Effect of temperature on viscosity of kokum, karonda, mango pulp and cashew apple syrup

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Abstract: The viscosity of the food products (kokum, karonda, mango pulp and cashew apple syrup) was determined at temperatures 20ºC, 30ºC, 40ºC, 50ºC and 60ºC and at different spindle speed such as 0.07, 0.09, 0.1, 1.1 and 17 r min^{-1} for mango pulp and 17, 140, 150, 160, 180 and 200 r min^{-1} for kokum, karonda and cashew apple syrup using Brookfield viscometer. The kokum, karonda, mango pulp and cashew apple syrup showed shear thinning behavior and pseudo-plastic in nature (n<1). The viscosity of kokum, karonda, mango pulp and cashew apple syrup decreased with increasing temperature. For the kokum syrup it decreased from 52.25 to 2.69 mPas, for karonda syrup it was decreased from 43.15 to 7.38 mPas, for cashew apple syrup it decreased from 64.06 to 3.17 mPas and for mango pulp it decreased from 19,581 to 1,669 mPas with increase in temperature from 20ºC to 60ºC. All the syrups showed the flow behavior index (n) less than 1 indicating pseudoplastic nature. TSS of kokum syrup, karonda syrup, cashew apple syrup and mango pulp decreased from 16.7 to 15.7 ºBrix, 18.87 to 17.85 ºBrix, 15.5 to 14.65 ºBrix and 26.8 to 25.73 ºBrix respectively with increase in temperature range between 20ºC to 60ºC.

Keywords: kokum, karonda, mango pulp, cashew apple syrup, rheology, viscosity

Citation: Swami, S. B., N. J. Thakor, and S. S. Wagh. 2013. Effect of temperature on viscosity of kokum, karonda, mango pulp and cashew apple syrup. Agric Eng Int: CIGR Journal, 15(4): 281−287.

1 Introduction

Rheology is the study of deformation and flow and knowledge about this physical property of food material is useful in their processing, handling and storage. Kokum is mostly grown in the Sindhudurga and Ratnagiri district of Konkan region. Ratnagiri district has 82 ha area with production of 84 t of fruit with average yield of 1.012 t ha^{-1}. The production level of kokum in the year 2005 is estimated 10,200 tonnes with productivity of 8.5 t ha^{-1} (Korikanthimath and Desai, 2006). The fruit has agreeable flavor and sweetish acid taste.

Cashew (anacardium accidental) is one of the important tropical crops and leads an international trade with prominent share. India is the largest producer, processor, exporter and second largest consumer of cashew in the world. Indian cashew exported to more than 60 countries all over the world and over 60% of cashew imports in USA are from India. Among the Agri-Horticultural commodities getting exported from India, cashew ranks the second position.

Karonda (Carissa carandas) is a hardy, evergreen, spiny and indigenous shrub. Fruits are sour and astringent in taste and are the richest source of iron containing good amount of vitamin C. They are very useful to cure anemia and its fruits have antiscorbuti properties. Raw or mature fruits are most suitable for making an excellent quality pickle, jelly and candy. Ripe fruits can be processed into ready-to-serve squash and syrup.

Received date: 2013-07-22 **Accepted date:** 2013-11-08

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Mango (mangifera indica) is known as the king among the fruits in India; and is exceedingly popular due to its pronounced flavour and distinctive taste. Moreover, India is the leading mango growing country sharing more than 50% (15.188 million ton) of the world's production (FAO, 2011). These mangoes are processed both at raw and ripened stages. The raw fruit, because of its acidic taste, is used for preparing chutneys, pickles, etc.; while the ripened fruit is used for preparing squashes, jam, jellies, sorbets, milk-shakes, nectar, mango leather and powder, sweet meat, etc. The present study was undertaken to evaluate the shear stress, shear rate behavior of kokum, karonda, mango pulp and cashew apple syrup at varied temperatures i.e. 20ºC, 30ºC, 40ºC, 50ºC and 60ºC.

2 Materials and methods

2.1 Viscosity measurements

Kokum, cashew apple, karonda syrup and mango pulp of 500 mL was obtained from Dapoli local market. Viscosity measurements were carried out using Brookfield viscometer model (DV-II+ Pro). The measurements were carried out at temperatures 20ºC, 30ºC, 40ºC, 50ºC and 60ºC. Spindle S64 were used in the present research work at different rotational speeds such as 17, 140, 150, 160, 180 and 200 r min^{-1} for kokum syrup, karonda syrup and cashew apple syrup and 0.07, 0.09, 0.1, 1.1 and 17 r min^{-1} for mango pulp as it does not give the viscosity above 17 r min^{-1}. The torque required to rotate the spindle in the sample, at a given revolution per minute was recorded for the different speeds. Four replications for each temperature were performed. 500 mL of syrup sample was taken in beaker and viscosity was measured at different rotational speeds at 1 min interval after its stabilization.

The Brookfield viscometer was leveled on the platform and the spindle S64 was attached to the viscometer by screwing them onto the lower shaft. The above mentioned syrups were filled in a 500 mL beaker. The spindle was dipped in the sample up to mark on it at the center of the beaker. The rheological data were recorded at the speeds mentioned above by pressing the enter key on the equipment. Viscosity was displayed in centipoise (cP) and torque was displayed in percentage. This viscosity is converted into mPa. Temperature of syrup during experiment was measured by dipping the temperature probe in the sample which was coupled to the viscometer. Various temperatures i.e. 30ºC, 40ºC, 50ºC and 60ºC of the kokum syrup were achieved by heating the syrup on gas burner for 5 min and recorded with the help of thermometer dipping in the sample. 20ºC was achieved by keeping sample in the refrigerator for one hour. The readings of viscosity and torque at 17, 140, 150, 160, 180 and 200 r min^{-1} were recorded. Four replications for each sample at each temperature were taken. Similar procedure was followed for karonda syrup, cashew apple syrup and mango pulp.

2.2 Measurement of total soluble solids (TSS) at different temperatures

The TSS of all the food products was measured by using digital handheld refractometer (Make: Atago, Japan). The prism of the refractometer was cleaned with the help of distilled water and tissue paper. The distilled water was used as the TSS value of distilled water is zero and is known. This was used as standard for calibration. Sample to be analyzed was kept at the lowest temperature i.e. at 20ºC in freezer 1 to 2 h at which first reading was to be taken. Sample of fruit products was then taken into the two separate beakers of 50 mL capacity. The sample was stirred with the help of spoon just to ensure a proper mixing and to have homogeneity. The temperature readings were taken using thermometer in ºC. Then 0.3-0.5 mL sample of fruit product was placed on the prism with the help of plastic spoon. Plastic spoon was used so as to avoid the damage to the screen and the prism. The equipment gives its TSS reading with-in 5 s.

Readings were taken at different temperatures ranging from 20º C to 60º C. To achieve these temperatures the sample was heated just above the set point temperature by 12ºC. When the sample was dropped on the prism of the refractometer the temperature is just reduced by 12ºC to get the actual set point temperature. Four replications were taken at each temperature. The average value was then calculated from four readings for each temperature. Same procedure was followed for all the remaining products. The graph of TSS versus temperature was then plotted and result was obtained.

2.3 Shear rate and shear stress calculation

The shear rate (γ) was calculated as per the procedure described by Razavi et al., (2007). Shear rate (γ) was calculated from the manufacturer's instructions as follows (Equation (1)) (Razavi et al., 2007).

$$\gamma = N \times 0.209 \quad (1)$$

where, γ = shear rate, s^{-1}; N = rotational speed, r min^{-1}.

Shear stress was calculated by the following Equation (2):

$$\tau = (\eta)\times\gamma \quad (2)$$

where, τ = Shear stress, Pas; η = Viscosity, mPas; γ = Shear rate, s^{-1}.

Flow behavior index was described by fitting the experimental data (Shear rate-Shear stress) with the power law model by the following Equation (3) (Razavi et al., 2007)

$$\tau = \kappa\gamma^n \quad (3)$$

where, k = Consistency coefficient, Pa; n = Flow behavior index (dimensionless).

If n<1, the nature of the fluid is pseudoplastic (shear thinning) and if n>1, the fluid is dilatants (shear thickening). Generally pseudoplastic nature is observed in syrups, juices, food products such as sesame paste/date syrup blend (Razavi et al., 2007), tomato paste (Heidarinasab and Nansa, 2010), totapuri mango juice, kesar mango juice (Dak et al., 2006; Dak et al., 2007), strawberry, raspberry, peach, prune puree (Maceiras et al., 2007).

2.4 Activation energy

Fluid foods are subjected to different temperatures and concentrations during processing, storage, transportation, marketing, etc. The effect of temperature on the apparent viscosity or consistency coefficient at a specific shear rate is generally expressed by Arrhenius relationship (Equation (4)) (Harper and Sahrigi, 1965; Vitali and Rao, 1984; Speers and Tung, 1986).

$$K = A_0 e^{\frac{E_a}{R.T}} \quad (4)$$

where, A_0 = Constant; Ea = Activation energy of flow, kJ mol K^{-1}); R = Universal gas constant (8.314 J mol K^{-1}); T = Absolute temperature, °K.

2.5 Statistical analysis

The flow behavior index (n), consistency coefficient (k) and correlation coefficient (r^2) were calculated by fitting the shear stress-shear rate data to the power law model using Microsoft office Excel 2007 software.

3 Results and discussion

3.1 Shear stress - Shear rate behavior for syrups

Flow behavior indexes of kokum, karonda syrup, cashew apple syrup and mango pulp at different temperatures are shown in Figure 1, Figure 2, Figure 3 and Figure 4.

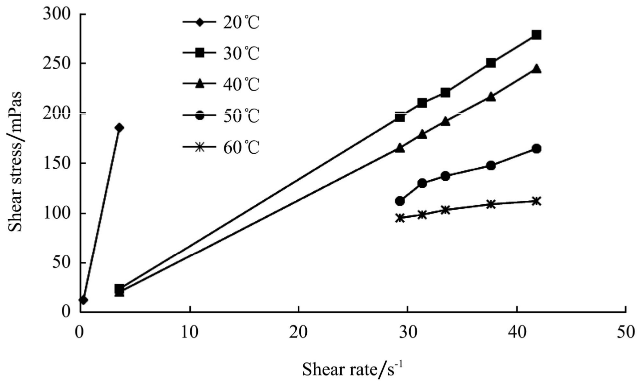

Figure 1 Shear stress versus shear rate for kokum syrup

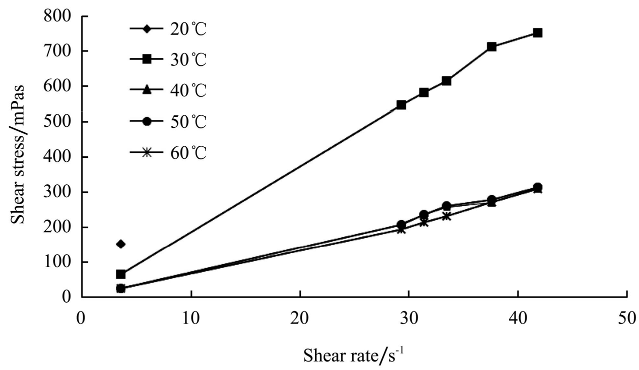

Figure 2 Shear stress versus shear rate for karonda syrup

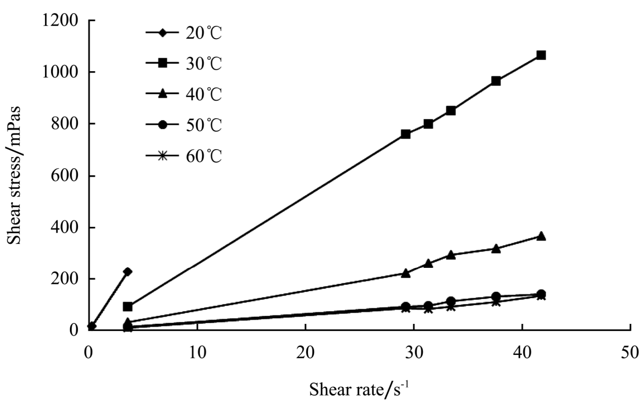

Figure 3 Shear stress versus shear rate for cashew apple syrup

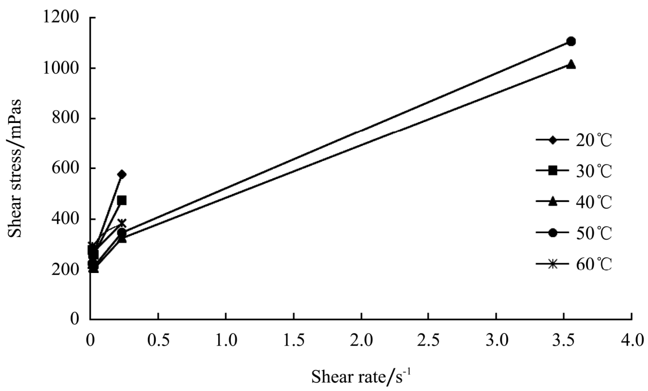

Figure 4 Shear stress versus shear rate for mango pulp

Figure 1 shows the effect of temperature on the rheological parameters of kokum syrup. Power law model well explained the flow behavior of kokum syrup with the high correlation coefficient. The flow behavior index decreased from 1.00 to 0.474 with increase in temperature from 20ºC to 60ºC. At all the temperatures, correlation coefficient were greater than 0.94. The kokum syrup showed the non Newtonian behavior. As the temperature increased from 20 - 60ºC the non Newtonian behavior increased. The similar results were observed in previous studies performed with sesame paste/date syrup blend (Razavi et al., 2007), tomato paste (Heidarinasab and Nanas, 2010), totapuri mango juice (Dak et al., 2006), strawberry, raspberry, peach, and prune puree (Maceiras et al., 2007).

Figure 2 shows the effect of temperature on the rheological parameters of karonda syrup. Power law model well explained the flow behavior of karonda syrup with the high correlation coefficient. The flow behavior index decreased with increase in temperature from 0.996 to 0.986 from 20ºC to 60ºC. At all the temperatures coefficients of determination were ≥ 0.96. The karonda syrup shows the non Newtonian behavior. As the temperature increases from 20ºC to 60ºC the non Newtonian behavior increases.

Figure 3 shows the effect of temperature on the rheological parameters of cashew apple syrup. Power law model well explained the flow behavior of cashew apple syrup with the high correlation coefficient. The flow behavior index decreased from 0.999 to 0.989 with increase in temperature from 20ºC to 60ºC. At all the temperatures, correlation coefficients were ≥ 0.95. The cashew apple syrup showed the non-Newtonian behavior.

Figure 4 shows the effect of temperature on the rheological parameters of mango pulp. Power law model well explained the flow behavior of mango pulp with the high coefficient of determination. The flow behavior index decreased from 0.284 to 0.116 with increase in temperature from 20ºC to 60ºC. At all the temperatures correlation coefficients were ≥0.89. The cashew apple syrup showed the non-Newtonian behavior. As the temperature increases from 20ºC to 60ºC the non-Newtonian behavior increases. Similar results were observed in previous studies performed with pulp, juice and nector of baneshan and neelum mango (Gunjal et al., 1985), and totapuri mango juice (Dhak et al., 2006).

3.2 Effect of temperature on viscosity

Values of viscosity obtained during the experiment for kokum, karonda syrup, cashew apple syrup and mango pulp are presented in Table 1. It was observed from the Table 1 that as the spindle speed (r min^{-1}) increased from 1.1 r min^{-1} to 200 r m^{-1} the viscosity decreased with increase in temperature for kokum, karonda syrup, cashew apple syrup and mango pulp. Mango pulp did not show viscosity above 17 r min^{-1} at any temperature. The decrease in viscosity can be attributed to the increase in intermolecular distances, because of the thermal expansion caused by the increase in temperature (Constenla et al., 1989).

3.3 Determination of rheological parameters

The flow behavior index (n), consistency coefficient (k) and correlation coefficient (r^2) of kokum, cashew apple syrup, mango pulp and karonda syrup were obtained by fitting the experimental Shear stress-Shear rate data to the power law model (Equation (3)). The values of flow behavior index, consistency coefficient and correlation coefficient for the above syrups are presented in Table 2. It was observed that for kokum syrup consistency coefficient decreased from 52.29 to 4.217 Pas with increase in temperature. For karonda syrup it was found that consistency coefficient decreased from 18.74 to 7.363 Pas with increase in temperature. For cashew apple syrup it was decreased from 64.04 to 2.884 Pas and for mango pulp it was decreased from 868.7 to 451.3 Pas.

Table 1 Effect of temperature and speed (r min^{-1}) on viscosity of food products

Sample	Speed /r min^{-1}	Viscosity /mPas				
		20ºC	30ºC	40ºC	50ºC	60ºC
Kokum syrup	1.1	52.25±0.22	-*	-*	-*	-*
	17	52.35±0.12	6.70±0.13	5.80±0.04	-*	-*
	140	-*	6.72±0.03	5.66±0.05	3.83±0.13	3.26±0.69
	150	-*	6.71±0.04	5.72±0.02	4.16±0.22	3.14±0.34
	160	-*	6.61±0.06	5.75±0.03	4.11±0.30	3.10±0.15
	180	-*	6.67±0.05	5.75±0.04	3.94±0.31	2.90±0.20
	200	-*	6.68±0.02	5.85±0.04	3.95±0.27	2.69±0.12
Karonda syrup	17	43.15±1.57	18.62±0.23	-*	7.61±0.87	7.32±1.61
	140	-*	18.69±0.17	7.21±0.68	7.06±0.66	6.65±1.72
	150	-*	18.54±0.23	7.49±0.87	7.57±0.81	6.83±1.58
	160	-*	18.38±0.41	7.71±0.50	7.77±0.60	6.96±1.59
	180	-*	18.96±0.48	7.20±0.37	7.43±0.53	7.25±1.47
	200	-*	18.03±0.71	7.42±0.57	7.50±0.54	7.38±1.36
Cashew apple syrup	1.1	64.06±0.87	-*	-*	-*	-*
	17	64.01±1.28	25.71±0.15	8.55±0.43	3.39±0.22	2.91±0.10
	140	-*	25.97±0.40	7.60±0.56	3.11±0.11	2.87±0.09
	150	-*	25.54±0.10	8.29±0.30	2.99±0.27	2.62±0.26
	160	-*	25.49±0.19	8.81±0.31	3.38±0.07	2.74±0.21
	180	-*	25.71±0.06	8.43±0.16	3.51±0.12	2.90±0.30
	200	-*	25.54±0.26	8.76±0.27	3.37±0.31	3.17±0.45
Mango pulp	0.07	19581.00±1456.08	19067.25±2097.44	15189.80±1628.14	15526.00±3722.53	20186.00±4719.81
	0.09	14545.25±1130.97	13963.51±1622.39	11081.00±1545.28	12030.75±2695.19	14730.23±3297.71
	0.1	12701.25±1172.69	12407.25±1505.15	9703.00±1408.30	10245.75±2100.02	13043.25±2894.44
	1.1	2518.25±111.50	2064.25±197.39	1415.00±84.43	1516.75±116.66	1669.00±187.00
	17	-*	-*	286.15±10.92	312.20±9.28	-*
	140	-*	-*	-*	-*	-*

Note: *-Not received any viscosity at these shear rates and food products.

Table 2 Rheological parameters obtained by fitting the Shear stress-Shear rate data to the power law model

Sr.No. Product	Temperature /ºC	Consistency coefficient/K	Flow behavior index/n	Correlation coefficient/r^2
1 Kokum syrup	20	52.29	1.00	1
	30	6.727	0.998	1
	40	5.798	0.997	0.999
	50	4.217	0.985	0.943
	60	19.36	0.474	0.973
2 Karonda syrup	20	-*	-*	-
	30	18.74	0.996	0.999
	40	7.410	0.999	0.961
	50	7.657	0.993	0.998
	60	7.363	0.986	0.998
3 Cashew apple syrup	20	64.04	0.999	1
	30	25.79	0.998	0.999
	40	8.499	0.996	0.996
	50	3.396	0.989	0.995
	60	2.884	0.997	0.995
4 Mango pulp	20	868.7	0.284	0.960
	30	648.1	0.219	0.949
	40	629.0	0.281	0.946
	50	680.3	0.288	0.951
	60	451.3	0.116	0.891

Note: *-Not received any viscosity at these shear rates and food products.

Table 3 shows the effect of temperature on the consistency coefficient at a specific shear rate (0.021 s^{-1}) is generally expressed by Arrhenius relationship. A_o and E_a values of Kokum syrup, Karonda Syrup, Cashew apple syrup and Mango pulp were determined based on the Equation (4). The r^2 and χ^2 values are also given in the table. $r^2 \geq 0.67$ and $\chi^2 \geq 5.44$ shows that the Arrhenius relationship is well fit to the experimental data.

Table 3 Constants of Arrhenius equation determined for Kokum syrup, Karonda syrup, Cashew Apple syrup and Mango pulp at 20-60ºC

Sample	A_0	E_a	SE	R^2	χ^2
Kokum syrup	1.89E-09	59.37	13.32	0.67	532.629
Karonda syrup	3.3E-05	33132.32	3.30	0.77	21.849
Cashew apple Syrup	1.32E-11	71164.55	1.34	0.99	5.444
Mango pulp	13.91169	9965.68	88.33	0.73	23411.800

Figure 5 shows the plot of $Ln(K)$ versus 1/T for Kokum syrup, Karonda Syrup, Cashew apple syrup and

Mango pulp. It was observed that all these food materials obey a linear relationship. The relationship of *Ln*(*K*) versus 1/T for Kokum syrup, Karonda Syrup, Cashew apple syrup and Mango pulp is given in Table 4, i.e. Equation (5), Equation (6), Equation (7) and Equation (8).

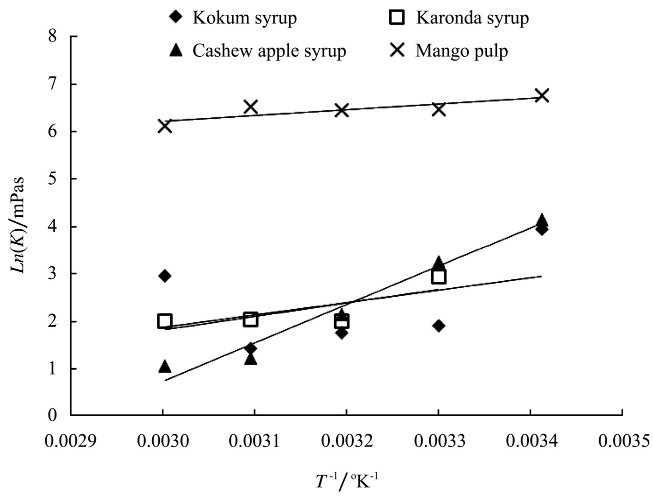

Figure 5 Relationship between *Ln*(*K*) and inverse of temperature (T^{-1})

Table 4 Equations for *Ln*(*K*) versus 1/T for food materials

Food Materials	Equations	R^2	Equation No.
Kokum syrup	$Ln(K)=\frac{2610}{T}+5.952$	0.61	(5)
Karonda syrup	$Ln(K)=\frac{2850}{T}+6.732$	0.62	(6)
Cashew apple syrup	$Ln(K)=\frac{8072}{T}+23.47$	0.96	(7)
Mango pulp	$Ln(K)=\frac{1226}{T}+2.537$	0.71	(8)

3.4 Effect of temperature on TSS of fruit products

The effect of temperature on the TSS of kokum, cashew apple, mango pulp and karonda syrup ranging from 20-60ºC is as shown in Figure 6. It was observed that the TSS of kokum, cashew apple, mango pulp and karonda syrup were decreased with increased in temperature from 20-60ºC. The TSS of kokum syrup were decreased from 16.7-15.7 ºBrix, for karonda syrup it was decreased from 18.87-17.85 ºBrix, for cashew apple syrup it was decreased from 15.5-14.66 ºBrix and for mango pulp it was decreased from 16.7-15.7 ºBrix from 20-60ºC.

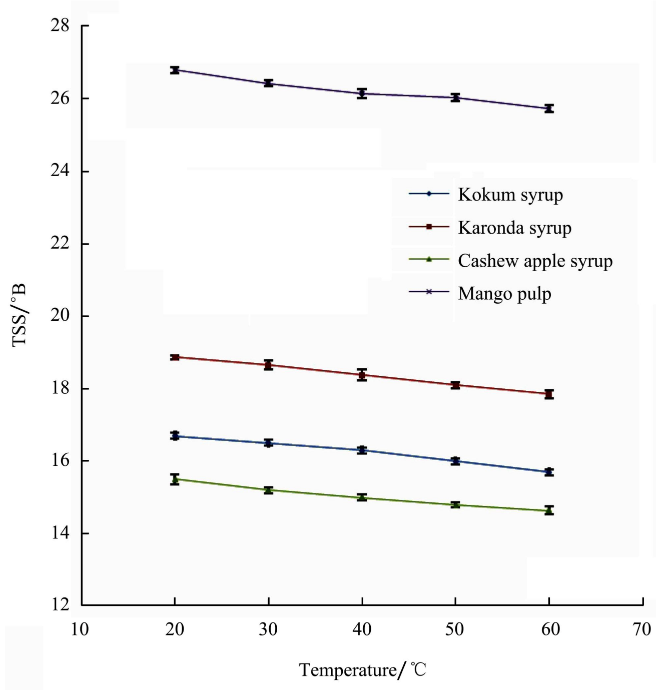

Figure 6 Effect of temperature on TSS of food samples

4 Conclusion

The viscosity of Kokum syrup, Karonda syrup, Cashew apple syrup and Mango pulp was decreased with increase in temperature. Kokum syrup, Karonda syrup, Cashew apple syrup and Mango pulp behaves as non-Newtonian, shear thinning fluid in temperature range of 20-60ºC and is successfully described by the power law model. The flow behavior index (dimensionless) decreased with increse in temperature, for kokum syrup it decreased from 1.00-0.474, for karonda syrup it was observed between 0.996-0.986, for cashew apple syrup it decreased from 0.999-0.989 and for mango pulp it was decreased from 0.28-0.11. Consistency coefficient was decreased with increased in temperature, for kokum syrup it was decreased from 52.29-4.21 Pas, for karonda syrup it was decreased from 18.74-7.36 Pas, for cashew apple syrup it was decreased from 64.04-2.88 Pas and for mango pulp it was decreased from 868.70-451.30 Pas respectively. TSS of kokum syrup decreased from 16.7 to 15.7 ºBrix, for karonda syrup it was decreased from 18.87 to 17.85 ºBrix, for cashew apple syrup it was decreased from 15.5 to 14.65 ºBrix and for mango pulp it was decreased from 26.8 to 25.73ºBrix with temperature range between 20ºC to 60ºC.

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