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Changes in physical and thermo-physical properties of sugarcane, palmyra-palm and date-palm juices at different concentration of sugar

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ABSTRACT

The process of making jaggery from three natural juices by boiling could be divided into three zones: rise in temperature to boiling (Zone I), slow rise in both boiling temperature and total soluble solids (TSS) (Zone II) followed by rapid rise in boiling temperature with concomitant increase in viscosity and TSS (Zone III). The juice samples in Zone III exhibited changes in boiling temperature, viscosity and TSS from 105 to 121 °C, 4.5 to 988 mPa s and 54.6 to 81.9 (% w/w) for sugarcane (*Saccharum officinarum*); from 104 to120 °C, 41.6 to 559 mPa s and 46 to 81 (% w/w) for palmyra-palm (*Borassus flabellifer* L.); and from 103 to 121 °C, 22.9 to 417 mPa s and 51 to 81 (% w/w) for date-palm (*Phoenix sylvestris* L.). Colour change $\left(\frac{\Delta E}{\Delta\ (\%\ \mathrm{w/w})}\right)$ was rapid in Zone III. Difference in colour among these jaggery samples might be attributed to amount of reducing sugars present initially and respective changes in properties during juice concentration.

1. Introduction

Jaggery, a sugar rich food product is produced all over the world under different names, such as *Gur* (India), *Desi* (Pakistan), *Panela* (Mexico and South America), *Jaggery* (Burma and African countries), *Hakuru* (Sri Lanka), *Htanyet* (Myanmar), *Panocha* (Philippines), *Rapadura* (Brazil), and *Naam Taan Oi* (Thailand) (Thakur, 1999). It is consumed directly or used for preparation of sweet confectionery items and ayurvedic/traditional medicines (Pattnayak and Misra, 2004), and it may have a role to reduce the chance of lung cancer (Sahu and Paul, 1998). Jaggery is prepared traditionally by concentrating sugarcane juice (*Saccharum officinarum*) in open atmosphere boiling. In addition, sap collected from palm trees such as palmyra-palm (*Borassus flabellifer* L.), coconut palm (*Cocos nucifera* L.), wild date-palm (*Phoenix sylvestris* L.) and sago palm (*Caryota urens* L.) are also used for preparation of jaggery (Pattnayak and Misra, 2004). The sap or juice collected from these trees contains around 10–12% total sugars; mainly comprised of sucrose, less amount of reducing sugars, and other minerals and vitamins (Dalibard,1999). All these jaggery products have their own characteristic taste and aroma and their production is seasonal. India produces about 6 million tonnes of jaggery annually, which accounts 70% of the total production in the world; 65–70% of the total jaggery is from sugarcane, the remaining 30% is from palms (Kamble, 2003).

The production of solid forms of jaggery involves: collection of juice by crushing canes or tapping the sap from palm trees; its filtration and concentration by boiling, cooling of concentrated juice followed by moulding, drying and storage (Fig. 1). The quality of the prepared jaggery, such as aroma, texture, colour and taste, is largely dependent on monitoring and controlling of various physical and chemical changes occurring during concentration, particularly when the process approaches the end point (high total soluble solid concentration). In absence of scientific data, this stage becomes critical, and is mostly tackled by the skill of the processor.

Variations in density, viscosity and boiling point rise for pure sucrose solution has been reported to be a function of concentration (Junk and Pancoast, 1973). Buera et al. (1987) have reported kinetics of colour changes due to caramelization of various single sugars with heating time. Physical and thermo-physical properties of the different juices have been found to exhibit a close relationship with temperature and water content (Ali et al., 2002). Singh (1992) and Sweat (1974) have reviewed thermo-physical properties of different vegetables, fruits and its juices. Several workers (Constenla et al., 1989; Telis-Romero et al., 1998; Patricia et al., 2005; Zuritz et al., 2005; Shamsudin et al., 2005) have reported mathematical models correlating thermo-physical properties of fruit juices, soluble solids content and temperature. According to Telis-Romero et al. (1998), in Brazilian orange juice, total soluble solids exhibited a significant role on its density, thermal conductivity, thermal diffusivity and specific heat compared to temperature when concentration and temperature were varied. However, no information on physical and thermo-physical properties of

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Nomenclature

a^*	CIE colour values	r	radial distance (m) from the probe, correlation coefficient
a	parameter for Chirife and Buera (1997) model	T_0 and T	temperatures at initial and final time, respectively (K)
b^*	CIE colour values	t_0 and t	initial and final time (s)
C	concentration (% w/w)	T_b	boiling temperature (°C)
C_p	specific heat (kJ kg^{-1} K^{-1})	TSS	total soluble solids (% w/w)
E_{cb}	parameter for Chirife and Buera (1997) model	X	mole fraction
ΔE	colour difference between two samples	α	thermal diffusivity (m^2 s^{-1})
k	thermal conductivity (W m^{-1} K^{-1})	γ	Euler's constant
L^*	CIE colour values	ρ	density (kg m^{-3})
q	heat produced per unit length per unit time (W m^{-1})	η_r	relative viscosity

sugarcane, palmyra-palm and date-palm juice is available in the literature.

The present study discusses the variations in some physical (boiling point, density, viscosity and colour) and thermo-physical (thermal conductivity and specific heat) properties of sugarcane, palmyra-palm and date-palm juices with changes in soluble solid (increase in total soluble solids). Furthermore, correlations among these changes with solid concentration in the syrup were explained.

2. Materials and methods

This study comprises of two parts: preparation of jaggery type from their respective juices was monitored at the site (while the evaporation process was in progress) with periodical measurements of temperature of the juice and total soluble solids (TSS). Other properties, i.e., density, viscosity, thermal conductivity, thermal diffusivity, specific heat and colour of the juice or syrup, collected at different stages of boiling, were measured at room temperature.

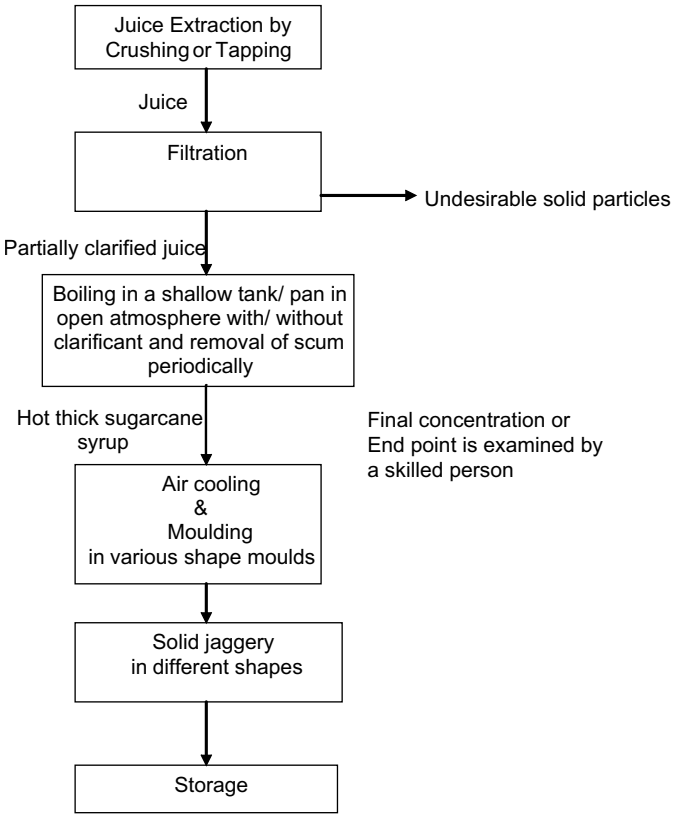

Fig.1. Process flow chart for solid jaggery preparation.

2.1. Preparation of sugarcane jaggery

Fifteen hundred (1500) litres of juice was extracted from 1.25 tonnes of sugarcane (variety Co 85 A 298) in Harapalem village (83°1′E, 17°40′N), Visakhapatnam district, Andhra Pradesh, India. The initial total soluble solid concentration of the juice was 17.2 (% w/w) (average). After filtration with a fine muslin cloth, concentration of sugarcane juice was carried out by open atmosphere boiling in a large circular pan made of iron. Lime water (60 ml/100 kg juice) was added at the initial stage of boiling and also intermittently for clarification of juice. It was for clarification of juice. Boiling of juice continued in a regulated manner for more than 3 h till the concentrated syrup attained a total soluble solids concentration around 82 (% w/w) while the temperature rose slightly beyond 120 °C. The end point concentration level was decided manually by dropping a small aliquot of hot syrup into cold water taken in a container where it solidified. The concentrated juice was then transferred to moulds and allowed to cool gradually till it solidified.

2.2. Preparation of palmyra-palm jaggery

About fifty five (55) litres of juice (sap) was collected from several palmyra-palm trees at Kharar village (87°19′E, 22°25′N), East Midnapur District, West Bengal, India with initial total soluble solid content of 16 (% w/w). It was first filtered through a fine muslin cloth and boiling was carried out in an open shallow aluminum pan. A mild bleaching agent at the rate of 5 g/50 l juice was added intermittently during boiling for clarification of juice. Boiling of juice continued in a regulated manner for more than 2 h till the syrup attained total soluble solids around 81 (% w/w). At that time, temperature rose to about 120 °C.

2.3. Preparation of date-palm jaggery

About sixty (60) litres of juice was collected from different date-palm trees at Kharar village, East Midnapur District, West Bengal, India with initial total soluble solid content of 12.9 (% w/w). Boiling of juice for jaggery preparation was almost similar to that of palmyra-palm. However, no clarificant was added during boiling of juice. Boiling of juice continued more than 2½ h till the syrup attained total soluble solids concentration of 81 (% w/w), with corresponding end point temperature around 120 °C.