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Rheology of *Cassia Caronda*: Effect of Temperature &TSS

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ABSTRACT

Karonda fruit is having a greater demand in both national and international market for making jelly, chutney, squash, jam, syrup and tarts. Thermal preservation (blanching) is a most effective method for enhancing the shelf life of Cassia Caronda(karonda) fruit, the most commonly used technique for preservation. Steady state rheological properties of the puree were determined at various temperature levels (278,288 and 303K). The second part was to examine the impact of temperature and total soluble solids (TSS) on the rheological conduct of karonda puree. The estimations of consistency index (k) were in the range of 97.072–376.08Pa•s^n, which shows decrement with the increment in temperature. However, it shows increment value of K with an increase in TSS. The impact of temperature on k was depicted by Arrhenius model. The activation energy of K was in the range of 1.01-40.90 kJ/mol K. Karonda puree showed shear thinning conduct and Power law display best-flow behavior. Apparent viscosity(η_{100}) values at a shear rate of 100 s^{-1} show a decrease trends with an increase in temperature. For the food processing sector, it is important to characterize the flow behavior during the transportation and processing operation of liquid food and flow conduct parameters are characterized as a set of parameters demonstrating the food quality indexes. The relationship of temperature and TSS of karonda on the rheological conduct of karonda puree was resolved to create a scientific model for anticipating the change of flow conduct during the process.

Keywords: Karonda, TSS, temperature, flow behavior index, consistency index

1. INTRODUCTION

karonda fruit is the species of flowering shrub in the dogbane family, found grown in wild in India, Malaysia, South Africa. It is native to the Indian subcontinent, Myanmar, Malacca,Sri Lanka and it was introduced in java where it runs wild. In India, it grows in Bihar, WestBengal, Maharashtra, Karnataka and other states. The fruits are used for pickle making because of its sour and astringent test. It is produced berry sized used for Jam, Jelly, Squash, Syrup, Chatney and Indian spices etc.The karonda fruit product is a rich source of iron and contains an adequate amount of Vitamin C, iron, calcium, phosphorus, minerals required for adequate health[1].Young fruits are pinkish white and get to be distinctly red to dark purple during the month of august to September when it was ripe. The color of ripe fruits varies from white, green and pinkish red depending on the genotype. For vegetable purposes fruits are harvested at the immature form, consumed and processed once it rich ripen stage. It is the best solution for biliousness and helpful for the cure of anemia. Traditionally it is prescribed for enhance female libido and to remove worms from the intestinal tract. The fruits have hostile to microbial and anti fungal properties and its juice used to clean old injuries, which have turned out to be infected. The fruit has a pain relieving activity and in addition a hostile to inflammatory one. The juice can be applied to the skin to assuage any skin issues. Generally, karonda has been utilized to treat anorexia and madness. Traditional healers of Chhattisgarh have skill in the treatment of various sorts of the tumor from karonda. They utilize its distinctive plant parts to dress the malignant injuries and to kill the maggots.

So rheological study on this fruits is having greater importance for the processing sector and it provides information on how to control the flow properties during design, development, and evaluation of process equipment. Although a large number of rheological data are available on different fruits and vegetable [2] but there is no literature available on rheological studies on varying temperatures range from (5-45c) and Brix content(4-8).It is could be used for jam, syrup, jelly and chutney preparation. A ready karonda is sweet, consumable and especially appropriate for tarts, puddings, and jams. The fruit is sharp and astringent and utilized for pickles. Besides preserving, the fresh fruits can be cooked as vegetables and used in place of cherry for the decoration of sweets and pastries.The present studies mainly focused to investigate the physicochemical and rheological characteristic of karonda puree of karonda fruit.

2. MATERIALS AND METHODS

2.1.Preparation of puree

Karonda fruits were obtained from the market and washed completely with water, de-stemmed and ready for experimentation in 2 h. If the sample were not utilized, then stored at 277K for further use. The yield of the fruit product after de-steaming is 65-70%. A known amount of fruit was submerged in an excess of water and subjected to blanching in the separate blanching media for 4 min to inactivate the enzyme present in the fruit. Adequacy and time of blanching were dictated by peroxidase inactivity test. Once the blanching is over, the fruit was promptly cooled to room temperature (301K) by placing in cold water. The fruit was comminuted into a puree using blender processor at 298K for 15 min. The puree was passed through a 14-work screen to get consistency. After the crushing, the puree was diluted with a proper quantity of distilling water to get an intermittent range of brick samples(4,5.5,7,8.5 ^{0}Brix) having various solid content of purees for rheological examination.

2.2.Physicochemical analysis of puree

The moisture content, Titratable acidity, and ascorbic acid were determined by titration method as mentioned[3]. While pH and TSS of the samples were verified using Digital pH meter(Systronics, India) and refractometer according to the manual instruction of apparatus. Three grams of sample was weighed in a crucible and heated in a muffle furnace at 550°C for 30 min. and cooled in desiccators. The ash content was calculated using the following equation [4]. Three grams of the test sample was weighed in a crucible and warmed in a muffle furnace at 550°C for 30 min and cooled in desiccators. The ash content was computed utilizing the below equation.

$$\text{Ash content(g/100g sample)} = \frac{\text{Weight of Ash}}{\text{Weight of sample taken}} * 100$$

2.3. Measurement of total soluble solids (TSS)

Total soluble solids (TSS) contents in karonda fruit pulp were determined with the help of Erma hand Refractometer(Make: Atago, Japan). As per manual instruction of the refractometer the prism was cleaned with the assistance of tissue paper and distilled water. A plastic spoon was used to placed 0.3-0.5 mL of the sample on the prism to avoid the damage on the prism screen. The equipment calibrated and gives its reading with-in a few seconds. Average out the readings after four replication experiment performed for each temperature. Care was taken that the Refractometer was washed with distilled water and wiped dry before every reading.

2.4. Determination of steady-state measurements

To find out the changes in rheological behavior a modular compact Rheometer MCR 102 (Anton Paar, GmbH, Germany) was used for the rheological test. All the test were conducted by using a four-bladed vane geometry ST22-4V-40 by precisely brought down vertically into the specimen container by 10 mm from the surface level [5]. After insemination, 35 ml of sample was poured into the Rheometer cup having test volume of 40ml. The temperature of the cup having sample was maintained at 303K. As the vast majority of the green vegetable, puree demonstrates non-Newtonian conduct because of the complex cell structure and communication between the particles. The analysis was performed at 1–100 s^{-1} shear rate range and its gives 100 data point for 300s of shearing at an interval of 3s.The measurements were replicated thrice at each temperature level range (5º, 15º, 30º). New samples were taken with applicable care for every experimentation to avoid the consequences of aging and to stay from high shear rate throughout sample loading.The rheological estimations were investigated utilizing the Rheoplus software package of AntonPaar GmbH.All the rheological estimations were tired triplicate according to given methodology [6]. Therefore, non-Newtonian models from equation 2-5 were considered for their stability in describing the flow. Before the sample is subjected to three cycle shear run from 0 to 100/s, steady state shear at 100/s for 5 min followed by

back to 0/s in next 5 min the spindle and filled sample cup were temperatures equilibrated. The rheograms were evaluated by the software (Rheoplus)using the power law model.
The experimental values of shear stress and shear rate were fitted to the following rheological models:

Power Law $\tau = K(\gamma)^n$

Herschel-Bulkley $\tau^{0.5} = \tau_0 + K(\gamma)^n$

Where: τ = Shear Stress (Pa)

γ = Shear rate (s-1)

K = Consistency index (Pa.s)

n = Behavior índex (dimensionless).

τ_0 =Initial shear stress (Pa)

The temperature dependence of the apparent viscosity at constant shear rate and consistency index can be described by the Arrhenius model:

$$\eta = A_\eta \exp\left(E_n / RT_a\right)$$

$$K = A_k \exp\left(E_k / RT_a\right)$$

Where η = apparent viscosity (Pa.s),

A_η = frequency factors for apparent viscosity at constant r.p.m(Pa.s)

A_k =consistency index (Pa.s^n)

E_n =activation energies for apparent viscosity at constant r.p.m(KJ mol^{-1})

E_k = consistency index (KJ mol^{-1})

T_a = absolute temperature (K)

R = universal gas constant (8.314 J mol^{-1} K).

3. RESULTS AND DISCUSSION

3.1. Physio-chemical characteristics

The moisture content of the fresh fruit was about 80%, which falls to 79% after blanching and draining which plays an important role in the growth and activities of plants. Since the karonda fruit are full of water, and the blanching was taken in a large volume of water so there is no significant loss in moisture. The sample was ground at a room temperature, so there was no chance of evaporation, the moisture content was remained 79% (wet basis).

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The total ash content determination was that of fruit sample analyzed (2.52%). The high ash content is a reflection of mineral contents preserved in the fruit materials and hence the reduction suggests a decline in overall mineral nutrients within the fruit tissues.

Table 1 Chemical constituents of karonda fruits

Parameter	Quantity
Moisture(%)	80.25±1.81
Ph	3.6
Ash content (%)	2.52±0.12
Titrable acidity(%)	0.62

Table 2 Parameters of the power law model fitted to the data of karonda puree

Brix (%)	Rheological parameters	278K	288K	303K
4	n	0.0926	0.157	0.163
	K	97.072	71.990	23.269
	R^2	1	1	1
	η_{100}	2.98	1.05	0.549
5.5	n	0.0467	0.0499	0.099
	K	244.87	241.413	160.583
	R^2	1	1	1
	η_{100}	3.7	3.07	1.96
7	n	0.0338	0.0567	0.038
	K	346.88	333.063	340.293
	R^2	1	0.999	0.999
	η_{100}	4.2	3.5	3.59
8.5	n	0.0342	0.0350	0.0349
	K	376.08	374.583	363.0778
	R^2	1	0.999	0.999
	η_{100}	4.64	4.32	4.24

Table 3 Rheological parameters of Herschel Buckley model

Brix (%)	Rheological parameters	278K	288K	303K
4	K	16.82836	81.27528	2.47E-04
	n	0.43544	0.048	2.44711
	R^2	0.998	0.992	0.999
	τ_0	69.12808	-10.347	37.14862
5.5	K	25.3832	11962.95	123.845
	n	0.22135	0.0012	0.11939
	R^2	0.999	0.999	0.999
	τ_0	234.4546	-11725.6	39.0487
7	K	20601.23	20951.74	16386.15
	n	4.68E-04	0.00111	7.70E-04
	R^2	0.999	0.998	0.999
	τ_0	-20243.8	-20626.6	-16039.5
8.5	K	3.38751	14275.24	63.26635
	n	0.696	0.00104	0.13814
	R^2			
	τ_0	387.833	-13903.7	307.3143

Table 4 Consistency index (K) and activation energy (E_a) values of karonda puree at different solid content and temperatures

Brix (%)	Rheological parameters	278K	288K	303K
4	Activation Energy(E_a)(KJ/mol)	40.90		
	r	0.95		
5.5	Activation Energy(E_a)(KJ/mol)	12.30		
	r	0.85		
7	Activation Energy(E_a)(KJ/mol)	11.37		
	r	0.89		
8.5	Activation Energy(E_a)(KJ/mol)	1.01		
	r	0.89		

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3.2. Rheological studies on purees

3.2.1. Effect of flow behavior on total soluble solid in puree

Tables 2 shows the parameters for the rheological models (Power Law) at the temperatures of 278K, 288K, 303K. The model of Ostwald-de-Waelle fit satisfactorily at all temperatures examined, with values for the coefficient of determination (R^2) greater than 0.97.The values of the flow behavior index (n) found for Ostwald-de-Waelle model were below the value of one (n <1), featuring thus a pseudoplastic behavior. The value of the behavior index (n) indicates the degree of pseudoplastic for fruit juices and pulps and that the further away that meet the unit, the greater the pseudo-plasticity of the product [7]. This behavior is best seen in Figure (2-4), where it can be noted that the slope of the curves decreases with increasing strain rates, which implies in a decrease in the viscosity when strain rate increases.

The degree of pseudo-plasticity mainly depends on upon flow behavior index (n) and consistency index (K). K value of puree decreases with different Brix content in % (4,5.5,7,8.5) except in case puree having 7% Brix value as temperature was raised from 278 to 303 K. However in the present work n value increases in all above total soluble solids of puree and the value is less than 1 which refer to shear thinning behavior but in case of puree having 7 ^{0}brix, n value decrease from 0.0567 to 0.038 with increase in temperature from 278 to 303 K. Rocket leave puree was found to have n between 0.04-0.2 [8] and Aloe Vera have n between 0.16-0.25 [9]. This is the behavior of common food materials such as purees and pastes, which have a large number of particles in the dispersion. The reason of shear thinning behavior is due to the complicated interaction of the particles in dispersion with each other.

At lower Brix value, molecules are separated from each other and freely move. With increase concentration, the molecules touch each other and for an entangled network because molecules force them to interpenetrate one another. Therefore, there is an increase of viscosity, which make the puree much steeper, and at the same time, the viscosity becomes more shear rate dependent.

Fig. 3 shows the flow curves (shear stress vs. shear rate) of different range of temperatures of purees at a fixed brix value. All of the purees presented a shear thinning behavior and they were not time dependant (non-thixotropy), which is consistent with earlier studies on apple puree [10] and other fruit purees [11,12].

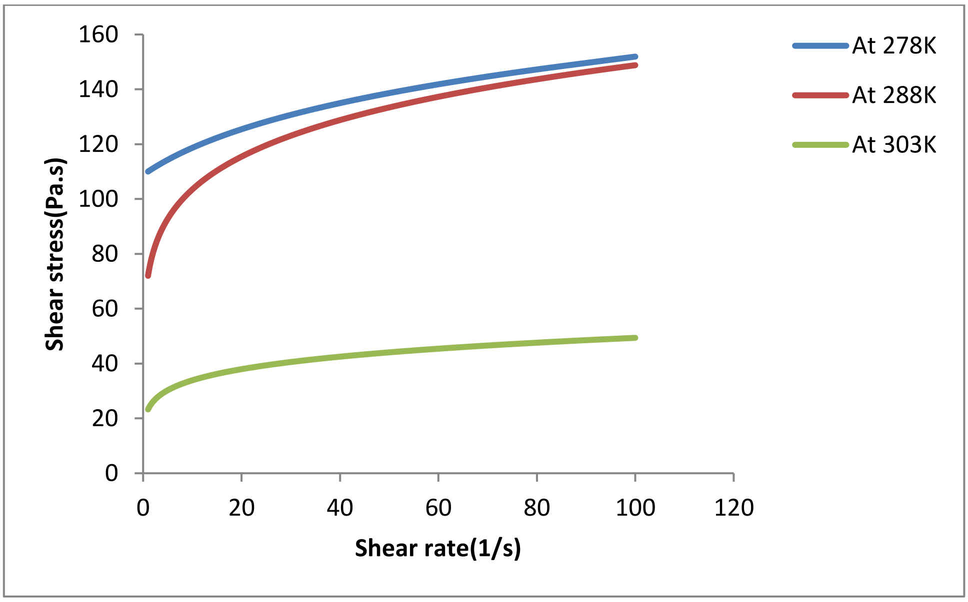

Figure.1 Shear stress vs. shear rate for the 4 ^{0}brix of karonda puree at various temperatures (T=278K-303K)

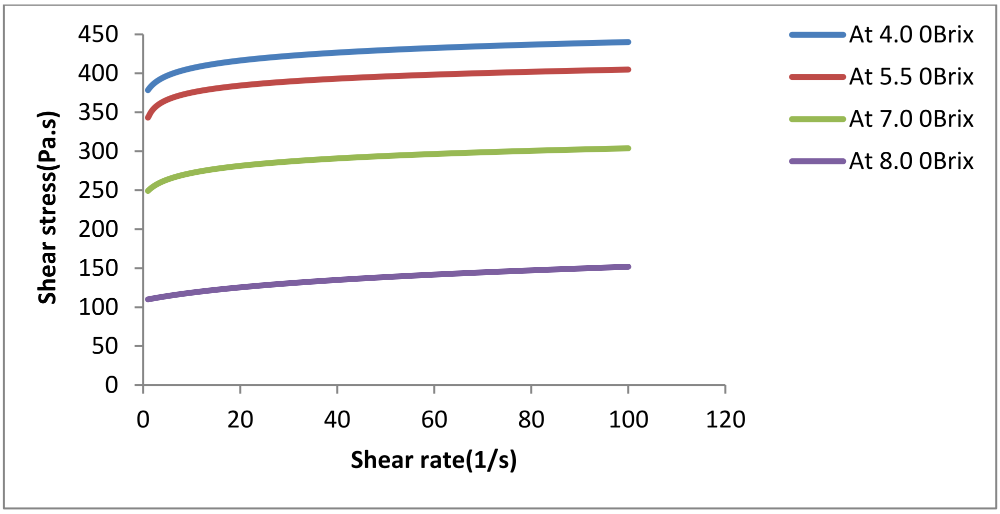

Figure.2 Rheogram for the various TSS value (4- 8.5 ^{0}brix) of karonda puree at temperatures of 278K

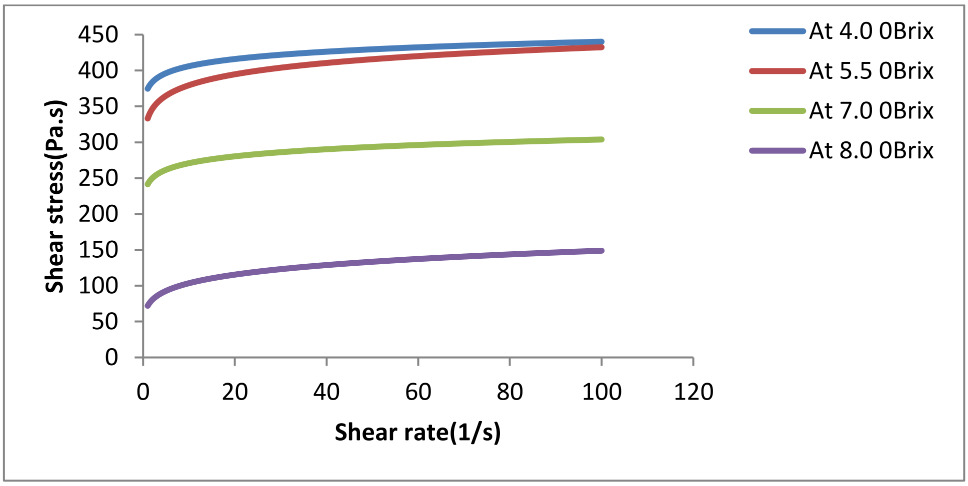

Figure.3 Rheogram for the various TSS value (4- 8.5 ^{0}brix) of karonda puree at temperatures of 278K

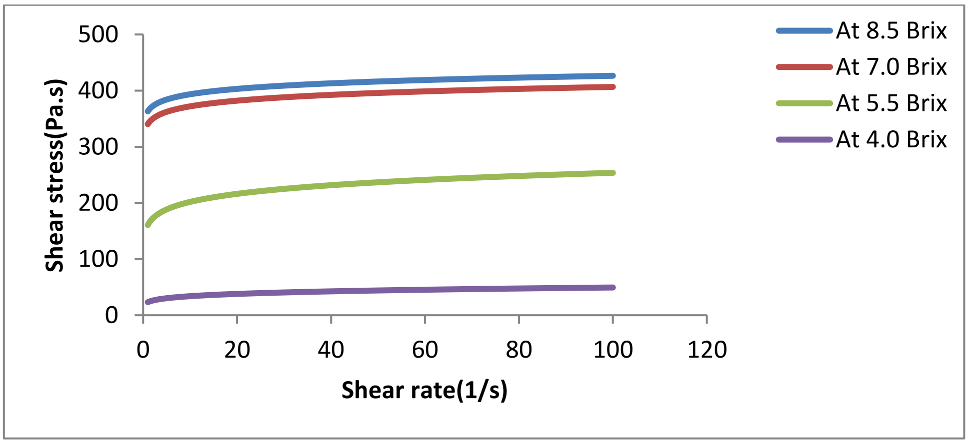

Figure.4 Rheogram for the various TSS value (4- 8.5 ^{0}brix) of karonda puree at temperatures of 278K

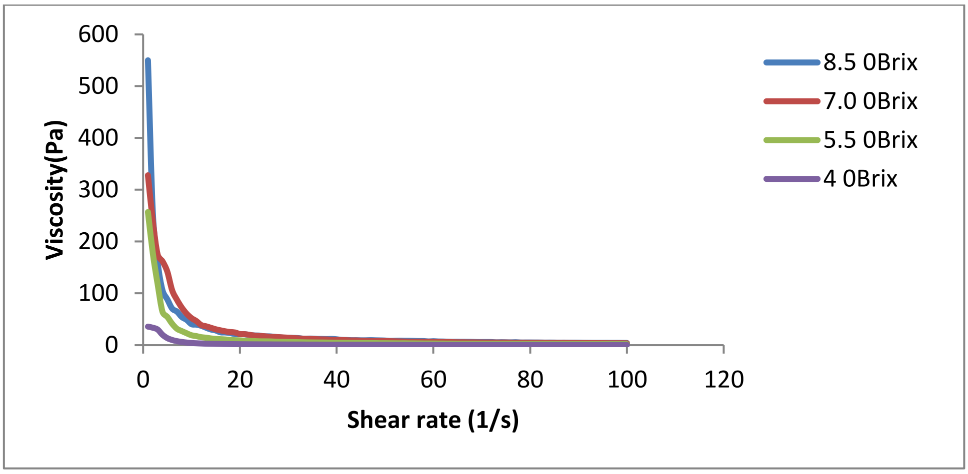

Figure.4 Rheogram for the various TSS value (4- 8.5 ^{0}brix) of karonda puree at temperatures of 303K

3.2.2. Rheological behavior of different concentrated puree with increasing temperature

Viscosity is a good index for Newtonian fluids, however, for non-Newtonian fluids, it cannot describe the changes as it is unpredictable, particularly for fluids like pastes and purees. On the other hand, Study of rheology is important as it helps in the modification of the processing condition to have products of better quality [2]. By grinding, viscosity decreased as well as the shear thinning behavior (n increased). Higher solid content causing a higher hindrance to the flow than the lower content due to its high viscosity. From tests made prior to rheological measurements was found that the puree of 8.5 % solid content was unstable due to its high sedimentation rate, and its rheological behavior was not so good. However the rheological measurements made at below 4 ^{0}brix value of solid content puree showed no adequate reliability to determine its flow behavior because of presented Taylor vortex, hence the concentrations of the puree(4 to 8.5^{0}brix) used for rheological study at constant ramped in shear rate from 1/s to 100/s. It showed an initial decrease of viscosity and afterward, it showed a constant value. The initial decrease of viscosity was attributed to an irreversible deflocculating[13]. The viscosity-shear rate curves of different concentrated puree were similar and the behavior was shear thinning. Viscosity decreased little when the shear rate increased and the flow became Newtonian. This is the characteristic of pseudoplastic fluids, which have been observed in our viscosity-shear rate diagrams.

3.2.3. Effect of temperature on rheological parameters

The rheological parameters of karonda puree were analyzed and fitted to Power Law models, noting that power law model was more appropriate to describe the rheological behavior of karonda puree in the ranges of temperatures and solid content The values of consistency indexes, K determined by the power law decreased with the increasing in temperature during the studying of clarified orange juice[14]. The graph of shear stress vs. strain rate obtained for the karonda puree with increasing temperatures of 278K, 288K, 303K and their respective adjustment by the model of Ostwald-de-Waelle is shown in Figure 2-4. The nonlinearity between shear stress and shear rate applied for the show a non-Newtonian behavior with slopes of flow curves decrease with increasing strain rate Moreover; it appears a decrease in viscosity with increasing strain rate and confirming the pseudoplastic behavior of the karonda puree. Generally, a decrease trends of viscosity due to increased intermolecular distances [15]. With the increase of temperature is seen in the case of for fruit juices and pulps [16]. Also reported similar behavior in his work on cranberry and concentrated juices [17].

4. CONCLUSION

Blanching was performed at a temperature of 363K for duration of 5 min to inactivate the microorganisms present in fruit puree. The rheology of blanched puree is studied by steady shear tests. The puree is found to exhibit power-law flow behavior with R^2 value greater than 0.97 as the temperature was raised from 301 - 333 K). Consistency index(K) value of puree decreases from 97.07 to 23.26 and flow behavior index(n) was found to vary from 0.092 to 0.163 as the temperature was raised from 278 to 303K for 4 ^{0}brix value. Similar types of trends also observed in other Brix value of the puree. Karonda fruit puree showed shear thinning behavior. Ostwald-de Waele model best described the flow behavior. The fluidity of the sample increased with increase in temperature, suggesting that storage and consumption temperature should be considered in order to achieve desired quality. The studied on karonda fruit purees apparent viscosity and its non-Newtonian behavior is influenced by the design and development of processing equipment because it decreases with the temperature and increases with the TSS content.

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