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Full Length Research Paper

Analysis of viscosity of jamun fruit juice, squash and jam at different compositions to ensure the suitability of processing applications

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Rheological behavior of jamun fruit (*Eugenia jambolana*) juice, squash and jam at different compositions was studied at the Institute of Food Sciences and Technology, Singh Agriculture University, Tandojam in 2007. LFRA Texture Analyzer of Brookfield Engineering was used to determine the flow properties and consistency of the products. Two indigenous cultivars of jamun (indigenous-V1 and Improved-V2) were exploited for processing application. The suitability of viscosity was based on the compositions of TSS, total sugars, acidity and pH of the products. Results revealed that squash and ready-to-drink juice of jamun had showed significant rheological behavior, however, jam has rather poor quality attributes and was more sticky. Thus, the study specifies the shear-rate and shears-stress values of jamun and their rheological behavior. This study would be a ready reference and helpful communication particularly to those desires for commercial processing of jamun products with customary feature.

Key words: Jamun cultivars, processing of jam, squash, juice, viscosity analysis.

INTRODUCTION

The increasing social and economic importance of food products, besides the technology complexity of producing, processing, handling and accepting, these highly perishable and fragile food materials like jamun fruit, requires a more extensive knowledge of their physical properties because, the rheological properties play an important role in the handling and quality attributes of processed foods. The rheological properties of fruits and vegetables are of interest for food technologist, due to different causes. Firstly, fruits and vegetables are increasing in importance in the contemporary human diet. Secondly, the rheological properties are relevant to several aspects of the study of these materials, including; the causes and extent of damage during harvesting, transport and storage; the human perception of product quality; and the physiological changes that take place in the product during growth, maturation, ripening and storage after harvest (Rao and Steffe, 1992).

Jam, jelly, juices and squash are usually produced by entrepreneurs and often encounter quality problems and do not meet the standard for these products. It is of utmost importance that a manufacturer must understand the scientific basis for producing a superior product which must meet the fundamental characteristics like, pH, TSS, total sugar and viscosity to ensure the standard excellence of the product. Studies on the flow behavior of juice, squash and consistency of jam is more important than its manufacturing. Information on the viscosity of fruit beverage as influenced by concentration and temperature is of particular importance. With this mixed flow system, the viscosity of the products are needed to determine the heat transfer rates, energy consumption with increase in concentration, and for controlling the temperature and flow rates of heating media to ensure continuous flow and gelling of food products. The flow behavior also influences the pump performance (Telis-Romero et al., 1999). Besides, for a newly emerging fruit processing system, it is important

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to document the influence of product flow properties on the systems in overall capacity and energy saving and for reducing handling cost (Lau, 1991).

While reviewing the rheological models of food products, Holdsworth (1993) emphasized the importance of accurate rheological data for calculation of volumetric flow rates, selection of pumps, determination of pressure drops for pipe sizing and power consumption for pumping systems, and for prediction of heat transfer coefficients for heating, evaporation and sterilization processes. At the time when the review by Holdsworth (1993) was published, only one study by Ibarz and Pagan (1987) on the rheological behavior of juices was available. Later, Rao (1999*)* compiled rheological data for a number of fluid foods, which included for various fruit beverages. He reported that single strength juices and concentrated clear fruit juices generally exhibit Newtonian flow behavior or close to it, and that sugar content plays a major role in the magnitude of the viscosity and the effect of temperature on viscosity. Krokida et al. (2001) recently collected additional data on rheological properties of fluid fruit and puree products and described that fruit and vegetable juices had been assumed to behave as non-Newtonian fluids. If fruit juices contain considerable amounts of pulps, or are very concentrated, they may show an additional resistance to flow represented by a yield stress (Hernandez et al., 1995; Telis- Romero et al., 1999). There is a significant change in viscosity when the fruit products are made through heating or cooking. This influences on velocity and temperature profiles, therefore, it is necessary to have knowledge about the influence of shear-rate, shear-stress and cooking temperature on the rheological behavior of fruit products. This paper reports the rheological behavior of jamun fruit juice, squash and jam.

MATERIALS AND METHODS

Two varieties of Jamun (indigenous and improved) were collected from the nearby orchard of Tandojam to make some products such as, jam, juice and squash. The entire processing and analysis was carried out in the laboratory of Institute of Food Sciences and Technology, Singh Agricultural University, Tandojm in 2007.

Jams, jellies, preserves, conserves, marmalades, and juices/squash are all gelled or thickened fruit products. Majority are cooked and preserved with sugar. Their individual characteristics depend on the kind of fruit used and the way it is prepared, the ingredients and their proportions in the mixture and the method of preparation. The methods for preparation of jam, squash, ready-to-drink juice, pulp powder and seed powder carried out during the present processing activity are as discussed further.

Jam

A known quantity of jamun fruit pulp and sugar was placed in a stainless steel kettle and heated to about 110°C under constant stirring and was turned low. Pectin, at 2 g/kg or 0.2%, mixed with some sugar, was then added into the fruit pulp and stirred constantly to prevent the pectin from clotting. When the pectin dissolved, the remaining sugar was added and dissolved completely in the mixture. The heat was then increased and the jam mixture was stirred constantly till it started boiling vigorously. In the remaining mixture, the product was stirred occasionally. Near the finishing point (approximately 221°C), acidifier (citric acid) at 4g kg^{-1} emulsion was used to justify the customary acidity. Also, sodium benzoate, as preservative at 1 g kg^{-1} by weight, was used at this stage.

Determination of the finishing point was done by removing samples at intervals, cooling, and reading the TSS by means of a refractometer equipped with a Brix scale. After the jam reached the standard TSS (68 to 70%), the heat was turned off and the surface scum/foam was removed. The pH of jam was 3.3 and 3.2 for V1 and V2 respectively. The jam was quickly put into jar-containers which were already cleaned and sterilized with boiling water for 30 min. The filling operation was done rapidly in order to prevent the temperature of the jam from falling below 190°C. The filled jar-containers were cooled in running cold water until they reached a temperature slightly above room temperature and were then air dried and labeled.

Viscosity analyses

Viscosity measurements were carried out using advanced equipment, LFRA Texture Analyzer, made by Brookfield Engineering. The experiments were carried out in the controlled stress mode to measure the viscosity of the juice, squash and jam having different compositions. About 150 to 250 ml of juice/squash and 250 g of jam was put into the stationary rheometer cup. The viscosities of the products were measured at temperatures between 25 to 26°C (±1).

RESULTS AND DISCUSSION

The present study describes the processing of beverage products made from jamun fruit. The study revealed that jamun might have a large quantity of natural pectin due to which jam solidifies before the completion of its cooking time, or before reaching the TSS at its standard end which is, 68 to 70% TSS. Miller et al. (1955) authenticated our hypothesis by reporting that white-fleshed jamun has adequate pectin and makes very stiff jelly unless cooking is brief or otherwise. Colin (1992) also reported that gel structure is determined by the concentration of pectin, which may range from 0.5 to 1.5% by weight of pure pectin supplied for commercial jam manufacturing. However, Egan et al. (1985) reported that pH below 3.0 may often result in hard gels. Therefore, results of this study suggest that jamun fruit should be fortified with other fruits deficient in natural pectin to obtain good quality jam without the addition of commercial pectin. Consequently, there are many fruits deficient in natural pectin. For instance, Barrett (1928) reported that more common purple fleshed fruits yield richly colored jelly but is deficient in pectin and requires the addition of a commercial jelling agent or must be combined with pectin-rich fruits like jamun. The jam product made during this study was aimed to be acceptable commercially, and ensured to maintain all

Table 1. Percent chemical characteristic of jamun products at initial stage.

Sample	pH	Acidity	TSS	Total sugar	Moisture (%)
Jam					
V1 (improved)	3.11	1.13	68.00	68.57	37.44
V2 (indigenous)	3.01	1.25	69.30	69.30	33.76
Squash					
V1(improved)	3.49	1.32	45.00	45.58	96.82
V2 (indigenous)	3.38	1.36	45.20	45.76	97.06
Juice					
V1 (improved)	3.77	0.51	18.10	18.56	94.50
V2 (indigenous)	3.28	0.56	18.28	18.57	93.65

important features such as, texture, color, appearance, consistency, thickness etc. During jam preparation, the ratio of pulp used was 45 parts of its weight whereas the cane sugar was 55 parts. Commercial pectin and citric acid used was 3 and 4 g/l emulsion respectively. FAO (1990a, b) described the same procedure, even for commercial jam manufacturing, which is a highly complex operation and where strict quality control procedures are employed to ensure uniform product.

The final Brix of jam was observed 68.00 and 69.30% whereas total sugars observed 68.57 and 69.85% at a pH of 3.11 and 3.01 with a titrable acidity of 1.13 and 1.25% whereas, final moisture content was found 37.44 and 33.76% in V1 and V2 jam respectively (Table 1). Our findings are in agreement with Taufik and Karim (1992) who reported that maintaining of 68 to 70% Brix not only gives taste but also protect jam from deterioration since microorganisms can not grow at 70% sugar concentration. Farkas (1991) and Colin (1992) reported that texture of jam is a composite property related to a number of physical properties such as, pH, sugar concentration, viscosity and elasticity, and their relationship is complex. Biswal and Bozorgmehr (1991) reported that maximum sucrose concentration that can be achieved in the liquid phase of the jam product is 67.89%. However, higher total sugar quantities (up to 70 to 72%) found in products is explained by increased reducing sugar solubility, resulting from sucrose inversion. Araújo et al. (2006) reported a detailed account on various processes required for the manufacturing of jam including sugar and acid ratio. Singh et al. (2007) reported that the most acceptable sensory properties (color, flavor, texture, taste) were those having a sugar concentration of 1.5 kg/l of fruit jam. Shakir et al. (2008) carried out a comparative study on mixed fruit jam. They reported that ascorbic acid decreased from 17.40 to 9.19 mg/100g, pH 3.64 to 3.22, and non-reducing sugars 46.00 to 16.69% during 3 months storage. In contrast, an increase was noted in acidity from 0.60 to 0.78%, reducing sugars from 16.55 to 47.30% and TSS from 68.5 to 71.2 deg Brix.

To prepare ready-to-drink juice, a mixture of sugar (8 to 10%) by its weight and 0.1% citric acid, pasteurized at 85 to 94°C with a concentration of 18% Brix (Table 1) was done. Sandi et al. (2003) described the pasteurization status of fruit juices subjected to three pasteurization time-temperature binomials 85°C/27s, 80°C/41s and 75°C/60s and stored for 120 days at 25±5 and 5±1°C. In our processing, all raw materials were directly mixed as a method of manufacturing. Sodium Benzoate 1 g/l by weight was used as preservative at the last stage of processing. Total sugar was analyzed as 18.10 and 18.21% at a pH of 3.77 and 3.28 in V1 and V2 juice respectively. These findings are closely related with other findings for juice as reported by Hernandez and Chen (1995) and Telis-Romero et al. (1999) who illustrate that if fruit juices contain more amount of pulps or are very concentrated, they may show an additional resistance to flow represented by a yield stress. Further, Taylor (2004) also discussed the same procedure associated with the processing of a wide range of fruit types to produce fruit juices commercially. Horváth-Kerkai (2006) described various steps involved in the processing and manufacturing of fruit-based beverages, for example, juices and fruit musts, fruit nectars and soft drinks with fruit content. Similarly, jamun squash was also prepared and the finished product contained 25% juice, 45.00 and 45.20 TSS, 45.58 and 45.76% total sugar at a pH of 3.49 and 3.38% with a final acidity of 1.32 and 1.36% in V1 and V2 squash respectively (Table 1). Our findings are comparable with Saikia and Saikia (2002) who reported initial pH range of the squash preparation (1.37 to 2.61) increased to 2.24 to 2.88, after 60 days of storage. The total sugar percentage range at day 0 (26.54 to 48.48%) also increased to 31.15 to 55.05%, after 60 days of storage. pH (1.37), TSS (48.0%), acidity (0.65%) and total sugars (48.48%) were found to contribute to the organoleptic qualities of the squash. Gatchalian and Leon(l992) also described the same method for fruit beverages. Farkas (1991) indicated similar remarks that,

Table 2. Viscosity measurement of jamun juice, squash and jam.

Samples	Shear rate s^{-1}	Shear stress dynes/cm^2	Final load (g)	Peak load (g)	Viscosity (poise)
Water					
R1	1.332	26.873	12.00	12.12	20174
R2	1.332	26.710	12.05	12.10	20052
Juice					
V1	1.332	33.602	14.35	14.55	25226
V2	1.332	32.574	14.37	14.47	24973
Squash					
V1	1.332	38.793	15.10	15.75	29123
V2	1.332	37.622	15.00	15.35	28244
JAM					
V1	1.332	63.725	21.91	22.75	47841
V2	1.332	61.396	21.88	21.98	46093

a major challenge facing food developers today is how to accurately and objectively measure texture and mouth-feel. Saikia and Saikia (2002) tested three methods for preparing squash from ripe Outenga fruit at its optimum maturity stage.

Viscosity in jam, squash and ready-to-drink juice

Results as shown in Table 2 indicated that jamun jam has 47841 to 46093 (poise) viscosity which is absolutely high. Viscosity standards for low and high viscosity ranged from, 20000 to 40000 poise (Rao and Steffe, 1992). Keeping in view the standard ranges of viscosity, it is concluded that jamun jam was more solidified and extremely disliked by the tasters. However, the other two products such as squash having 29123 and 28244(poise) and ready-to-drink juice 25226 and 24973 (poise) viscosity in V1 and V2 respectively were in accordance with the quality conditions. Santanu et al. (2007) stated that jam is an intermediate moisture food containing fruit pulp, pectin, sugar and acid. The effect of sugar and pectin concentration, pH, shear rate and temperature are the time dependent rheological properties. Our findings can be compared with Mezger (2002) who measured viscosities of two fruit juices, pomegranate and pear with a capillary flow technique. The range of measurements for pomegranate juice was from 293.15 to 363.15 K at atmospheric pressure 0.101325 MPa and for concentrations 23, 30, 35, and 40 deg Brix. For pear juice, it was from 298.15 to 363.15 K at atmospheric pressure and for concentrations 20, 25, and 30 deg Brix. For two selected concentrations (11.0 deg Brix for pomegranate and 15.2 deg Brix for pear juice), the measurements were performed at three pressures (0.101325, 5, and 10 MPa).

Results in Table 2 showed the viscosity versus shear rate for jamun juice at 18%, squash 45%, and jam 68 to 70% deg Brix TSS at temperatures 25 to 26°C. The concentrations can be comparable with Kuo et al. (2008) who described the application of a non-contact ultrasonic system to measure the sugar content and viscosity of reconstituted orange juice. Juszczak and Fortuna (2004) studied the rheological behavior of concentrated cherry juice over a wide range of temperatures (10 to 60°C) and concentrations (50 to 63.8 deg Brix). Sogi (2003) described the rheological properties of watermelon juice on a rotational viscometer over the soluble solid and temperature range of 50 to 70deg Brix and 5 to 50°C respectively. Rai et al. (2005) presented an artificial neural network (ANN) model for the prediction of viscosity of fruit juice as a function of concentration of sugar and temperature. The viscosity data of juices (1.53 to 3300 mPas) were obtained from the literature for a wide range of concentration (5 to 70 deg Brix) at (30.7 to 71.7°C) temperature. Lin et al. (2003) described an experimental apparatus, which is specially designed and built for measuring shear dependent thermal conductivity for food liquids. However, Charanjit et al. (2007) governed strongly the quality and viscosity of tomato juice by mechanical and thermal abuse during processing. It is thus, proved that jam has significant difference whereas juice and squash have no significant difference between the standards already recognized for flowability and viscosity.

Flow behaviour and rheological properties are associated to the quality of jam, squash and juices which are highly considered in commercial manufacturing. Therefore, it is important to maintain them as a quality check during manufacturing. Some other researchers also affirm the importance of rheological properties. For instance, Rao and Steffe (1992) reported that rheological

Table 3. Brookfield LFRA texture analyzer test settings and data.

Equipment	LFRA # LV4
Mode	Normal
Spindle	4LV (2.5 diameter)
Speed of spindle (N)	5.0 (mm/second)
Trigger	10 (g)
Distance	10 mm
Radius of spindle (Rb)	0.1588 cm
Radius of container (Rc)	4.5 cm
Actual length of spindle	3.101 cm
Effective length (L)	
Water: (R1 and R2)	3.010 and 3.021 cm
Juice: (V1 and V2)	2.891 and 2.902 cm
Squash: (V1 and V2)	2.711 and 2.722 cm
Jam: (V1 and V2)	2.381 and 2.392 cm

properties are relevant to several aspects including the causes and extent of damage during processing and storage; the human perception of product quality; and the physiological changes that take place in the product during growth, maturation, ripening and storage after harvest. Mezger (2002) stated that the influence of concentration-dependent flow instabilities in the narrow gap of the cylindrical spindle measuring system, considered a possible explanation for the observed deviations at higher shear rates. Telis-Romero et al. *(*1999) reported that flow behavior also influences the pump performance. Lau (1991) and Holdsworth (1993) emphasized the importance of accurate rheological data for calculation of volumetric flow rates, selection of pumps, determination of pressure drops for pipe sizing and power consumption for pumping systems, and for prediction of heat transfer coefficients for heating. Rao (1999*)* compiled rheological data for a number of fluid foods, which included for various fruit beverages. Krokida et al. (2001) recently collected additional data on rheological properties of fluid fruit and puree products. They stated that fruit and vegetable juices/concentrates are assumed to behave as non-Newtonian fluids. Hernandez et al. (1995) and Telis-Romero et al. (1999) described that, if fruit juices contain considerable amounts of pulp or are very concentrated, they may show an additional resistance to flow represented by a yield stress.

Operating parameters of spindle geometries

The following equations and mathematical descriptions were undertaken for obtaining shear rate and shear stress values to identify the flow behavior of jamun juice, squash and gelling strength of jam viscosity (Table 3).

Shear rate

(SEC^{-1}): $$\gamma = \frac{2W\,R_C^{2}\,R_B^{2}}{X_2(R_C^{2} - R_B^{2})} \quad (1)$$

Shear stress

(dynes/cm^2): $$\tau = \frac{M}{2\pi(R_B^{2} - R_B^{2L})} \quad (2)$$

Viscosity

(Poise): $$\eta = \frac{\tau}{\gamma} \quad (3)$$

Where:

W = angular velocity of spindle (RAD/SEC)

$[=(\frac{2\pi}{\;}N]$, N=NPM

Rc = radius of container (cm); Rb = radius of spindle (cm); X = radius at which shear rate is being calculated (Rc-Rb); M = torque input by instrument (final load);L = effective length of spindle

Conclusion

The viscosity measurement of food product is much useful behavioral and predictive information to take guidelines in formulation, processing and product development. Hence, this study was partially employed as a quality check during production of jam, squash and juices. Jamun juice and squash were found excellent in its quality; however jam was not so appreciated because of tough gel formation.

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