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Effect of Reducing Pulp-Particles on the Physical Properties of Carrot Juice

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Abstract: Sedimentation is a main problem in carrot juice. Several studies reported that cloud stability could be improved by using polysaccharide stabilizer and reducing pulp content, however these might affect texture attributes of the product. This study evaluated physical properties of carrot juices that were prepared by using different machines i.e. (i) hydraulic pressing, (ii) hammer mill, and (iii) high pressure homogenizer, which reduced sizes of the carrot pulps to 332, 283, and 82 μm diameter, respectively. No significant changes ($p < 0.05$) in the pulps diameter during storage at 4°C for 2 weeks were seen. Apparent consistency of the products was not significantly different (2.08 - 2.16), however a significant difference was found in serum viscosity (1.23, 1.31, and 1.41, respectively) that indicated that the smaller pulp size had higher relative viscosity. After 14 days, both viscosities of all samples tended to slightly decrease. Values of pH and total soluble solids (°Brix) of all samples were 3.39 - 3.42 and 11.0 -11.2, respectively, while colors were 86.3 lightness (L), 40.4 redness (a), and 75.8 yellowness (b). These characteristics remained constant during storage. The homogenization process provided the product with a higher viscosity due to smaller pulp sizes, which did not have any effects on the quality factors such as the color, pH and °Brix of the carrot beverages.

Keywords: Carrot juice, pulps reduction, sedimentation, physical properties

INTRODUCTION

Carrot juice is an excellent source of β-carotene (provitamin A), ascorbic acid, tocopherol and phytochemicals including good sources of dietary fiber and minerals. The phytochemical substances in carrot are composed of phenolic compounds, terpenes, and carotenoids which act as free radical quenchers and antioxidant agents (Heinonen, 1990; Desobry *et al.*, 1998; Johnson, 2003). These provide health benefits to reduce high cholesterol, protect against cardiovascular disease, and against DNA damage (Heinonen, 1990; Winston, 1997) and promote anticancer enzyme activity. Though the consumption of carrot juice continues to increased, however, the formation of sediment in the juice is one of the major reasons for some of the consumers to reject it (Beveridge, 2002; Alklint, 2003). Additionally the sediment can adversely influence the quality of juice beverages by absorbing flavor substances and color agents (Corredig *et al.*, 2001).

Sediment velocity relies on the particles' diameter, the particles' density, the density of the solution and the viscosity of the solution. Reduction of particle size, and incorporation of polysaccharide stabilizers are simplified

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means for solving the problem of juice sedimentation. Applying hydrocolloids in juice products for improving cloud stability, many studies reported that the level of hydrocolloids addition was limited and also dependent on the variety of juice products and the juice process (Corredig *et al.*, 2001; Beveridge, 2002; Reiter *et al.*, 2003; Qin *et al.*, 2005). Higher level of hydrocolloids addition provided adverse quality in product texture. Pulps reduction is an interesting method to promote cloud stability of juice because it can stabilize clouds and only mechanical equipment is needed (Tetra Pak, 1999; Wennerstrum *et al.*, 2002; Hamatschek *et al.*, 2004). Due to limited research in this area, the effect of reduction of carrot pulps on physical properties and sediment in carrot beverage was the aim of this study.

MATERIALS AND METHODS

Processing Carrot Juice Beverages

The carrots were washed, peeled, and cut. Cut carrots were blanched in 0.01% citric acid solution at 90°C for 10 minutes. The carrots were ground and juice was extracted by hydraulic pressing. A hammer mill (0.002 inch mesh screen) and a high pressure homogenizer were used to reduce carrot pulps. Some sugar (9%), citric acid (0.3%), and salt (0.2%) were added to formulate the 30% carrot juice beverage. Carrot beverages were pasteurized at 95°C for 1 minute and then hot-filled and kept at 4°C for 2 weeks.

Particle Size Distributions

The size distributions of the particles in carrot juice were determined by laser diffraction using a Mastersizes S (Malvern Instruments, UK), using 1.73 and 1.33 as the refractive indices of cloud and dispersed phase, respectively, and 0.1 as the absorption index for cloud particles. Samples (2–5 ml) were introduced into the small volume presentation unit of the instrument, which already contained ~100 ml of deionized water. In this unit, the sample was pumped through the optical cell by a stirrer that rotates at ~200 rpm. Size distributions (volume fractions against particle size) were calculated, and the weight-average sizes were expressed as $D_{3,2} = \sum_i n_i d_i^3 / \sum_i n_i d_i^2$ and $D_{4,3} = \sum_i n_i d_i^4 / \sum_i n_i d_i^3$, where n_i is the number of particles of diameter d_i.

Apparent Consistency

The determination of apparent consistency or relative viscosity of juice beverage was performed according to the AOAC Official Method (2000; 967.16). Calibration of the capillary viscometer was done by adding water to tube at 24 ± 1°C and establishing steady flow. Flow was stopped by placing a finger over the end of the capillary tube. The tube was completely filled to the overflow point and leveled off with a spatula or by sighting across the top of tube. The finger was removed from the tube and timing immediately begun. The time required for the top of meniscus to reach the calibration line must be 13.0 ± 0.2 seconds ($t_{solvent}$). For sample determination, the test sample was adjusted to 24 ± 1°C and mixed thoroughly without incorporating air bubbles. It was then added to the tube and analyzed by the same method as the calibration. Time ($t_{solution}$) was recorded to the nearest 0.1 second for the top of the meniscus to reach the calibration line. The relative viscosity (η_{rel}) of juice was calculated from $\eta_{rel} = t_{solvent} / t_{solution}$.

Serum Viscosity

The supernatant or serum was separated from juice samples by centrifugation at 4200 x g for 15 minutes at 20°C. Kinematic viscosity of serum (η / ρ) was measured using a Canon-Fenske (Kimax 300) capillary viscometer. The sample (10 ml) was placed in the viscometer. The time t which the liquid took to fall between two engraved marks on the viscometer was measured at 25°C for temperature control. The capillary constant k was determined using water as a standard and

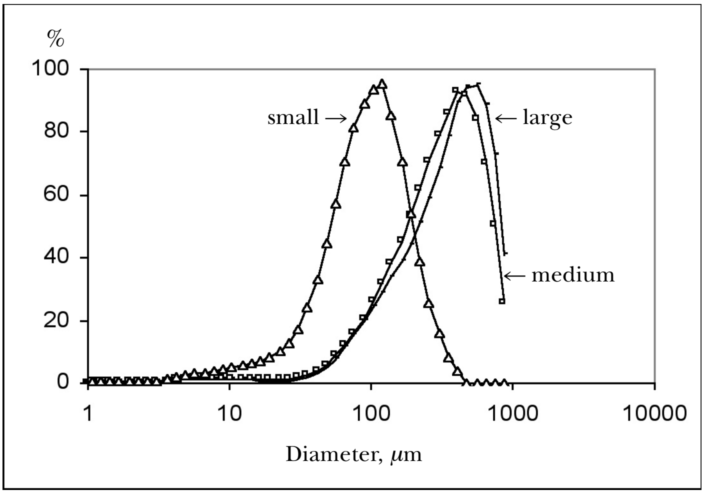

Figure 1: Particle sizes distribution of carrot juices with large, medium, and small size carrot pulps

the kinematic viscosity of the solutions was calculated from $\eta/\rho = kt$.

Color Measurement

Hunter L, a, and b parameters of the beverages were measured with a Chroma-Meter (Model CR-200, Minolta, Japan) in the transmission mode. The instrument was standardized each time with a white ceramic plate (L=100; a=0; b=0). Color difference, ΔE, was calculated from a, b, and L parameters, using Hunter-Scotfield's equation: $\Delta E = (\Delta a^2 + \Delta b^2 + \Delta L^2)^{1/2}$, where $\Delta a = a - a_0$; $\Delta b = b - b_0$; and $\Delta L = L - L_0$. The subscript "$_0$" indicates initial color.

pH and Total Soluble Solid

pH of carrot beverages was determined by using a pH meter with a glass electrode (Model 82-63, Orion Research, Inc., Beverly, MA). Total soluble solid content was measured by a Hand Refractometer (Atago, Model N1, Tokyo, Japan). The sample was placed on the prism of Refractometer then the daylight plate was closed, and the scale where the boundary line intercepts was read. The percentage scale of the Refractometer was shown in grams of sucrose or total soluble solids in 100 grams of aqueous solution and was equal to Brix number (°Brix).

Statistical Analysis

This research was performed by completely randomized design and data were analyzed by ANOVA at level of significance $p<0.05$ using Duncan's analyzed mean significant value. All measurements were repeated three times.

RESULTS AND DISCUSSION

Reduction in Size of Carrot Pulps by Using Different Machines

Passing the carrot juice through hydraulic pressing, a hammer mill, and a homogenizer showed 339, 276, and 82 μm (Figure 1) for mean diameter of pulps, respectively. Particle size distribution (Figure 1) of both juices from hydraulic pressing and the hammer mill were in the range 10 -1000 μm diameter, whereas using the homogenizer provided mean particle sizes between 5-500 μm diameter. Applying a homogenizer for size reduction of the carrot pulps produced the smallest pulps as well as showing a narrow range of size distributions when compared with the hammer mill and the hydraulic pressing. The homogenization process was highly efficient to break up large pulp particles into smaller sizes (Tetra Pak, 1999; Wennerstrum *et al.*, 2002). Generally, homogenization is applied

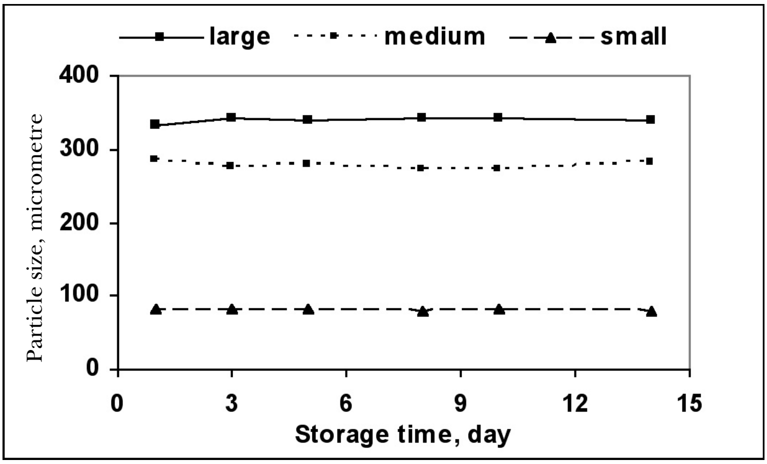

Figure 2: Mean diameter of particle sizes of carrot beverage with large, medium, and small pulps dispersion during storage at 4°C for 2 week

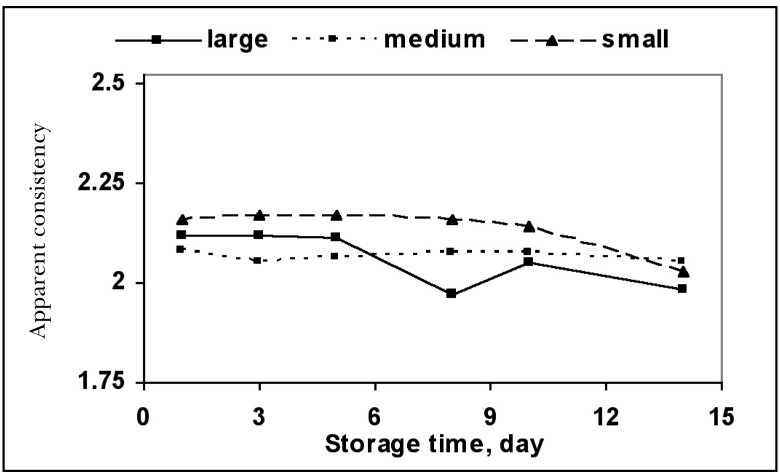

Figure 3: Apparent consistency of carrot beverages with large, medium, and small pulps dispersion during storage at 4°C for 2 weeks

to reduce the size of fat globules or particles in liquid and disperse them evenly in milk products or soy-based beverages (Tetra Pak, 1999; Durand *et al.*, 2003; Lemarchand *et al.*, 2003). The homogenization process produced juices of high quality.

Formulation of 30% Carrot Juice Beverages: Relation to Particle Sizes

Using hydraulic pressing, a hammer mill, and a homogenizer to reduce particle sizes of carrot pulps provided juices with large, medium, and small pulps, respectively. These carrot juices were formulated as 30% carrot juice beverages and stored at 4°C for 2 weeks. After formulation, no significant ($p<0.05$)

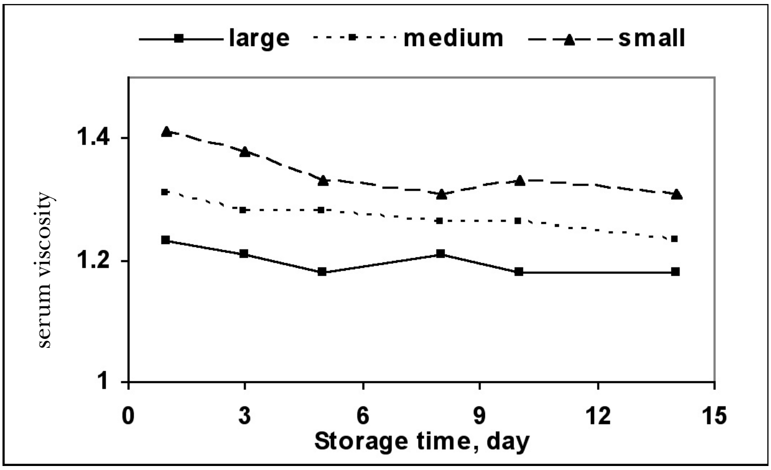

Figure 4: Serum viscosity of carrot beverages with large, medium, and small pulps dispersion during storage at 4°C for 2 weeks

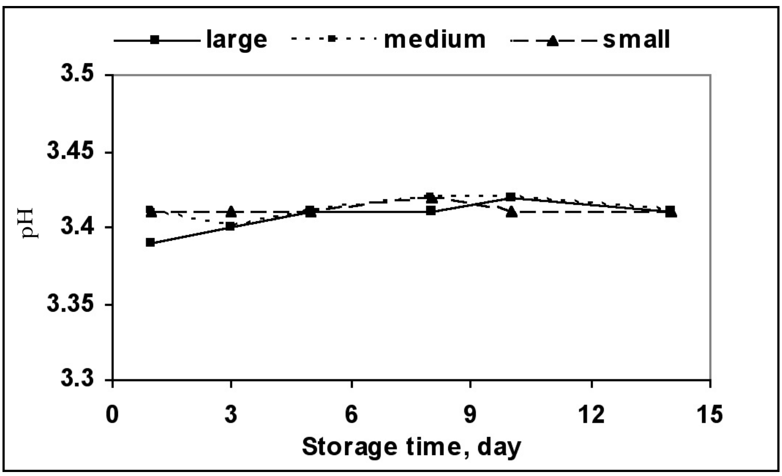

Figure 5: Changes in pH of carrot beverages with large, medium, and small pulps dispersion during storage at 4°C for 2 weeks

changes in mean pulps diameter of carrot beverages with large, medium, and small particle sizes were observed (Figure 2). The addition of ingredients to formulate 30% carrot beverages did not affect the mean particle sizes of carrot pulps, because all ingredients were well dissolved. During storage for 2 weeks, the particle sizes of carrot beverage with large, medium, and small pulps were similar to day one of storage (Figure 2). Thus the preparation of carrot juice by heating carrot prior to juice extraction may enhance cloud extraction and cloud stabilization (Genovese *et al.*, 1997; Beveridge, 2002), because the enzymes pectinmethylesterase (PME) and pectinesterase (PE) were inactivated. PME and PE could increase the molecular weight of solid suspensions by cross-

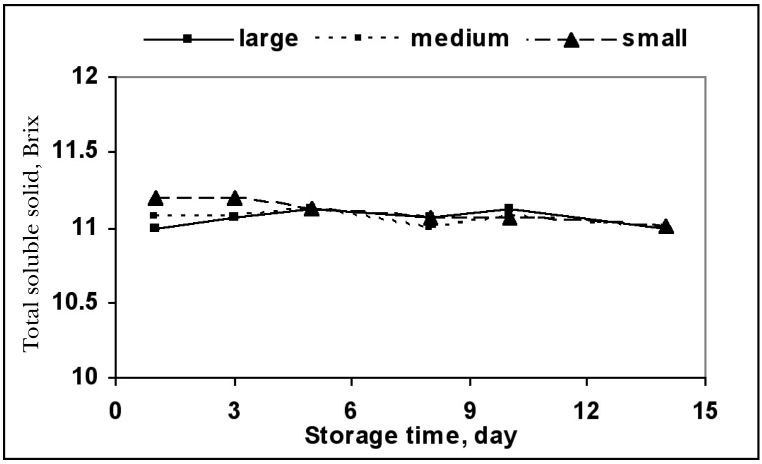

Figure 6: Changes in total soluble solid of carrot beverages with large, medium, and small pulps dispersion during storage at 4°C for 2 weeks

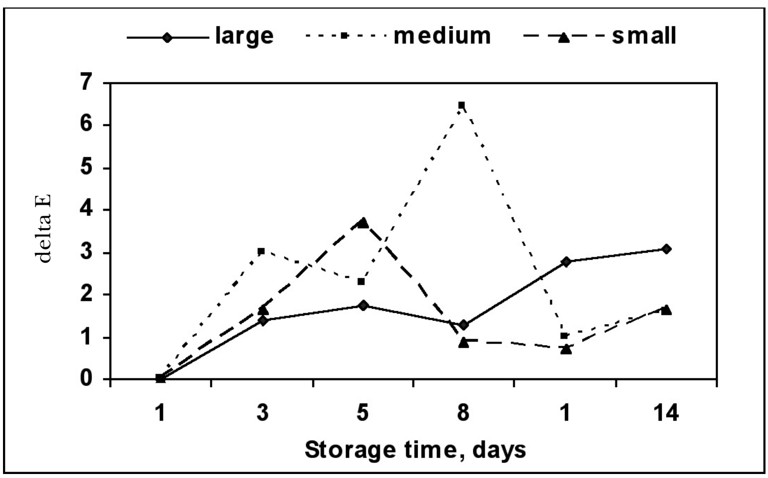

Figure 7: Changes in ΔE of carrot beverages with large, medium, and small pulps dispersion during storage at 4°C for 2 weeks

linking pectin and/or by acting on insoluble pectin at the surface of cloud particulates, thereby leading to flocculation and causing juice clarification. Additionally slightly acidified blanching water of the carrots also promoted cloud stability of juices. In accordance with Reiter *et al.* (2003) and Sim *et al.* (1993), acidification of the carrot mash before extracting juice resulted in highest cloud stability, as acid conditions influenced protein precipitation before extracting the juice. From these results, it can be summarized that factors of ingredient addition (sugar, citric acid, and salt) and storage time (4°C for 2 weeks) did not affect the mean particle sizes of carrot beverages which were prepared by different processes.

Table 1: Sediment test of carrot beverages with large, medium, and small pulps dispersion during storage at 4°C for 2 weeks

Carrot beverages	Sediment (storage time, days)				
	1	3	7	10	14
Large size pulps	+	++	+++	+++	++++
Medium size pulps	+	++	+++	+++	++++
Small size pulps	x	x	x	x	x

+ The amount of sedimentation of carrot samples (the more plus the higher in sediment)

Effects of Reducing Carrot Pulps on the Physical Qualities of Carrot Beverages Viscosities

The changes in physical properties of carrot beverages were evaluated. Apparent viscosities of samples with large, medium, and small pulps showed not significant ($p<0.05$) differences and were between 2.08 to 2.16 at day one of storage (Figure 3). However the highest apparent viscosity was found in a sample with small pulps suspension whereas the apparent viscosities of both samples with large and medium pulps indicated a little difference. The serum viscosity values (Figure 4) were highest in carrot beverage with small size carrot pulps followed by the samples with medium and large particles, and were 1.41, 1.31, and 1.23 (significant ($p<0.05$) difference) at day one of storage, respectively. As the storage time increased, both apparent viscosity and serum viscosity of all beverage samples showed a reducing trend, even though the beverage with small carrot pulps was still the highest in apparent viscosity and serum viscosity over the period of storage. Small pulp particles and small pulp size distribution resulted in higher apparent viscosity and serum viscosity. Applying homogenization can provide size reduction of carrot pulps and also makes the product more viscous. In addition, the high pressure process could induce pectin release from the middle lamella due to more breakdown of the carrot tissue. Consequently, the homogenized juice featured a higher viscosity when compared to the carrot juice processed through a hammer mill or by hydraulic pressing. In many cases, homogenization can reduce the amount of stabilizers and other ingredients that need to be added (Tetra Pak, 1999).

The Sediment Test

The sediment at the bottom tube of carrot beverages with various size carrot pulps were examined by observation of the physical appearance (Table 1). Sediment was observed in both samples with large and medium carrot pulps after one day storage at 4°C and the amount of sediment of these samples increased during extended storage time, whereas the sample with small pulps dispersion did not display the sediment over the storage time. Results obtained from these studies suggest that the difference in sedimentation of samples was probably caused by different velocity of carrot pulps migration to the bottom due to the gravitational acceleration, the viscosity of system, and the density difference between the solids and the supporting liquid (Corredig *et al.*, 2001; Beveridge, 2002; Reiter *et al.*, 2003; Qin *et al.*, 2005). The smaller the size of the carrot pulps, the lower the density difference between the pulps and surrounding liquid, which retarded the pulps migration or sedimentation. According to Stoke's law, coarse cloud particles do not keep floating due to the large particle diameter. Reiter *et al.* (2003) stated that particle size and density of pulps were shown to be decisive for suspension stability, whilst both partial charge and serum viscosity did not show any effect on cloud stability of carrot juices. Nonetheless the blanching step and heating process of carrot juice production stabilized cloudiness but did not prevent sedimentation. Yen and Song (1998) had reported that acidification and heat treatment of guava puree increased the stability of the suspended cloud. Furthermore the reduction of carrot pulps to smaller particles by high pressure homogenization could increase the viscosity of the suspending phase due to the particles sizes as well as the greater presence of soluble pectin in the juice.

pH and Total Soluble Solids

Carrot beverages with large, medium, and small size particles had pH in the range of 3.39 - 3.42 but there were no significant changes in pH of any samples during storage at 4°C for 2 weeks (Figure 5). The results of total soluble solids (Figure 6) showed that there were between 11.0 - 11.2 °Brix in all samples over the period of storage. No significant changes ($p>0.05$) in mean values of either pH or total soluble solids of all treatments were observed when the storage time increased. Saldana *et al.* (1976) did not find changes in the pH of pasteurized carrot juice. Rivas *et al.* (2006) also observed non-significant changes ($p>0.05$) in pH and °Brix during storage of pasteurized blended orange and carrot juice. Changes in the °Brix and pH values indicated juice spoilage due to fermentation of sugars by microorganisms. From these results, it can be implied that all the carrot beverage samples being investigated still had good quality for microorganisms and safety for consumers. Generally, the shelf life of pasteurized juice or beverage is approximately 1 - 2 weeks when kept in a refrigerator. Addition of some acid substances to decrease in the pH of the product prolonged the shelf life due to the concentration effect of the undissociated acid which impeded the microorganism. In this study, some citric acid was added to improve the product taste as a consumer requirement and the pH of all carrot beverages was less than 4. As pH equal to or less than 4.5 was highly effective in heat-pasteurized juice to destroy microbes and could be used at temperatures between 60 and 100°C for a few seconds, including it could promote shelf-life stability. Adjustment of pH of carrot juice, nonthemally treated, by adding hydrochloric acid caused an inhibitory effect on microbial growth, particularly decreasing the juice pH < 4; the shelf-like was drastically prolonged (Alklint *et al.*, 2004).

Color

The color of all carrot beverages was bright orange by visual perception. The large, medium, and small size carrot pulp beverages did not affect the color of the products, which were around 86.3 of lightness (L), 40.4 of redness (a), and 75.8 of yellowness (b) at the beginning of storage (data not shown). When the storage time was increased for 2 weeks, the color values of all beverages showed a slight difference from the beginning which correlated to the results of ΔE. Changes in ΔE values (Figure 7) of all samples tested over the storage time were about 1 to 6. Sim *et al.* (1993) reported that color attribute is one of the major problems associated with carrot juice products. Change in color of carrot juice involves the co-precipitation of color substances such as β-carotene with larger molecules or enzymatic and oxidative discoloration (Desobry *et al.*, 1998; Qin *et al.*, 2005). In this study, only a minimal difference in the color values and ΔE of all beverage samples with increasing storage time were observed. Contrary to the results of the sediment test of the beverage samples (except for a sample with small size carrot pulps), the amount of sedimentation increased with extended storage time. These results were probably caused by the preparation technique for color measurement, in which the sample was well shaken to re-suspend the sediment before analysis. Heat treatment in blanching and pasteurization process of carrot juice production controlled enzymatic browning and also improved color stabilization in the juices (Genovese *et al.,* 1997).

CONCLUSIONS

Using homogenization to reduce sizes of carrot pulp particles was more efficient than using a hammer mill and a hydraulic pressing. The small size carrot pulps (82 μm diameter) in pasteurized carrot beverage can be a stable cloud of the product for 2 weeks of storage, as well as providing increased apparent viscosity and serum viscosity when compared with the carrot beverages with large and medium pulps. In addition, reduction of carrot pulps into smaller sizes did not have any effects on other quality factors such as the color, pH and °Brix of the carrot beverages.

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