STUDIES ON EFFECT OF TEMPERATURE AND CONCENTRATION ON THERMOPHYSICAL PROPERTIES OF CHOKANAN MANGO JUICE

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ABSTRACT

The thermophysical properties of mango (Mangifera indica L.) juice of the Chokanan variety at medium maturity as affected by temperature and concentration were studied. The thermophysical properties were determined at concentrations between 10˚ to 40˚ Brix and temperatures between 30˚ to 80˚C with exception of the rheological properties which were determined at 30˚C. The effect of concentration on their viscosity at 30˚C can be described by Power Law Model. The results indicated that Chokanan Mango juice behave as Non-Newtonian fluids for concentration range from 5˚ to 25˚ Brix. The density (ρ) decreased with an increase in temperature, while the specific heat capacity (Cp) increased as temperature increased. However, the thermal conductivity (k) was not influenced by temperature. The apparent viscosity (μ), and density (ρ) increased as concentration increased.

Keywords : *Apparent Viscosity, Density, Flow Behaviour Index, Flow Consistency Coefficient, Mango Juice, Specific Heat Capacity, Thermal Conductivity*

NOTATION

Cps	specific heat capacity, kJ/kgK
m_w	mass fraction of water
m_p	mass fraction of protein
m_F	mass fraction of fat
m_c	mass fraction of carbohydrate
m_a	mass fraction of ash
C_{pw}	specific heat of water, kJ/kgK
C_{pp}	specific heat of protein, kJ/kgK
C_{pF}	specific heat of fat, kJ/kgK
C_{pc}	specific heat of carbohydrate, kJ/kgK
C_{pa}	specific heat of ash, kJ/kgK
k	thermal conductivity, W/m˚C

Greek

ρ	Density, kg/m^3
μ	apparent viscosity, mPas
τ	shear stress, Pa
γ	shear rate, 1/s
κ	flow consistency coefficient, Pa.s
n	flow behaviour index

INTRODUCTION

The demand for fruit beverages is largely based on their nutritive value, flavour, aroma and colour. Fruit juice is a source of vitamins, minerals, carbohydrates, amino acids, flavoid compounds and probably other still unidentified constituents.

The mango (*Mangifera indica L.*) is one of the most favoured and valuable commercial fruits growing throughout the tropics. Among fruits, mango occupies top position in India, covering an area of roughly 1.28 million hectares [1]. The mango is a member of the family Anacardiaceae, also known as the cashew nut family. There are at least 62 species in the genus, of which 15 bear edible fruit. The mango originated in the Indo-Burma region and has been cultivated in India for over 4,000 years, where it is an integral part of the Indian culture. Indian traders introduced mango into Malaysia and East Asia.

In Malaysia, mangoes are mainly found in Peninsular Malaysia at 7,529.75 hectares broadness. The productions are focused in Perlis, West Kedah, East Trengganu, North Perak, Negeri Sembilan and Malacca [2]. In industrial processes, it is important to have knowledge of the physical chemical properties [3]. They influence the treatment received during the processing and good indicators of other properties and qualities of food. These benefited the producers, industries and the consumers [4].

Many of the methods in use today for the analysis of foods are procedures based on a system introduced initially by two German scientists, Henneberg, and Stohmann [5], for the analysis of animal feedstuffs and described as the *"Proximate Analysis of Foods"* such as moisture, crude fat, crude protein, crude fibre and mineral element.

Several techniques including steady and non steady state methods have been used to evaluate the thermal conductivity of food systems [6]. The line heat source thermal conductivity probe is recommended for most food applications because it is simple, fast, convenience, low cost and suitable for small sample sizes [7].

Mohsenin [8] discussed many methods to determine the specific heat. Recently however, the differential scanning calorimeter (DSC) is recommended for measuring specific heat. It is well suited because it is capable of scaning a wide range of temperatures. Its disadvantages include: expensive, a comparative device, difficult to obtain homogenous samples and "cantankerous" device [7].

The objective of this study is to investigate the effect of temperature and concentration on the thermophysical properties of mango juice from 5˚ Brix to 25˚ Brix and temperatures from 30˚ to 80˚C. Also the physico-chemical characterisation of mango juice such as proximate analysis, pH, sugar content, water activity and freezing point was determined.

MATERIAL AND METHODS

Sample preparation

Mango (*Mangifera indica L.*) from Chokanan variety was purchased from the market in Seri Kembangan, near the university, during the 2002/2003 seasons. Fruits were selected based on percentage of skin yellowing, according to standard specification and grade by FAMA (Federal Agricultural Marketing Authority). To obtain samples of fruits of uniform maturity, the half ripe fruit of Chokanan mango was selected. The skin colour of the fruit is greenish yellow; flesh firm, sweet sour and edible fresh but not palatable. A peeler was used in peeling process of mangoes. After peeling, mango pulp was extracted using a juice extractor (Green Power Juice Extractor, Model GP-E1503 Gold). The juice was filtered using net filter to remove any fiber from the juice. The juice was concentrated using a freeze-dryer (SB 0440, US) and diluted with distilled demineralised water in order to obtain different concentration. The concentrations used were 5˚, 10˚, 15˚, 20˚ and 25˚Brix. The juice was stored in an incubator (PROTECH model DD-1050) at 4˚C.

Proximate Analysis

Mango juice with concentration of 15˚ Brix was used in the proximate analysis. The analysis included protein, carbohydrate, fat, ash, moisture and fibre. Water content was measured using an oven method and the Soxhlet method was used for the fat content. Determination of fibre in mango juice was based on the method by Lees [9], and Meloan and Pomeranz [10]. The Kjeldahl method was used for protein determination. For ash content, the sample was first dried in an oven at 100˚C before being transferred to a muffle furnace at 550˚C until a white or light gray ash resulted. Three replications of all of these measurements were carried out.

Freezing point

Freezing point of the mango juice was determined by freezing the sample using an Air Blast freezer (model FT36-C). A 250 ml sample at 15˚ Brix was placed in a 300 ml beaker. Magnetic stirrer was used to get a homogenous juice. The temperature inside the sample was measured using thermocouple sensor probe type HOBO TMC6-HC. Thermocouple sensor probe was located at the centre of the beaker.

Physico-chemical properties

The samples of mango juices at 15˚ Brix were characterised by the following physico-chemical determinations: soluble solids concentration (Atago refractometer), pH (CyberScan pH meter), water activity meter, a_w (Decagon Pawkit) and sugar content by High Performance Liquid Chromatography (TASCO, US). All the experiment was conducted at room temperature. Three replications of all of these measurements were carried out.

Viscosity

Viscosity of the mango juice was determined using a rotational viscometer RT 20 (Haake, Germany). The sample was placed in a cylindrical metal container and the spindle (ZIN 40 DIN) was inserted into the sample. Measurements were taken at 30˚C and for concentration range from 5˚ to 25˚ Brix at 5˚ Brix intervals. Single shear rate value is presented to show the influence of temperature and concentration on viscosity.

Density

The density was determined using a pycnometer for temperature from 30˚C to 80˚C at 10˚C intervals and concentration of Chokanan mango juice from 5 to 25˚ Brix at 5o Brix intervals. The temperature was controlled by a thermostatic water bath (Memmert). The density was calculated according to the equation by Earle [11].

Thermal Conductivity

Thermal Conductivity was determined using a thermal properties analyser type KD2, manufactured by Decagon Devices Incorporation. It was operating based on the line heat source method and the values were obtained directly from the digital readout. Measurements were taken from 30˚ to 80˚C at 10˚C intervals. The concentration of mango juice varied from 5˚ to 25˚ Brix at 5˚ Brix intervals.

Specific heat capacity

Specific heat capacity was determined from proximate analysis using the expression proposed by Heldman & Lund [11]:

$$Cps = m_w C_{pw} + m_p C_{pp} + m_F C_{pF} + m_c C_{pc} + m_a C_{pa} \quad \text{..................... (1)}$$

RESULTS AND DISCUSSIONS

Proximate analysis, freezing point and physico-chemical properties

The results of the proximate analysis, freezing point and physico-chemical properties of mango juice are shown in Tables 1 and 2 respectively.

From Table 1, it is shown that the experimental values for the proximate analysis of Chokanan mango juice at 15˚ Brix. It is clear that the solid content of the mango juice consist predominantly of carbohydrates (90%).

The thermal properties of frozen foods depend significantly on their water content in the frozen state [12]. In the concept of freezing point depression, it is known that a food consists of the product solids and water. As sensible heat is removed, the temperature of the mix containing solids and water decreased. From the cooling curve, the initial freezing point of mango juice at 15˚ brix was -1.06˚C. This value is close to those reported by Heldman and Singh [13] for several juices in the range of - 0.8˚ to – 1.2 ˚C.

The pH of mango juice at 15˚ brix was 4.23, which is between the value of 3.67 for orange juice [4] and the value of 4.0 to 5.0 for guava [14].

Table 2 shows that the water activity of mango juice is 0.91 at 15˚ brix. The value of water activity may range from 0 to 1, but for fruits and vegetables, the values typically range from 0.97 to 1. The result shown in Table 2 seems to indicate that the disaccharide (sucrose) are the dominant carbohydrates compared to the monosaccharide (glucose and fructose).

Table 1: Results for proximate analysis of mango juice (15˚ Brix)

PROPERTY	EXPERIMENTAL VALUE
Moisture Content (%)	82.6 ± 0.14
Ash (%)	0.47 ± 0.01
Protein (%)	0.81 ± 0.02
Fiber (%)	0.47 ± 0.02
Fat (%)	0.06 ± 0.01
Carbohydrate (%)	15.59 ± 0.01

Table 2: Results for Physico-chemical Properties of mango juice (15˚ Brix)

PROPERTY	EXPERIMENTAL VALUE (30˚C)
Freezing point (oC)	-1.06 ± 0.02
pH	4.23 ± 0.15
Water activity	0.91 ± 0.04
Glucose (%)	0.85 ± 0.15
Fructose (%)	1.89 ± 0.13
Sucrose (%)	3.33 ± 0.02

Effect concentration on apparent viscosity

The rheological properties were determined at 30˚C for different concentration at 5˚, 10˚, 15˚, 20˚ and 25˚Brix. The shear stress and shear rate data was fitted to a Power Law Model defined as:

$$\tau = \kappa \gamma^{n} \quad \text{.......} \quad (2)$$

The apparent viscosity is given by

$$\mu = \kappa \gamma^{n-1} \quad \text{.......} \quad (3)$$

Table 3 shows the changes of the flow behaviour index (n) and the consistency coefficient (κ) at different concentrations and temperature 30˚C. It is clear that the power law model fit the data well for all the concentrations used. This indicate that Chokanan mango juice for concentration range from 5˚ to 25 ˚Brix is non-Newtonian.

Effect of temperature and concentration on density

Figures 1 and 2 show an increase in density with an increase in concentration of mango juice and with a decrease in temperature. The values of density that have been obtained for mango juice are comparable with values obtained by Ramos and Ibarz [4] for clarified peach juice and orange juice and values obtained by Zainal et al., [15] for pink guava. The experimental values obtained can be well fitted with the same equation proposed by Ramos and Ibarz [4].

Effect of temperature and concentration on thermal conductivity

The experimental results obtained for the thermal conductivity of mango juice at several concentrations and temperatures are shown in Table 4.0. The results also show that thermal conductivity of mango juice was not significantly affected by temperature for the temperature range used. However, the thermal conductivity decreased with an increase in concentration. According to Zainal et al., [15], the thermal conductivity decreased slightly as did that for tomato juice.

Table 3: Power law for various concentration (30ºC)

Concentration (˚ Brix)	k (Pa.s)	n	R^2
5	0.338	0.729	0.99
10	1.088	0.657	0.99
15	2.695	0.602	0.99
20	4.735	0.579	0.99
25	20.916	0.451	0.99

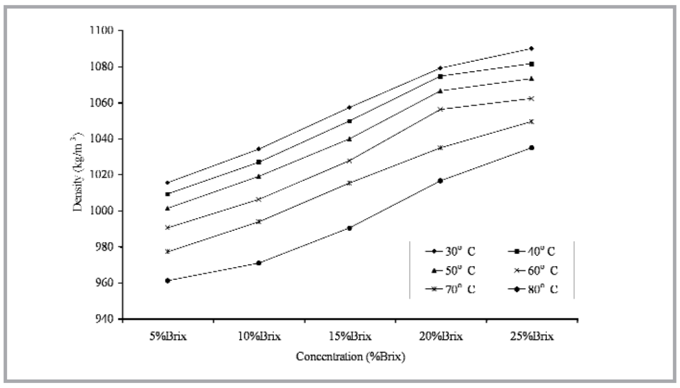

Figure 1: Effect of concentration on density at different temperatures

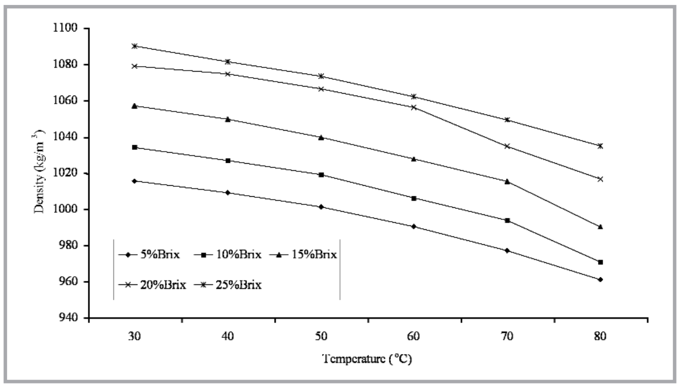

Figure 2: Effect of temperature on density at different concentrations

The thermal conductivity of a food product is a function of water content and structure [12].

Effect of temperature and concentration on specific heat

The relationship between specific heat capacity and temperature can be presented as a straight line where the specific heat increased with increasing temperature (Figure 3). The relationship can be expressed as:

$$C_p = 3.68 + 0.00035T \; J \; kg^{-1}\,{}^{\circ}C^{-1} \quad \text{at } 15\% \text{ Brix}$$

The standard error for the intercept is (± 0.00486) and for the slope is (± 0.0035). Similar results were also reported for pink guava [15], and orange juice [16].

CONCLUSION

Thermophysical properties of Chokanan mango juice at different temperatures and concentrations were determined experimentally in three replicates. Density (ρ) and specific heat (Cp) was found to be influenced by temperature while the thermal conductivity (k) is not temperature and concentration dependent. Chokanan mango juice for the concentrations investigated behave as a non-Newtonian fluid. ■

Table 4: Experimental values for thermal conductivity at different concentration and temperature for mango juice

C (˚ Brix)	5	10	15	20	25
T (˚C)	Thermal Conductivity (W/m˚C)				
30	0.56	0.51	0.53	0.49	0.51
40	0.55	0.52	0.53	0.41	0.50
50	0.57	0.51	0.54	0.52	0.51
60	0.55	0.53	0.56	0.56	0.52
70	0.60	0.57	0.56	0.57	0.54
80	0.60	0.56	0.57	0.56	0.57

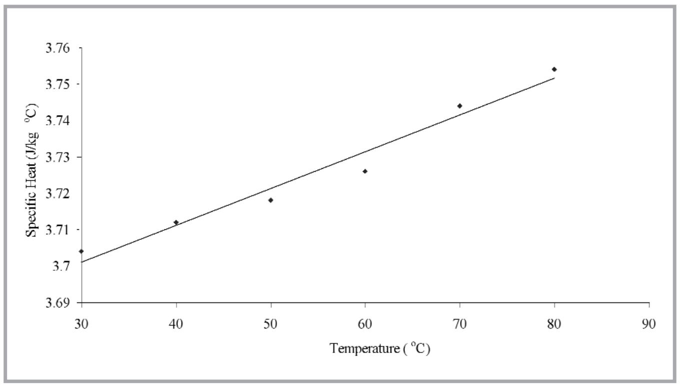

Figure 3: Specific heat at different temperatures for mango juice at 15˚Brix

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