Rheology of Star Fruit Pulp (Averrhoa Carambola L.)

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Abstract:
Rheological properties of food fluids are useful for quality control, texture evaluation, and food structure determination. The rheological behavior is dependent on the size, form and concentration of solids in suspension and the system structure. Star fruit (*Averrhoa carambola L.*) pulp was obtained from the crude fruit and treated enzymatically, pasteurized and homogenized at 11000 rpm for 2 min and 22000 rpm for 5 min. The pulp presented Newtonian characteristics with R^2 values greater than 0.98. Enzymatic treatment under 55°C for 1 h reduced the crude pulp viscosity from 1.84 to 1.22 mPa·s. Pasteurization under 100°C for 10 min increased the viscosity at around 26% in relation to the crude pulp, resulting in a turbid and homogeneous product. To evaluate the influence of the insoluble solids, filtration or concentration to 50% from the initial volume were carried out using laboratory procedures. Filtration of the pasteurized pulp promoted a viscosity decrease of 60% while concentration increased the viscosity from 2.28 to 7.98 mPa·s.

Zusammenfassung:
Die rheologischen Eigenschaften von Lebensmittelfluiden sind für die Qualitätskontrolle, die Bewertung der Textur und die Bestimmung der Struktur von Lebensmitteln nützlich. Das rheologische Verhalten hängt von der Größe, der Form, der Konzentration des Feststoffs in der Suspension und der Struktur des Systems ab. Sternfruchtbrei *(Averrhoa carambola L.)* wurde aus der rohen Frucht erzeugt und enzymatisch behandelt, pasteurisiert und während 2 min bei 11000 U/min und während 5 min bei 22000 U/min homogenisiert. Der Brei besaß Newtonsche Eigenschaften mit R^2-Werten, die größer als 0.98 waren. Enzymatische Behandlung unter 55 °C für 1 h reduzierte die Viskosität des rohen Breis von 1.84 mPa·s. auf 1.22 mPa·s. Pasteurisierung unter 100 °C für 10 min erhöhte die Viskosität um ca. 26% im Vergleich zur Viskosität des rohen Breis, was zu einem trüben und homogenen Produkt führte. Um den Einfluss eines unlöslichen Feststoffs zu bewerten, wurden eine Filtration und Konzentrierung von bis zu 50% des Anfangsvolumens mit Labormethoden durchgeführt. Die Filtration des pasteurisierten Breis führte zu einer Viskositätserniedrigung von 60%, während die Konzentrierung die Viskosität von 2.28 mPa.s. auf 7.98 mPa·s. erhöhte.

Résumé:
Les propriétés rhéologiques des fluids alimentaires sont utiles pour le contrôle de qualité, l'evaluation de texture, et la détermination de l'estructure de l'aliment. Le comportement rhéologique depend de la taille, de la forme et de la concentration des solides en suspension, et de l'estructure du système. La pulpe de *L'Averrhoa carambola* L. a été obtenue a partir du fruit in natura, enzymatiquement traitée, pasteurisée et homogénéisée sous 11000 rpm et 22000 rpm pendant 2 et 5 minutes, respectivement. La pulpe a presenté characteristiques Newtoniènes avec R^2 plus grands que 0.98. Le traitement enzymatique sous 55°C pour 1 h a ramené la viscosité de la pulpe brute de 1.84 aux 1.22 mPa·s. La pasteurisation sous 100°C pendant 10 minutes a augmenté la viscosité à environ 26% par rapport à la pulpe in natura, ayant pour résultat um produit opaque et homogène. Pour évaluer l'influence des solides insolubles, la filtration, ou la concentration a 50% du volume initial, ont éte effectuées en utilisant des procedures de laboratoire. La filtration de la pulpe pasteurisée a favorisé une diminution de viscosité de 60% tandis que la concentration augmentait la viscosité de 2.28 a 7.98 mPa·s.

Key words: Rheology, pulp, homogenization, viscosity, star fruit

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	Crude		
	No homogenization	Homogenization 11000 rpm for 2 min	Homogenization 11000 rpm for 2 min
Viscosity (mPa s)	1.39 ± 0.07	1.27 ± 0.16	1.15 ± 0.07
Sol. Solids (g 100mL^{-1})	7.50 ± 0.04	7.40 ± 0.05	7.40 ± 0.05
	Pasteurized		
	No homogenization	Homogenization 11000 rpm for 2 min	Homogenization 11000 rpm for 2 min
Viscosity (mPas)	1.75 ± 0.07	1.53 ± 0.08	1.37 ± 0.13
Sol. Solids (g 100mL^{-1})	9.70 ± 0.04	9.60 ± 0.05	9.60 ± 0.06

	Crude	Crude concentrated	Pasteurized	Pasteurized concentrated
Viscosity (mPas)	1.84 ± 1.21	5.39 ± 1.19	2.28 ± 0.17	7.98 ± 0.69
Sol. Solids (g 100mL^{-1})	8.90 ± 0.06	12.10 ± 0.20	11.20 ± 0.10	15.40 ± 0.10
Ins. Solids (g 100mL^{-1})	5.15 ± 0.06	16.00 ± 0.06	2.85 ± 0.05	12.70 ± 0.06

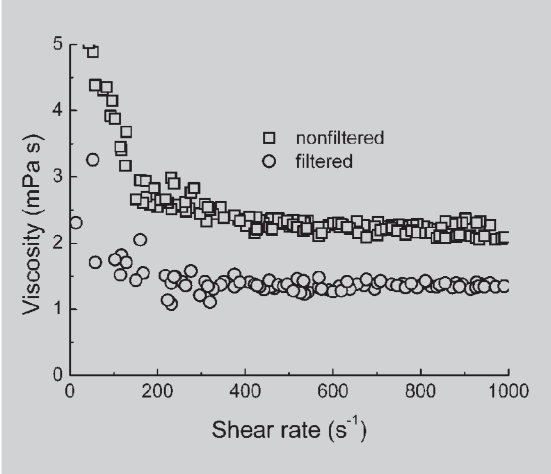
Table 3 (above): Viscosity (mPa·s) and soluble solid content (g100 mL^{-1}) for filtrated, crude and pasteurized pulp.

Table 4: Viscosity (mPa·s) and soluble solid content (g 100mL^{-1}) for concentrated, crude and pasteurized pulp.

Figure 6 (right): Rheological behavior of the filtrated and non-filtrated pasteurized pulp.

decrease, being not influenced by the treatment intensity. Also the cells cohesion and hydrogen bonds are weakened [20], cells separation is facilitated, resulting in lower particle sizes as the comminution intensity increases. The lower diameter found was for the enzyme treated and pasteurized pulp submitted to the homogenization of 22000 rpm for 5 min. These results are in accordance to Servais et al. [21].

Figure 6 shows the influence of filtration on the pasteurized pulp. Large particles ($D_p > 40\,\mu$m) withdrawal decreases viscosity by around 40%. Table 3 shows the homogenization effect on the viscosity and soluble solids content in crude and pasteurized, filtrated, homogenized pulp. Previous tests showed a high sediment amount for crude sample, probably due to the pectinesterase action on pectin. It builds precipitated, complex compounds in acidic medium with calcium. Filtration leaves out major particles, sedimented or suspended, resulting in a lower solids content (Tab. 3) compared to the non-filtrated sample (Tab. 2). The viscosity also decreases as comminution increases. Comparing Tabs. 1 and 2, it can be seen that viscosity of the pasteurized pulp decreases from 2.28 ± 0.17 to 1.75 ± 0.07 mPa·s when samples were filtrated (Fig. 6). On the other hand, filtration causes a decreasing from 2.14 ± 0.10 to 1.53 ± 0.08 mPa·s for homogenized samples under 11000 rpm for 2 min, and from 1.82



±0.10 to 1.37 ± 0.13 mPa·s for samples under 22000 rpm for 5 min. It corresponds to a viscosity decrease of 23.4, 28.5, and 24.7%, respectively.

The concentration of the star fruit pulp up to 50% of its initial volume affected the viscosity. Table 4 shows the viscosities and soluble solids content of the concentrated, crude and pasteurized samples. Results showed that concentration to the half volume did not double the soluble solids content and it can be supposed that part of the solids pass to the insoluble phase due to the increase of concentration. Around 2.85 g, for the crude pulp, and 3.5 g, for the pasteurized pulp leave the solution. There is a significant increase of the insoluble solids, from 5.15 to 16 g 100mL^{-1} to the crude pulp, and from 2.85 to 12.7 g per 100mL to the pasteurized pulp, that seems to influence the viscosity increasing.

As the soluble solids content increase with the pulp concentration is lower than the insoluble solids content, there must be a smaller influence of both on viscosity. This is reinforced by the comparison of the non-concentrated crude and pasteurized pulp. In this case, by increasing the soluble solids content from 8.90 to 11.20 g per 100mL, viscosity increases just 0.44 mPa·s, from 1.84 mPa·s in the crude pulp, to 2.28 mPa·s in the pasteurized pulp. The concentration step includes a particle coarsening due to attraction forces forming agglomerates, in which water is confined [10]. This justifies the soluble solids content decrease in the solution. The Newtonian behavior presented by the star fruit pulp in this work is similar to natural orange juice [22 - 24], or clear grape juice [25], and clarified cherry juices [26].

4 CONCLUSION

Star fruit pulp presents low values of suspended solids, which is the most important factor responsible by the rheological behavior. The suspension after processing steps shows a Newtonian behavior, with R^2 values greater than 0.98. The enzymatic treatment reduced the viscosity by around 34% in relation to the crude pulp and

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decreased the pulp viscosity. Enzymes and pasteurization steps increased both suspended and insoluble solids contents, with a consequent increase of the viscosity. Homogenization influences the suspension viscosity by decreasing the particle size. It does not change the soluble solids of the crude sample, but decreases its viscosity due to the size particle diminution. Filtration resulted in suspensions with low solids content and lowest viscosity. It was also observed that the star fruit pulp concentration to 50% of the initial volume increased viscosity of the pasteurized pulp, but the behavior remained Newtonian.

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