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Effect of substitution of stevioside and sucralose on rheological, spectral, color and microstructural characteristics of mango jam

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ABSTRACT

An attempt was made for manufacturing low calorie mango jam by replacement of sucrose with alternative sweeteners (stevioside and sucralose). Manufacture of mango jam with desired jam-like soft solid characteristics was feasible only with 25% stevioside or sucralose substitution. Herschel Bulkley and Hahn model adequately described the steady state and time dependent rheological behavior of stevioside/sucralose jam, respectively. Consistency index and yield stress values of jam samples decreased with increasing substitution of stevioside or sucralose due to reduction of total soluble solids (TSS). Flow behavior index increased with decreasing TSS values, signifying liquid like behavior of jam. Dynamic rheological tests characterized mango jam as a weak gel. L^* (lightness), b^* (yellowness) and C^* (chroma) values increased with stevioside/sucralose substitution in jam. The spectral features for C–C and C–O stretching indicated its importance in 'gel' like structure formation due to hydrophobic interaction in mango jam samples.

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1. Introduction

Jam is an intermediate moisture food prepared by boiling fruit pulp with sucrose, pectin, acid, and other ingredients (preservative, coloring, and flavoring materials) and is consumed widely in the world (Lal et al., 1998; Baker et al., 2005). Jam should contain more than 68.5% total soluble solids (TSS) and at least 45% fruit (P.F.A, 2004). In addition to its sweetening effect, sucrose contributes to soluble solids, an effect that is essential for the physical, chemical, and microbiological stability; provides body and mouthfeel; improves appearance (color and shine); and makes gelation of pectin possible (Hyvönen and Törmä, 1983). Nowadays, due to the growth of health food industry reduction of sucrose content of food products by full or partial replacement of sucrose using alternative sweeteners have become a viable option for producing low calorie/zero calorie foods. Low calorie food products of good quality can be made by incorporating combinations of non-caloric and carbohydrate sweeteners (Nabors, 2001). Carbohydrate or non-carbohydrate sweeteners (xylitol, sorbitol, aspartame, acesulfame-K, cyclamate, stevioside, sucralose, or, combinations of these) can be used for partial or full replacement of sucrose to prepare jam with lower amounts of sucrose (Hyvönen and Törmä, 1983). The food product incorporating alternative sweetener should have similar textural and rheological characteristics and taste to that of the traditional product. An appealing texture and rheology are critical aspects of fruit jam quality.

Sucrose acts as a dehydrating agent for the pectin molecules, permitting closer contact between the chain molecules during jam manufacturing (Suutarinen, 2002). Stevioside and sucralose are non nutritive high intensity sweeteners, acid- and heat- stable, and can be used for jam preparation without compromising taste. One sugar unit of stevioside occurs as a D-glucopyranosyl functionality attached β to a carboxyl group, whereas the second is a sophorose [2-*O*-(β-D-glucopyranosyl)-D-glucose] unit attached β to a aglycone (Fig. 1(a)). Sucralose (1,6-dichloro-1,6-didedoxy-β-D-fructofuranosyl-4-chloro-4-deoxy-α-D-galactopyranoside), one of the most promising candidate as an ideal non-nutritive sweetener is obtained by selective chlorination of sucrose (Fig. 1(b)). The selective chlorination produces profound changes in sweetness intensity and stability of sucrose, without compromising taste. Both are highly soluble in water, and have negligible effect on the pH of the solutions (Kinghorn et al., 2001; Goldsmith and Merkel, 2001).

Rheological behavior of jam has been widely studied (Carbonell et al., 1991a,b; Gabriele et al., 2001; Álvarez et al., 2006; Basu et al., 2007, 2011; Basu and Shivhare, 2010). It has been established that the rheological properties of jam are mainly affected by the amount and type of sugar added, acidity, proportion and kind of pectin used, fruit pulp content, and process temperature. There are few systematic studies undertaken on development of fruit jam using alternative sweeteners (Abdullah and Cheng, 2001; Gajar and Badrie, 2001; Khouryieh et al., 2005; Acosta et al.,

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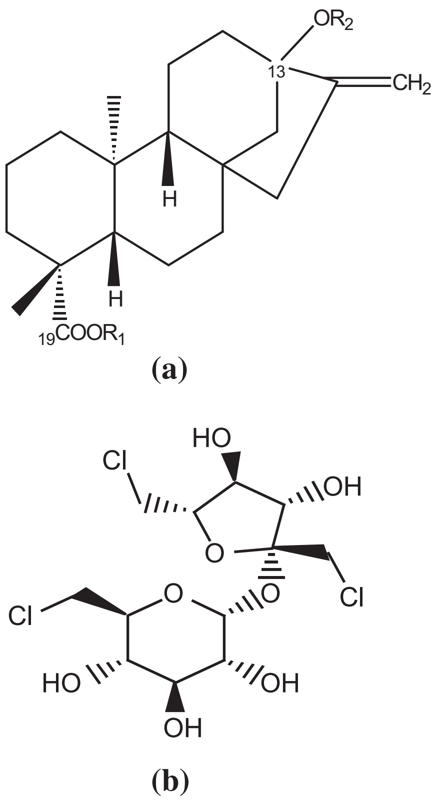

Fig. 1. Chemical structure of (a) stevioside, and (b) sucralose.

2008). There is limited study available on jam color characteristics (Abers and Wrolstad, 1979; Suutarinen, 2002; Zafrilla et al., 1998) during storage, but no literature is available for color development during gelation or jam manufacturing. Also, there is little scientific information available in literature on variation of rheological, textural, and microstructural properties and spectral behavior of fruit jam with different alternative sweetener concentrations. The present work is an attempt to study the feasibility of replacement of sucrose with two non nutritive sweeteners (stevioside and sucralose) in jam manufacturing and to investigate the effect of sucrose to alternative sweeteners (stevioside and sucralose) ratio on the rheological, textural, color, spectral, and microstructural characteristics of mango jam.

2. Materials and methods

2.1. Materials

Canned mango pulp (*Totapuri* variety) was procured from M/s Nirmal Services, New Delhi. Sucrose was procured from the local market while pectin (degree of esterification (DE) = 75%, methoxyl content = 6%) was procured from SD Fine Chemicals (Mumbai, India). Citric acid, sodium bicarbonate, and sucrose were purchased from Loba Chemie (Mumbai, India). Stevioside (Herboveda, Noida, India), and sucralose (Tate and Lyle, London, UK) were used to prepare jam with alternative sweeteners. Spectroscopic grade acetone (Himedia, Mumbai, India) were used for sample preparation and cleaning of pellets in FTIR spectroscopy.

2.2. Jam manufacturing

Mango pulp was weighed using a balance (least count ± 0.1 mg, CP-220, Sartorius, Germany), and TSS (±1 °Bx) was measured using a hand refractometer (Erma, Tokyo, Japan). The pH of the pulp was adjusted to pH = 3.4 by addition of 10% (w/v) citric acid or sodium bicarbonate solution and measured using a pH meter (Elico, New Delhi, India). Jams were prepared according to experimental plan reported in Table 1. Studies on development of traditional mango jam revealed that better quality product was made at 3.4 pH, 1% pectin, and 60–70% sucrose concentration (Basu and Shivhare, 2010). Therefore, production of jams with alternative sweeteners was carried out only at pH = 3.4 and 1% pectin by partially or fully replacing 60, 65, and 70% sucrose. In case of mango jam manufactured with alternative sweeteners, the% sucrose level which was replaced partially or fully by incorporation of alternative sweeteners was termed as alternative sweetener level. For example, stevioside level = 70 represents stevioside jam made by replacing 70% sucrose with partial or full substitution. Four levels of sucrose substitution (25, 50, 75, and 100%) were carried out with stevioside and sucralose (Table 1). The substitution was done on the basis of mass of sucrose used and relative sweetening index of each sweetener was considered for estimation of the amount needed for supplementation. The relative sweetening index values as mentioned by the manufacturer of stevioside and sucralose were 500 and 600, respectively. Desired amount of sucrose and alternative sweeteners (on pulp basis) were added to the pulp and mixture was transferred in an open stainless steel pan. The mix was heated on a gas burner at low flame temperature (190 ± 1 °C) and TSS was monitored during boiling. Pulp-pectin-sugar-acid mix was stirred continuously with a glass-rod during boiling. The mix was taken out at selected TSS level to study the spectral, textural, and rheological attributes with gelation. Heating was stopped when TSS reached 65–66 °Bx for full set jam and the mixture was poured into 100 mL glass beakers and cooled under ambient condition. Otherwise, the heating was stopped in other samples (which did not reach the desired TSS) till browning appeared and produced color change. The beakers were then covered with the ethanol dipped butter paper to prevent microbial growth and stored for 24 h in an incubator (Narang Scientific Works, New Delhi, India) at 30 °C for proper setting of jam. Analytical grade sucrose was used to prepare jam samples for FTIR study.

2.3. Rheological measurements

2.3.1. Steady state rheology

Rheological properties of samples were measured using a rheometer (Model MC1, Paar Physica, Germany). Yield stress of the samples was measured in duplicate by the direct yield measurement program of the MC1 Paar Physica rheometer. The procedure is increasing the stress on the sample logarithmically and finding out the point where the sample starts to deform/flow (initiation of shear rate). That point is calculated by the instrument software as yield stress. Basu et al. (2011) provides the detailed description for steady state rheological measurements. All the tests were replicated thrice and average values were used in analysis.

Steady state rheological behavior of mango jam was studied at 20, 30, 40, 50, and 60 °C. Shear rate was increased linearly from 0.1 to150 s^{-1}. Steady state relationship between shear stress- shear rate of food materials is expressed in terms of Herschel Bulkey model (Eq. (1)).

$$\tau = \tau_0 + K\dot{\gamma}^n \tag{1}$$

where, τ is shear stress (Pa), τ_0 is yield stress (Pa), $\dot{\gamma}$ is shear rate (s^{-1}), K is consistency index (Pa.s^n), and n is flow behavior index (dimensionless) signifying the extent of deviation from Newtonian behavior.

Dependence of the flow behavior of fluid foods on temperature can be described by the Arrhenius relationship (Saravacos, 1970; Steffe, 1996):

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