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STUDY OF DESIGNING AND ENGINEERING FACTORS AFFECTING FLOW SYSTEMS OF LIQUID FOODS

By

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B. Sc. Agric. Sc. (Agricultural Engineering), Fac. of Agric., Ain Shams Univ., 2009
M. Sc. Agric. Sc. (Agricultural Engineering), Fac. of Agric., Ain Shams Univ., 2015

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Approval Sheet

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ABSTRACT

Shereen Shalaby Sayed Shalaby: Study of Designing and Engineering Factors Affecting Flow Systems of Liquid Foods. Unpublished Ph.D. Thesis, Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University, 2022.

This study aimed to investigate the effect of designing and engineering factors, such as pipe diameter and material as well as measuring the loss in pressure and friction during the flow of food liquids with different texture patterns, and using different engineering methods to reduce this loss to reduce energy consumption and this is particularly important in reducing the cost of production in general, and reducing maintenance costs for production lines that can work on lowering operating pressures and increase their service life .

A variable frequency drive (VFD) was used to control a single-phase induction motor's speed to pump guava and strawberry juice at two solid concentrations (9°Bx and 11°Bx). Next, the pressure drop was measured in stainless steel and acrylic pipes of three diameters (25, 20 and 12 mm).

The pressure drop percentage difference before and after using the VFD at varied flow rates (3,4.5,6,9,10.8 L/min) with 10 repetitions at 5 min intervals was evaluated. The pressure drop reductions' range was 19.2 %–32.4% for the guava juice and 23.3% – 30.4% for strawberry juice after using the VFD, which resulted in reductions in the pump's total head and driving power by the same ratio. Another comparison was made between pressure drop in acrylic and stainless steel pipes at the same diameters and flow rates and the results showed that the pressure drop in acrylic pipes was lower than that of the stainless-steel pipes with average differences ranging from 30.9% to 38.1% for guava juice concentrates and from 35.2% to 38.5% for strawberry juice concentrates.

The rheological properties of guava and strawberry juice were studied, and rheological parameters were measured at various temperatures. At all temperatures and concentrations examined, the results revealed that all materials showed non-Newtonian pseudoplastic behavior and suited well to the power law model, with flow behavior index (n) values less than unity (0.48-0.77) for guava juice and (0.44-0.75) for strawberry juice. The results offer helpful information for predicting how heat variations during processing influence the behavior of guava and strawberry juice concentrates.

Keywords: Pressure drop, Pipe flow, Variable frequency drive, Reynolds number, Rheological properties, Guava juice and Strawberry juice.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
$\boldsymbol{\tau}$	shear stress, (Pa)
$\boldsymbol{\mu}$	viscosity, (Pa. sec)
t	temperature (^{o}C)
γ	shear rate, (s^{-1})
k	Consistency coefficient, (Pa. s^{n})
μ_a	the apparent viscosity, (pa. s)
$\mathbf{E_a}$	the activation energy of flow, (J/ mole)
R	the gas constant (8.314J/mole °K)
T	the absolute temperature, (K).
n	flow behavior index
ρ	fluid density, (kg. m^{-3})
V	average flow velocity, (m. s^{-1})
D	tube diameter (mm)
Δp	pressure drop (Pa)
$f\ exp$	Fanning friction factor
$ftheo$	theoretically calculated friction factor
Re	Reynolds number
Re_{Gr}	generalized Reynolds number
VFD	variable frequency drive
C_R	aspect ratio
$kfitt$	fitting's loss coefficient
$hfitt$	Fitting head losses
$\Delta Pfitt$	pressure drop over the fitting
α	kinetic energy coefficient
$kcon$	loss coefficient for contractions
°Bx (Brix)	is the sugar content of an aqueous solution

INTRODUCTION

Fruit juices have been a vital ingredient in many people's diets in recent years. They are a clear or consistently unfermented liquid meant for immediate consumption, obtained by crushing or any other engineering process from fresh, ripe fruits. Because they give good taste and a variety of nutrients exist naturally in fruits, they are nutritious beverages that can play a key role in a healthy diet. They are provided in both natural and processed concentrations (**Salehi 2020**).

Guava fruit contains three to six times more vitamin C than citrus fruits (50–300 mg/100 g fresh weight), as well as polyphenol compounds, flavonoids, and oleanolic acid all of which can help to prevent lipid peroxidation, protein damage, and nucleic acid breakdown caused by reactive oxygen species **(Arima and Danno 2002).** The guava fruit is mostly eaten raw, Beverages, jams, juice, and dried and canned items are all produced by the guava market. (**Asha et al., 2013**).

Polysaccharides (lignin, hemicellulose, cellulose, and pectin), tannins, protein, and tannins make up most of the colloids found in guava juice. During storage, these particles may settle, resulting in juice heterogeneity. Because pectin is commonly coupled with plant polymers and cell detritus with fiber-like molecular structures, it makes juice clarifying difficult, causing clogging during filtration. Guava juice becomes viscous and thick because pectin is present **(McCook-Russell et al., 2012).**

Egypt is one of the world's leading strawberry producers. Egypt is the world's fourth-largest strawberry producer in terms of production volume. In 2016, it ranked fourth, behind the United States, Turkey, and Spain, with 435.3 thousand tons. (**Moussa et al., 2019**).

Strawberries are high in minerals and phytochemicals such as flavonoids, anthocyanins, and phenolic acids, among several others.