

EFFECT OF RHEOLOGICAL PROPERTIES OF SOME FRUIT CONCENTRATES ON THEIR PROCESSING

By

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APPROVAL SHEET

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ABSTRACT

The rheological properties of orange and apple juice concentrates were studied over the range concentration (40, 45, 50, 55, 60, 66 °Brix) for orange concentrate and (51, 56 , 61 , 66 , 71 °Brix) for apple concentrate. The measurements were studied over temperature 4, 10, 30, 40, 50, 60, 70°C, and shear rate 2.2-22 sec⁻¹ for orange concentrate, 9.3-93 sec⁻¹ for apple concentrate. Shear rate shear stress -, data indicates that orange concentrate behaves as pseudoplastic non-Newtonian fluid, while apple concentrate behaves as Newtonian fluid at temperature (30, 40, 50, 60, 70°C and pseudoplastic at (4, 10°C). Dependence of apparent viscosity on temperature was fitted to Arrhenius law

Also, this study includes the dependence of the apparent viscosity on concentration of orange and apple concentrates that follows the power law relationship. The generalized Reynolds number was employed taking in consideration the results at different shear rates. Calculation of pressure drop in laminar flow and the power of the pump needed to pump the concentrates to the tank at 10 °C and then to the filling machine at 4°C were carried out.

Keywords: Rheology, fruit concentrates, flow behavior, friction factor, pressure drop.

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INTRODUCTION

Citrus fruits have an important place in the world fruit juices production Cooper and Chapot (1977)

Apples are amongst the most widely grown and consumed fruit crops. Annual world apple production was estimated to be more than 40 million tons in 1992 and 1993, of which more than 5 million tons were processed to obtain apple juice. Concentrated fruit juices were first sold in the US market in 1945 Stacy (1988). At that time, the greatest volume of apple juice was processed into a 70 -75°Brix concentrate to reduce volume and weight, which resulted in lower costs for packaging, storage and transportation. Now, apple juice concentrate may be stored and shipped throughout the world as a relatively stable product. Concentration has also solved the problem of seasonal nature of crops and allowed economic utilization of perishable agricultural products Rao (1989).

In the food industry, knowledge of the physical properties of food is fundamental in analyzing the unit operations. They influence of the treatment adopted during processing are good indicators of other properties and qualities of food. These benefit the producer, the industry and the consumer Ramos and Ibarz (1998).

Knowledge of the physical properties of food is fundamental in analyzing the unit operations applied in the food industry. The study of these food properties and their responses to process conditions is necessary because they influence of the treatment received during the processing also because they are good indicators of other properties and qualities of food. Viscosity and its variation with concentration and

temperature are very important for the food industry in general and for fruit derivatives in particular, since it is necessary for the design and the optimization of several processing operations (e.g., pumping, evaporation, membrane filtration etc Ibarz *et al.* (1992)

Calculating the drop of pressure in pipeline flow due to friction is important during the design of the pipeline and the selection of pump. The mechanical energy balance equation (commonly known as the “engineering Bernoulli equation”) for an incompressible fluid in a pipe is used for the hydraulic analysis of flow conditions of viscous non-Newtonian fluids Holland and Bragg (1985) Brodkey and Hershey (1988).

Rheology is the science of deformation and flow behaviour of matter. The consistency of a Newtonian fluid like water, milk or clear fruit juice can be characterized by the term viscosity. Viscosity of non-Newtonian fluid, however, changes with changing rate of shear and hence should be characterized by more than one parameter(Heldman and Singh 1981), Rizvi and Mittal (1997).

Knowledges of rheological properties of fluid foods important for quality, understanding the texture, process engineering application, correlation with sensory evaluation, designing of transport system, equipment design (heat exchangers and evaporators), deciding pump capacity and power requirement for mixing etc. Kramer and Twigg, (1970), Dodeja, *et al.* (1990); Barbosa-Canovas, *et al.* (1996)

Knowledge of viscosity is of primary importance to the fruit juice industry. The accurate viscosity data over wide temperature, pressure, and concentration regions are needed for a various research and engineering

applications in any branch of the food industry. The viscosity of fluid food is an important property which has many applications in food technology, such as developing food processes and processing equipment, the control of products, filters and mixers, quality evaluation and an understanding of the structure of food and raw agricultural materials Alvarado and Romero (1989) and Walker and Prescott (2000).

Therefore, the aim of the present work is

- 1- To study the effect of solid concentration (wt %) of apple and orange concentrates on the apparent viscosity of apple and orange concentrate.
- 2- To study the effect of shear rate on the apparent viscosity of apple and orange juice concentrate.
- 3- To study the effect of temperature on apparent viscosity of apple and orange juice concentrate.
- 4- To study the effect of time on apparent viscosity and shear rate.
- 5- To study the effect of rheological parameters on the power of the pump needed to transfer the concentrates from evaporator to the mixing tank and then to the filling machine.

REVIEW OF.LITERATURE

1. The Concept Rheology

The mechanics of liquid-solid suspension is regarded as a branch of science of great complexity. Depending on the components involved and their fundamental properties, fluid-solid suspensions often exhibit flow behavior governed by a new set of properties, which lead to entirely different responses when subjected to stress or motion. The relationship between the rate of deformation (rate of shear) and the corresponding development of shear stress are referred to as the rheological behavior (rheological property) of the fluid. Rheologists are concerned with both the measurement of the deformation of a fluid with stress and the formulation of mathematical relation between deformation of rates and stress. These relations are called rheological models or constitutive equation. Cheremisionoff and Gupta (1983).

2. Food Rheology

Many food materials have distinct physical properties in addition to their nutritional value, which is known as rheological characteristics that make a significant contribution to the overall quality of the product. Food materials are more complex, however, and their flow properties may be strong functions of the way in which they have been previously processed. For example, the flow behavior of yoghurt is a function of it: if those bonds are disrupted by stirring or pumping, the flow properties of the materials may change. This can be seen clearly by comparing a set and stirred yoghurt bought from a supermarket and containing the same

ingredients. The set materials behaves essentially as solid, whilst the stirred yogurt has properties more like a liquid.

Rao and Anantheswaran (1982) reported that several foods, such as milk, syrups, filtered dilute juices, and vegetable oils, are Newtonian fluids. For these foods, knowledge of the viscosity function and its dependence upon temperature and concentration is sufficient for engineering design.

Knowledge of the rheological properties of fluid foods is essential for the proper design and operations, as well as for understanding of the pertinent transport processes in the operation Rielly (1997).

3. Fundamental properties of fluids

Viscosity or consistency is an appearance property of great importance with such food products as ketchup, juices, creams, fruit, preserves, jams, jellies and mayonnaise; Kramer and Twigg (1970).

To be able to study the rheological behavior of any material, first we have to know the general terminology for fluid flow. Fluids may be classified into Newtonian and non-Newtonian according to their flow character. Another important classification is whether they are time dependent or not. Sherman (1970)

Cheremisinoff and Gupta (1983) stated that there are many basic fluid properties that are of fundamental importance including mass density, specific volume, surface tension, viscosity and specific gravity. Among these properties, viscosity requires the greatest in attention in the study of fluid flow. The viscous nature of a liquid is a direct derivative of

the molecular attraction that offers resistance to shear and, consequently, to the resulting flow or deformation induced by the shear.

4. Time – Independent fluids

As shown in Figure (1), there are different types of fluids belonging to this classification Rao and Anantheswaran (1982)

- a. Newtonian fluids.
- b. Non-Newtonian fluids.
 1. Bingham plastic fluids.
 2. Shear thinning fluids (pseudoplastic fluids).
 3. Viscoelastic fluids.

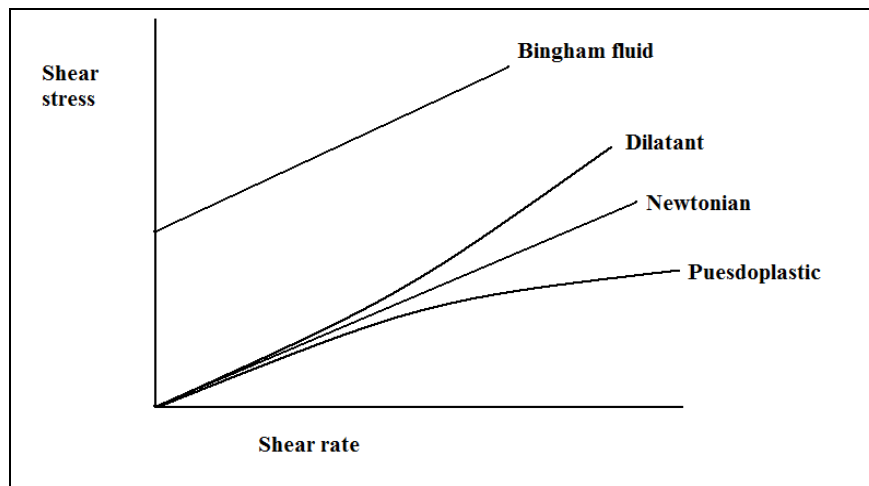


Fig.1. Types of non- Newtonian fluids Rao and Anantheswaran (1982)

a. Newtonian fluids

Where an ideal elastic solid produces an elastic displacement when a shear stress is applied, a fluid produces viscous flow. Newtonian flow implies that the rate of viscous flow is proportional to the shear stress, but many fluid systems do not fall within this category.

Newtonian flow can be conveniently explained by means of a simple model, (Fig. 2), which assumes that the liquid consists of many layers in parallel.

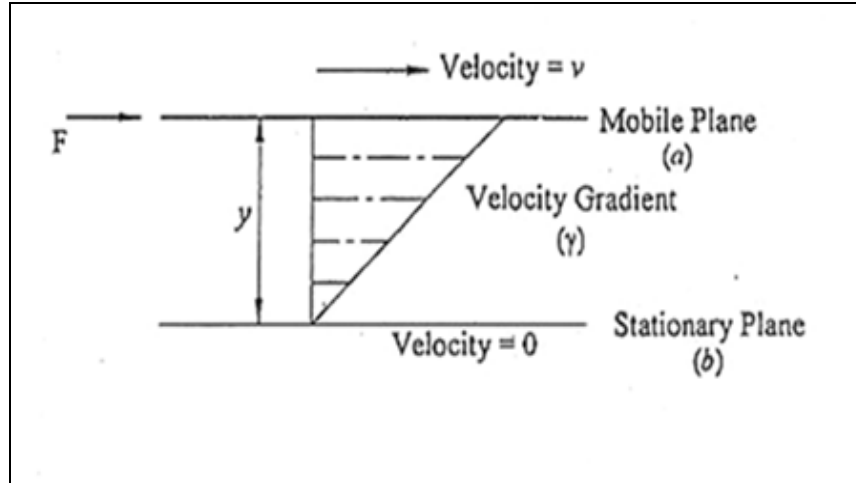


Fig. 2. Model to illustrate Newtonian flow (Sherman, 1970).

The lowest layer (b) is held stationary, and a force (F) is applied to the uppermost layer (a) so that it moves with a constant velocity (v) in the direction of (F). The liquid layers between (a) and (b) does move with the velocity (v) also, but instead it varies with the distance from (a). In the layer adjacent to (a) it is still (v), but it then falls away from layer until at (b) it is zero. (F) is opposed by the viscous drag between the parallel layers that are moving with different velocities. The rate of change in fluid velocity is given by dv/dy , where (y) represents the distance between planes a and b. It is usually known as the velocity gradient (γ), which is equal to the rate of shear, while the force per unit area (F/A) applied to (a) represent the shearing stress (τ), following the definition given for Newtonian flow equation (1) as reported by Sherman (1970):

$$\tau = \mu \frac{dv}{dy} \quad (1)$$

The proportionality constant in equation (1) is the "Newtonian viscosity".

The viscosity of Newtonian liquids does not change with a change of shear rate (Fig.3). Such "true liquids" are chemically pure and physically homogeneous; therefore, food products which are suspensions, do not fall into this classification. Materials of Newtonian type include: water, most oils, sugar and dilute gelatins, solutions, etc. Kramer and Twigg (1970).

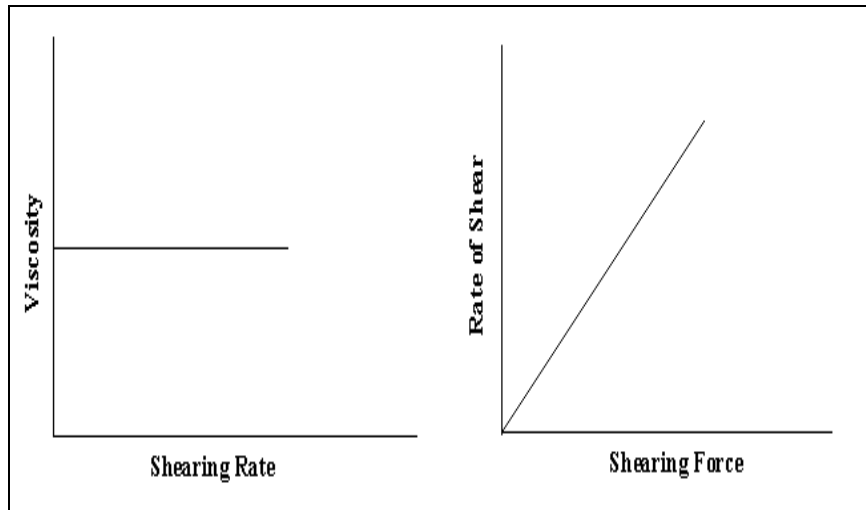


Fig. 3. Viscosity characteristics of Newtonian fluids (Kramer and Twigg, 1970).

Several foods, such as milk, syrups, filtered diluted juice, and vegetable oil, are Newtonian fluids. For these foods knowledge of the viscosity function and its dependence upon temperature and concentration is sufficient for engineering design Rao and Anantheswaran (1982).