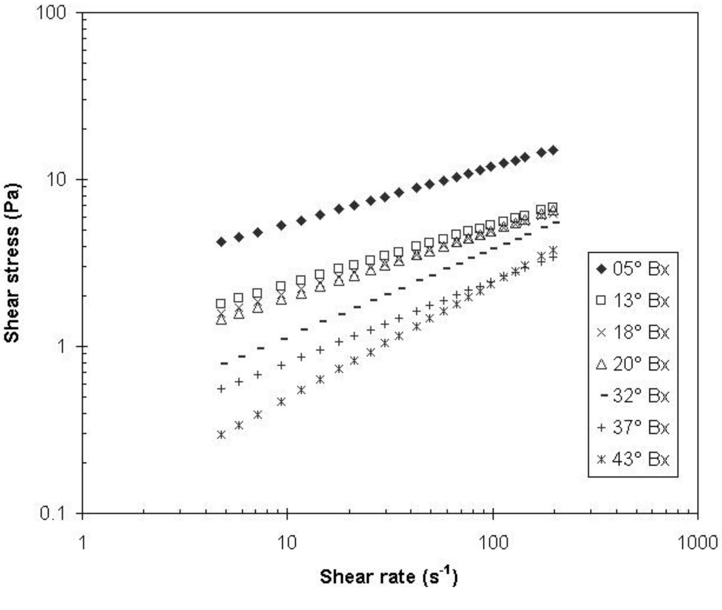

Figure 2. Flow curves for single strength (5.0°Bx) tomato juice samples reconstituted from pastes of varying °Bx produced from a common original juice

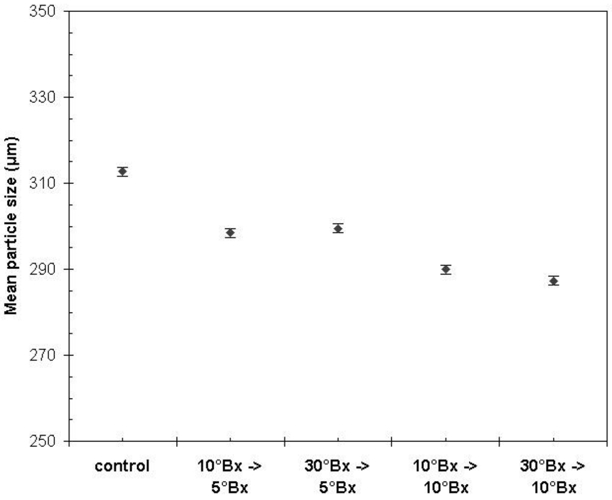

Figure 3. Mean particle sizes in original (control) juice, and reconstituted samples

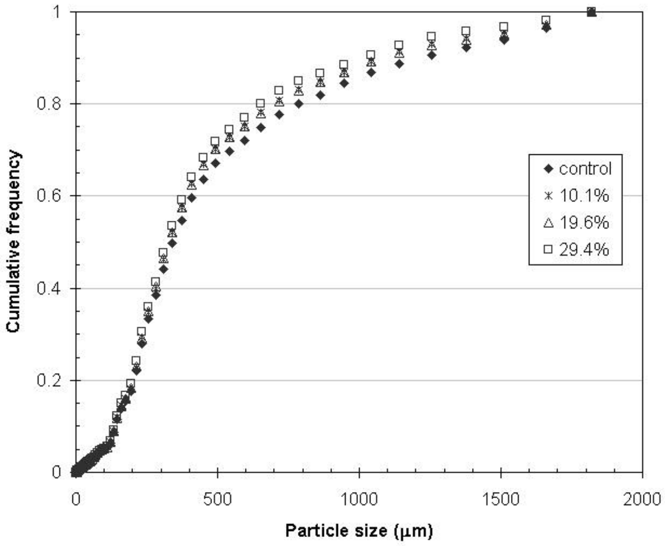

Figure 4. Cumulative histogram of particle sizes in single strength tomato juices reconstituted from different ^{o}Bx pastes. Control is original juice.

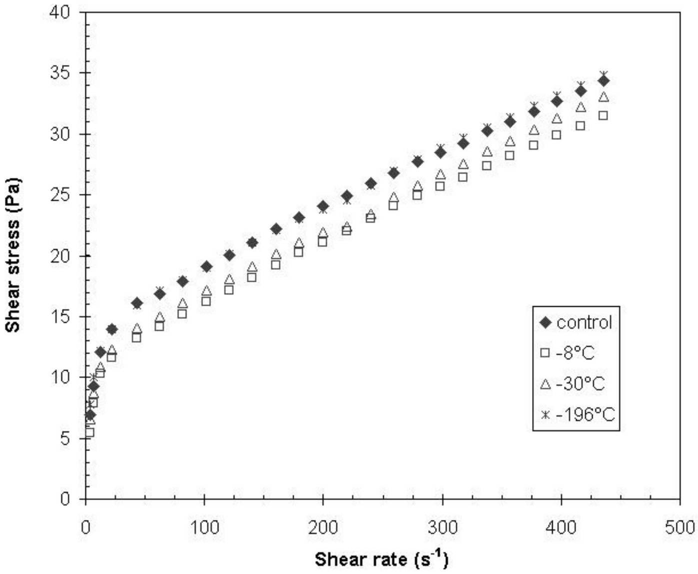

Figure 5. flow curves for thawed tomato juices after freezing at different temperatures. Control is original juice.

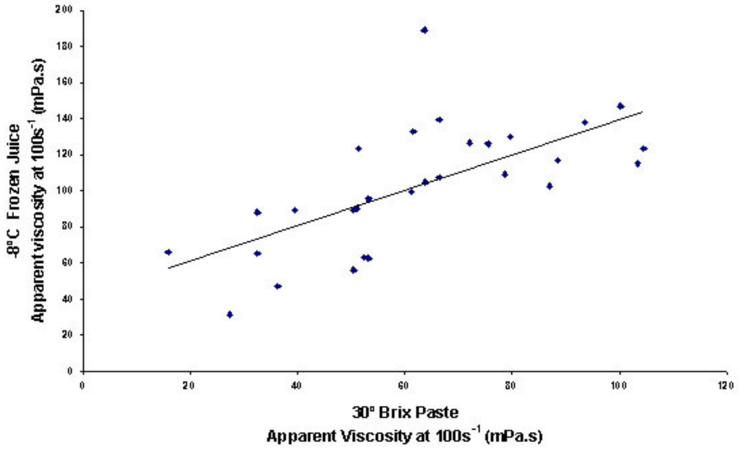

Figure 6. Comparison of apparent viscosities of thawed frozen juices with apparent viscosities of diluted 30^{o}Bx pastes

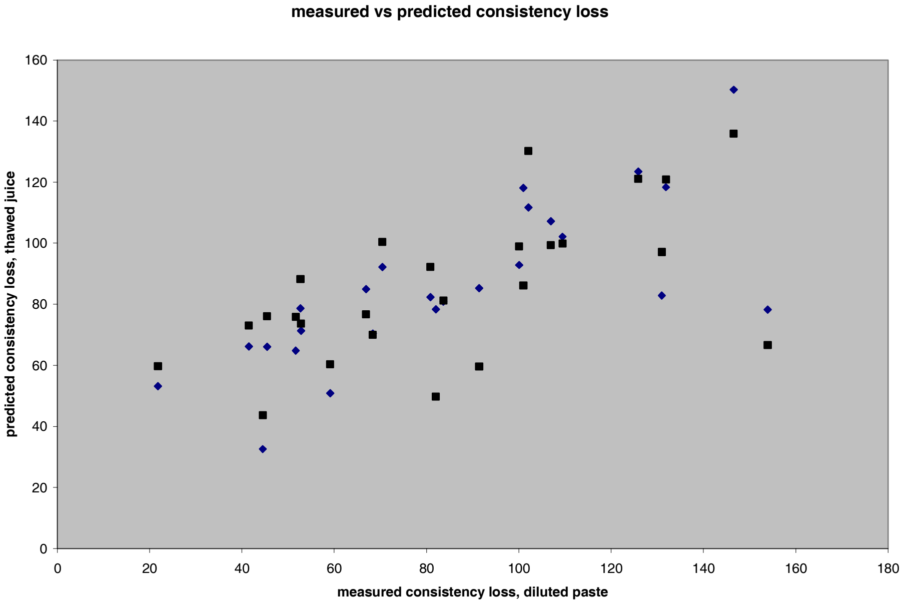

figure 7. Comparison of predicted vs measured consistency loss for diluted pastes from different tomato cultivars.

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