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Effect of Vacuum Evaporation Concentration on Lycopene Content and Rheological Properties of Watermelon Juice

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ABSTRACT

Comparative study of two methods of concentration, namely open-pan heating (OP) and rotary vacuum evaporation (RVE) of watermelon juice was performed to achieve concentrations of 10°, 20°, 30 °, 40° Brix respectively for both and subsequent effect on lycopene content, rheology and sensory attributes was examined. Juice from open-pan heated samples showed 31.1, 70.3, 76.3, and 83.0% of lycopene degradation for 10°, 20°, 30°, 40° Brix respectively; whereas for same levels of concentrations rotary vacuum evaporation showed 12.6, 28.7, 33.7 and 49.8% reduction in lycopene content respectively. The weight concentration factor (WCF) was better for RVE than OP. The shear stress and viscosity behavior followed power law; was better fitted for RVE, and within the test condition exhibited pseudo plastic behaviour.

Key words: *Vacuum concentration, Watermelon juice, Lycopene, Rheology.*

INTRODUCTION

The watermelon (*Citrullus Vulgaris*) belonging to cucurbitaceae family, is a native plant of tropical Africa. It is cultivated throughout the warmer parts of the world for its fruit which is used as dessert. In 2012, the world‘s largest producers of watermelon were China, followed by Iran, Turkey, Brazil, and the United States, respectively, which accounted for more than three-fourth of the world‘s production. Watermelons do not exhibit improvement in flavour after harvesting, therefore picked when fully ripe. As ripening progresses, total solids and total sugars increase and reducing sugars decrease which are partly used in respiration while rest changed to sucrose. Watermelon is highly valued for its delicate flavour, taste of pulpy portion, sweetness and its attractive red colour. The use of watermelon juice and its preservation has not received much attention though literature concerning fruit juice technology is extensive[7].

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Lycopene, a lipid soluble red colour carotenoid antioxidant, is synthesized by many plants and microorganisms but not by animals and human[13]. Lycopene is a highly efficient oxygen radical scavenger and providing protection against cardiovascular disease and some cancers. It is a highly unsaturated open straight chain hydrocarbon consisting of 11 conjugated and 2 unconjugated double bonds[11]**.** Preliminary research indicates that watermelon may also have antihypertensive effects.

Fruits are commonly consumed either in the form of fruit slices or juices. Freshly prepared juices may also have nutritional difference due to the processing condition[3]**.** Nutrients in the fruits, especially carotenoids are unstable when exposed to oxygen, heat, or lights[5]**.** Watermelon juice and products based on juice can differ widely in their total soluble solids, concentration, particle size and viscosity and flow properties. Preservation of single strength juice is not economical, since the water content of fruit juices is very high, about 75-90%[16]**.** Concentration of fruit juices not only provides microbiological stability but also permits economy in packaging and distribution. Total carotenoids content in fresh watermelon juice was reduced from 4.568 to 0.929 mg/100 g and lycopene from 4.403 to 0.82 mg/100 g when heated at 90°C for 5 h[20].

Within the globalization of the food industry, the demand for quality juice and juice type beverages have increased. Two types of fruit juice market are generally exist, obtained by simple squeezing and then submitted to mild pasteurization and juices made from concentrate[18]**.** Concentration is achieved via several methods such as evaporation, freeze and osmotic techniques[10]**.** In atmospheric concentration the residual water is removed via evaporation therefore high temperature, long time heating can lead to changes in colour, flavor and final quality of the product due to the possibility of oxidation, browning and maillard reaction[12]**.** Hour used as HTST process to produce 65°B concentrates from watermelon juice[9]. Colour of the reconstituted juice was similar to that of fresh juice. During concentration of lime juice, rise in temperature led to browning. Also, the millard reaction between reducing sugars and a-amino groups was the most important cause of browning in apple juice concentrates[8].

Rheology is a science interrelated to the flow of fluids and deformation of material[4]**.** The different types of flow behavior like Newton, Power law, Bingham and Herschel-Bulkley model may be fitted by means of mathematical models that have been broadly used in the rheological characterization of food materials. Rheological characteristics of the fluid played a major role[14]. Foods have a wide variation in their structure and composition and hence they exhibit flow behaviour ranging from simple Newtonian to time dependent non-Newtonian and viscoelastic[15]. Central composite design can be used to analyses the effect of particle size, temperature and total soluble solids on the rheological properties of watermelon juice Experimental values of consistency coefficient k, varied from 0.178–0.628 $Pa.s^n$ and flow behaviour index n from 0.281 to 0.949[21]. Apple juice is a Newtonian liquid, but concentrated, undepectinised and filtered juice is a shear thinning fluid[19]. As the concentration of fluid increases its viscosity also increases[15].

In order to utilize this valuable produce detailed knowledge regarding its rheological properties is required under diverse processing conditions. Present study was undertaken to study the effect of heating methods on lycopene concentration, visual colour and rheological characteristics of watermelon juice.

MATERIALS AND METHODS

Sample preparation

The ripe watermelons of ‘Sugarbaby’ variety were obtained from local market of Narela, Delhi (India). Watermelon was cut and peel was separated. Juice was extracted by using Maharaja Whiteline Food Processor FP-300 juicer. The juice was then passed through a muslin sieve of size 0.5 mm into samples weighing 100 g each. Four samples were then concentrated using an electric heating mantle (Hi-Tech, India, 1000ml, 300W) by continuous stirring up-to known brix. These samples were also concentrated to various TSS

10, 20, 30 and 40°B using Rotary Vacuum Evaporator (Rotavapor R-210, Buchi, Switzerland) with buit-in water bath at a temperature of 50 °C and vacuum Pump (Vacuum Controller V-850) to maintain 100 mm Hg Pressure (133 mbar on the RVE vacuum controller). The speed of rotation was kept around 80 RPM. These samples were immediately tested for lycopene content and then kept in deep freezer until further study on rheology. All samples were prepared in triplicates.

Lycopene extraction and determination

Lycopene was extracted using acetone and petroleum ether[17]**.** Sample (5g), was extracted using acetone in a pestle and mortar till the residues became colourless. Lycopene was then transferred into a 20 ml petroleum ether phase by diluting acetone extract in a separating funnel. 5% in 20 ml sodium sulphate was added in the funnel gently after shaking. Approximately 20 ml more petroleum ether was obtained to get a clear separation. Most of the colour was notable into the upper petroleum ether layer. The two phases were separated using the funnel and the lower aqueous phase was re-extracted for residual lycopene, if any. The volume of the extracts was made up to 100 ml by adding petroleum ether. Finally, absorbance was measured at 503 nm using UV visible spectrophotometer (ELICO, SL 159).

Absorbance (1 unit) = 3.1206 µg lycopene/ml

Colour measurement (visual colour)

The CR-400 Chroma Meter (Konica Minolta Inc., Japan) was calibrated with standard white tile (L = 93.47, a = -0.41, b = 3.99). The sample was placed in sample handling dish and the handheld colourimeter was used to note the L, a and b values. The mean values were recorded. Hunter L, a, b parameters were used as the colour scale where L value represented lightness (100 for white and 0 for black), a value signified greenness and redness (-60 for green and 60 for red) and the b value represented the change from blueness to yellowness (-60 for blue and 60 for yellow.

Rheological measurement

A programmable Rheometer MCR 52 (Anton Paar GmBH, Austria) with the measuring system of concentric cylinder and a probe DG 26.7 in the arrangement was used for doing the rheological studies owing to the less viscous behaviour of the product. The concentrated triplicates of the sample were mixed and then sample of each concentration was analysed on rheometer. The temperature was set at 20°C in a water circulating chiller which kept the temperature tolerance in a -/+1 range. The shear rate was varied from 10-300 /s and samples were studied for rheology.

RESULT AND DISCUSSION

Effect of OP and RVE on lycopene content of watermelon juice

The change in lycopene content as an effect of thermal concentration was studied as a comparison for two different methods, namely – open-pan heating and rotary vacuum evaporation. The effect of temperature on watermelon juice has already been found to degrade lycopene with an increase in temperature. As shown in figure 1, the concentration in TSS (°Brix) was attained for a watermelon juice sample of initial weight 100 g. Fresh, 10°, 20°, 30°, and 40° Brix samples were analysed for their lycopene content. Lycopene degrades to a very higher value in open-pan, but comparatively, the degradation in RVE was significantly less.

From Table 1, it was observed that as the concentration increases, the L, a, b values also tend to change. The 'a' value has 98% correlation to the lycopene content for watermelon juice [7]**.** Though not very evident, there is a rising trend in 'a' value. Also, the 'a' values of rotary vacuum evaporated samples are faintly above the open-pan heated samples. The reason for higher value of redness at 30o Brix may be counted as a maxima point in the combo effect of lycopene degradation and concentration augmentation. The redness reduces approaching 40° Brix, because a trace of browning starts into the juice concentrate. The observed loss of lycopene can be attributed to the oxidation and isomerization reactions of lycopene during the processes, which directly affect the antioxidant capacity**.** Also, in open pan heating there was unsteady heating, direct contact with oxygen and higher temperatures of processing. All of which are derogatory for lycopene. On the contrary, the juice concentration in rotary vacuum was carried out at lower temperature, and also the rotation of the vessel enables effortless evaporation of watermelon juice surplus moisture, without causing a major destruction to lycopene.

Effect of OP and RVE on rheological behaviour of watermelon juice

The rheological behaviour of watermelon juice at various concentration levels, attained by either open-pan heating or rotary vacuum evaporation was studied. Power Law or Ostwald de Waele Equation was used to study the shear stress behaviour of watermelon juice for the applied shear rate of 10-300/s. The Power-Law is a very simple empirical model extensively used for engineering calculations due to its simplicity of having only two parameters. It has been used for describing many liquid foods, such as sour soup juice, orange juice concentrate[1] and many other fluids. This model described well the shear rate-shear stress data (equation 1).

$$\tau = k\gamma^n \qquad (1)$$

Where τ is shear stress (Pa), γ is shear rate (s-1), n is flow index and k is Consistency coefficient (Pa·sn).

Viscosity is a measurement of a frictional force (resistance) of a fluid. Fluids resist such an applied force (or another object‘s motion through the fluids) with each layer‘s motion with different velocities. The viscosity of juices strongly depends on inter-molecular forces between molecules and water-solute interactions, which result from the strength of hydrogen bonds and inter-molecular spacing as both are strongly affected by the temperature and concentration. Also, the high-temperature heating which is inevitable in open-pan system causes tremendous vibrations at molecular level, causing breakdown of soluble solids and making them insoluble. This was observed even in the weight reduction for equal degree of concentration achieved. The Weight Concentration Factor (WCF) describes that in order to compensate with the conversion of TSS into insoluble or broken down solids, more moisture needs to be removed to attain equal degree brix. The increase in temperature significantly decreases the magnitude of viscosity because of the increase in thermal energy of the molecules which enhances the mobility of molecules and increases inter-molecular spacing[22]**.** The rheological behaviour of melon juice was described by the Power-Law Table 2. It was observed that, the value of ‘k’ in rotary vacuum evaporated samples, showed an increasing value with the increase in the total soluble solid (TSS) content of the juice. Several reports have shown the same result for different juices such as orange juice, pineapple juice, pomegranate juice, and cherry juice. The flow consistency index, K, increased with an increase in concentration. This effect can be endorsed to a rise in the interactions between the particles, as the number of particles that come into contact increases. However, flow behaviour index was not significantly influenced by concentration. Within the tested conditions, the concentrates exhibited a pseudo plastic behaviour. The experimental results were well fitted by Power-Law model but almost all of the results were not satisfactorily or totally fitted by Herschel-Bulkley model which may be because of lack of yield stress. Several authors have reported a similar type of results for different juices and other products such as pomelo [9]**,** Mango juice of Kesar variety[2]**,** and kiwifruit juice[5]. If the value of n is more than 1, it is shear thickening. If value of ‘n’ is equal to 1, the fluid shows Newtonian behavior. From Table 2 it is notable that values of ‘n’ are not in a trending or uniform pattern during open-pan heating. On the other hand, the flow behaviour index for vacuum evaporated sample is in an approximate bracket of 0.8 to 0.9, which shows uniform shear thinning characteristic.

Table 1: Comparative L, a, b values of lycopene in OP and RVE heating

TSS (°Brix)	Lycopene Content	L	a	b
Open Pan				
8 (Fresh)	5.200	47.86	22.88	16.16
10	4.759	36.385	15.5	12.29
20	5.150	25.24	18.87	8.99
30	7.801	24.81	21.34	8.67
40	7.020	22.18	15.95	6.47
Rotary Vacuum Evaporator				
8 (Fresh)	5.2	47.86	22.88	16.16
10	5.978	39.21	18.67	11.95
20	9.083	24.64	21.5	8.11
30	16.575	22.68	24.7	7.93
40	16.9	21.6	16.81	5.22

Table 2: Comparative power law model application for OP and RVE heating

Concentration	Temperature(°C)	k	n	R^2
°Brix				
8 (Fresh)	20	0.0165	0.6297	0.931
Open Pan Heating (OP)				
10	20	0.0311	0.5192	0.6295
20	20	0.2666	0.2726	0.8049
30	20	0.0498	0.6866	0.9837
40	20	0.0552	0.7823	0.9971
Rotary Vacuum Evaporation (RVE)				
10	20	0.0035	0.9023	0.8909
20	20	0.0147	0.8153	0.9647
30	20	0.0588	0.7983	0.9782
40	20	0.0717	0.8416	0.9981

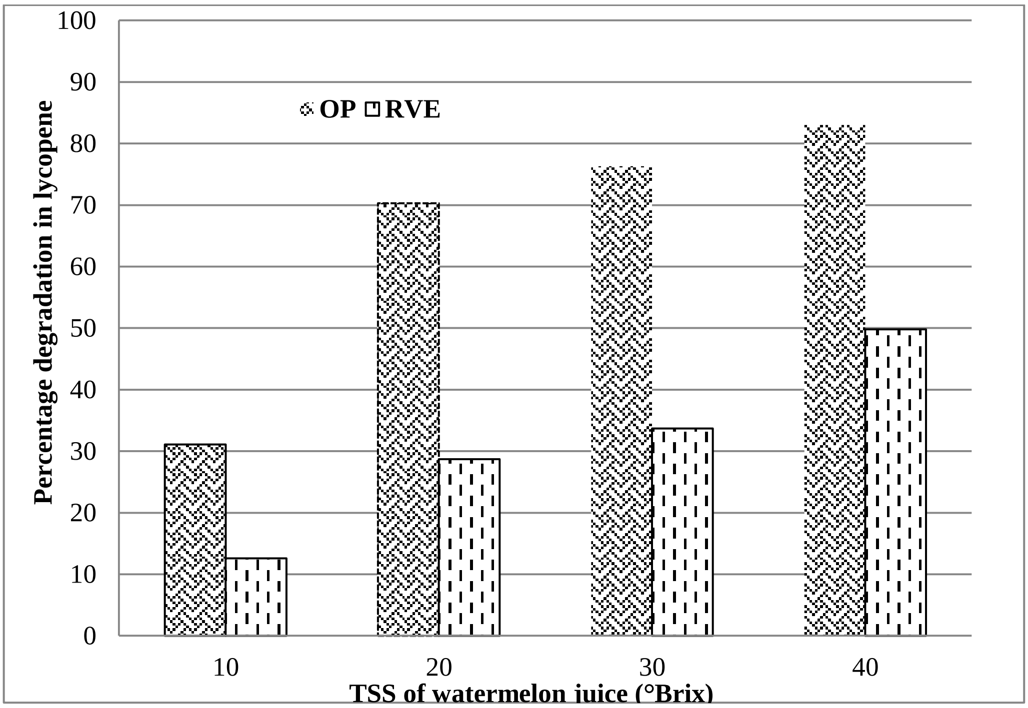

Fig. 1: Percentage reduction of lycopene in OP and RVE.

CONCLUSION

Rotary Vacuum Evaporation is a better technique compared to other techniques such as open pan method, owing to the high moisture typicality of watermelon fruit, where non-thermal novel processing technologies may not be so fruitful. The concentrated juice obtained by RVE had better rheological characteristics and Weight concentration Factor, which otherwise means that the Soluble Solid were well retained in quality in the RVE treated juice. The loss of lycopene was comparatively less, almost half at every stage, which is a very crucial constituent of watermelon juice. The visual colour, which is the mostly sought quality parameter for consumer acceptance was better in RVE treated juice, and was solid in nature, unlike OP juice, where visual colour appeared like disintegrated particles all-over in the solution. Visual colour showed insignificantly notable correlation with the lycopene content.

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