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Brief communication

Rheological Behavior of Fruit and Vegetable Purees and Tomato Sauce

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ABSTRACT

The purpose of this article is to determine the rheological behavior of fruit and vegetable purees as well as tomato sauces at a temperature of 25^{0}C and to find in the literature a rheological model that describes their behavior. Fruit and vegetable purees as well as tomato sauces have a non-Newtonian behavior. These were studied with the Brookfield DV-III Ultra reovascometer at 25^{0}C. The Herschel-Bulkley model was found for products with pseudoplastic behavior, while the law of power and the Bingham model for the others. The clarified and desiccated fruit juices as well as the carrot juice showed a Newtonian behavior.

Keywords: Rheology, Fruit, Tomatoes, Vegetables.

INTRODUCTION

Rheology is the science that deals with the study of the flow and deformation of bodies over time under the action of forces applied to them. Dealing with the study of requests and the response of bodies to requests, rheology establishes mathematical models that formulate the response function of a body subjected to these requests.

The general qualitative terms used to describe rheological properties are viscoelastic, Newtonian, non-Newtonian, thixotropic and dilatant; the quantitative parameters used are viscosity, elasticity, shear rate, shear strain and shear stress. The broadest view of liquid rheology is obtained by using oscillatory flow at a selected frequency because both viscosity and elasticity are revealed; constant flow revealing only viscous properties. It is also important to know the concept of the microstructure of a liquid since it is the basis of the rheological properties. A liquid with an isotropic structure has a perfect arrangement of the molecules in the structure; in the anisotropic liquid, the structure has a preferential directional orientation. The structural organization of the elements determines how the liquid flows and the microstructural organization is influenced by 3 distinct flow factors: a liquid at rest is isotropic, flowing liquids can become anisotropic and induced flow breaks down anisotropically when the flow is stopped.

Pseudoplastic fluids are non-Newtonian fluids, independent of time. According to the Herschel-Bulkley model, in the case of these fluids τ_o=0,n<1 (but obviously it is positive) and K>0. Taking into account, for these fluids, the Herschel-Bulkley model is simplified and will have the shape of the model Ostwald or the law of power.

$$\tau = K \cdot \dot{\gamma}^n \quad (1)$$

Pseudoplast behavior is common for products obtained from fruits and vegetables. A (ideal) rheogram for a pseudoplast fluid with K= 0.4 Pa.sn and n=0.65 is shown in Fig. 1. During flow, these materials can have three distinct regions. A lower region, close to zero for shear rate, where apparently the behavior would be a Newtonian fluid, and from the slope of this initial portion can be calculated the apparent viscosity (ηo), also called limit viscosity at zero shear rate. For the model in Figure 1 ηo=2004mPa. S[3-12].

A second region, at high shear rates, is the upper one, which like the lower region has a linear tendency to rheogram, and appears to be a characteristic region of a Newtonian fluid. From the slope of the upper portion, η∞ is calculated, a quantity called the limit viscosity at the infinite shear rate. For the ideal fluid in the figure, η∞ = 24.1mPa.s.

The third region, the most important, is the middle region, a region for which the nonlinearity of the rheogram is obvious. This region is most often examined when the performance of specific food processing equipment needs to be considered.

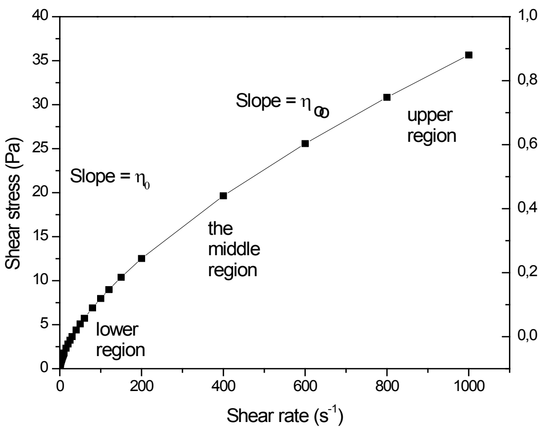

Fig. 1. Rheogram of a pseudoplast fluid with K=0.4 Pa.s^n sin=0.65

For these fluids, the apparent viscosity depends on the shear rate.

$$\eta_a = \frac{\tau}{\dot{\gamma}} = K \cdot \dot{\gamma}^{n-1} \quad (2)$$

Because the exponent in expression (2) is negative, the apparent viscosity decreases nonlinearly as the shear rate increases.

The purpose of this article is to find some rheological equations from the literature that fully describe the behavior of fruit and vegetable purees as well as tomato sauces.

MATERIAL AND METHODS

The fruits studied were: fruit sauce, worst apricot and peach peach. The composition in solid substance of sauce fruit is between 8.5 and 10.5%. The composition in solid substance of worst apricot is between 17.7 and 59.3%. The composition in solid substance of peach peach is between 10.9 and 58.4%. The measurements were performed on a Brookfield DV-III Ultra rheoscometer, at a temperature of 25°C both for fruit and vegetable purees and for concentrated tomato juice.

RESULTS AND DISCUSSION

A number of liquid fluids exhibit pseudoplastic flow behavior. In most cases, this non-Newtonian behavior can be attributed to either the presence in solution of high molecular weight substances or solids dispersed in the fluid phase. Depending on their size and concentration, solid particles may remain suspended in solution or, under the action of gravity, may settle. Thus, in the case of orange juice, the solid particles remain in suspension when the juice concentration is higher than 20° Brix. In contrast, when the juice concentration is below 20° Brix, the same particles tend to settle. For this reason a number of concentrated fruit and vegetable purees can be considered pseudoplastic fluids, even if they can be classified as food suspensions. In the case of concentrated orange juice, its flow behavior is pseudoplastic, the apparent viscosity increasing with increasing pulp content. In 60° Brix orange juice, a 25% decrease in its viscosity was found after being treated for 15 min in an ultrasonic field with a frequency of 20kHz. This reduction in the value of the apparent viscosity can be attributed to the disintegration under the action of the ultrasonic field of the suspended particles.

A large number of fruit and vegetable purees are produced for public consumption. Some of them, such as apple sauce or pear puree, are consumed directly, while others, such as tomato puree, are used as intermediate products. The vast majority of them are pseudoplastic fluids. The consistency (synonymous with the apparent viscosity) of these products is an important qualitative parameter and is often measured with measuring instruments at a single point such as: Adams consistometer, Bostwick consistometer, Stormer viscometer, etc. These tools are considered satisfactory in the quality control of these products, but are not suitable for research.

Tables 1-3 show values of rheological characteristics (K and n) for some pseudoplastic fluids.

Table 1: Rheological characteristics for fruit and vegetable products[1]

Product	Solid (%)	Temperature (°C)	n	K(Pa.sn)
Sauce fruit	8.5	26	0.44	4.18
	9.6	26	0.45	5.63
	10.5	26	0.45	7.32
Worst apricot	17.7	26.6	0.29	5.4
	23.4	26.6	0.35	11.2
	41.4	26.6	0.35	54
	44.3	26.6	0.37	56
	51.4	26.6	0.36	108
	55.2	26.6	0.34	152
	59.3	26.6	0.32	300
Peach peach	10.9000	26.6000	0.4400	0.9400
	17.0000	26.6000	0.5500	1.3800
	21.9000	26.6000	0.5500	2.1100
	26.0000	26.6000	0.4000	13.4000
	29.6000	26.6000	0.4000	18.8000
	37.5000	26.6000	0.3800	44.0000
	40.1000	26.6000	0.3500	58.5000
	49.8000	26.6000	0.3400	85.5000
	58.4000	26.6000	0.3400	440.0000

Table 2: Rheological characteristics for pear sauce[1]

Solid content (%)	Temperature (°C)	n	K (Pa.sn)
15.3	26.6	0.35	4.25
24.3	26.6	0.39	5.75
33.4	26.6	0.38	38.5
37.6	26.6	0.38	49.7
39.5	26.6	0.38	64.8
47.6	26.6	0.33	120
49.3	26.6	0.34	170
51.3	26.6	0.34	205
45.8	32.2	0.479	35.5
45.8	48.8	0.477	26
45.8	65.5	0.484	20
45.8	82.2	0.481	16

Table 3: Rheological characteristics for concentrated tomato juice[1]

Solid content (%)	Temperature (°C)	n	K (Pa.sn)
5.8	32.2	0.59	0.223
5.8	38.8	0.54	0.27
5.8	65.5	0.47	0.37
12.8	32.2	0.43	2
12.8	38.8	0.43	2.28
12.8	65.5	0.34	2.28
12.8	82.2	0.35	2.12
16	32.2	0.45	3.16
16	38.8	0.45	2.77
16	65.5	0.4	3.18
16	82.2	0.38	3.27
25	32.2	0.41	12.9
25	38.8	0.42	10.5
25	65.5	0.43	8
25	82.2	0.43	6.1
30	32.2	0.4	18.7
30	38.8	0.42	15.1
30	65.5	0.43	11.7
30	82.2	0.45	7.9

It is obvious from these tables that the values for K and n depend on the nature of the vegetable raw material from which the product was obtained. For such a product, the values of the consistency coefficient (K) are strongly influenced by the total solids content of the product, however, the influence on the flow behavior index (n) is very small in the peach puree and in the apricot puree and apple and pear sauces solids content does not influence this parameter. From Table 2 it can be noticed that the temperature variation does not influence the value of n, instead K decreases with increasing temperature. The above remarks also apply to concentrated tomato juice (Table 3).

Tomato pastes are products obtained by concentrating natural tomato juice to a content of 24-30% soluble solids and which have not been diluted by the addition of water and/or tomato juice. Tomato concentrates are products obtained by diluting tomato paste with water and/or tomato juice. Structurally, tomato concentrates consist of flocculants or aggregates of solid particles in a continuous medium. Tomato paste has a relatively homogeneous structure with a strong structural network. For different varieties of tomato paste with a solids content of 50-82%, the size of the flow behavior index is n=0.13 - 0.30 and the consistency coefficient K=77.8-324.5 Pa.sn[3-12].

CONCLUSION

The rheological properties of fruit and vegetable products depend on the shear rate, the consistency coefficient, the flow behavior index, the Bingham plastic viscosity and the activation energy depending on the soluble solids content and temperature. The Herschel-Bulkley model was found for products with pseudoplastic behavior, while the law of power and the Bingham model for the others. The clarified and desiccated fruit juices as well as the carrot juice showed a Newtonian behavior.

REFERENCES

1. Steffe, J. F. Rheological Methods in Food Process Engineering, Ediția a 2-a, Freeman Press, 2807 Still Vallez Dr., East Lansing, MI 48823, USA., **1996**.
2. Rao M.A., *J. Text. Stud.*, **1977**, *8*, 135–168
3. Rao M. A., Cooley H. J., *J. Text. Stud.*, **1992**, *23*, 415–423
4. Holomb D.N., Tung M.A. Rheology, chapter in "Encyclopedia of Food Science and Technology", *John Wiley and Sons, Inc.*, **1991**, *4*, 2258-2264.
5. Velez-Ruiz J. F., Barbossa-Canovas G. V., *Critical Reviews in Food Science and Nutrition.*, **1997**, *37*(4), 311–359.
6. Kokini, J. L. Rheological properties of foods, cap. 1 în "Handbook of Food Engineering" (D.R. Heldman, D.B. Lind, eds.), Marcell Dekker, New York., **1992**, 1–38.
7. Schowalter, W. R., Christensen, G. *J. Rheol.,* **1998**, *42*(4), 865-870.
8. Dimonte, G.; Nelson, D.; Weaver, S.; Schneider, M.; Maudlin, F.; Gore, R.; Baumgardner, J. R. *J. Rheol.*, **1998**, *42*(4), 727-742.
9. Stanciu I., *Journal of Science and Arts.*, **2019**, *3*(48), 703-708.
10. Stanciu I., *Journal of Science and Arts.*, **2019**, *4*(49), 938-988.
11. Stanciu I., *Journal of Science and Arts.*, **2011**, *1*, 55-58.
12. Stanciu I., *Journal of Science and Arts.*, **2018,** *18*(2), 453-458.