International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 365-374 www.ijaem.net ISSN: 2395-5252

Determination of Rheological Properties of Bombax Costatum

Ikerave A.F., Irtwange S.V., Ahemen S.A.
Akperan orshi college of agriculture, yandev, gboko, nigeria
Federal university of agriculture, makurdi, nigeria
Benue sstate university, centre for food technology and research, makurdi, nigeria

Submitted: 25-01-2022 Revised: 05-02-2022 Accepted: 08-02-2022

ABSTRACT
Bombax Costatum belongs to the family Bombacaceae with Bombax as genus name, and is commonly called red flower, silk cotton tree or red kapok tree. In Nigeria, it is locally known as Kurya or Gujjiya in Hausa, Kutupkaci in Nupe and Genger in Tiv. It is a deciduous tree growing straight up to about 30m tall and 1m diameter and does well on stony soil. It is a plant little cultivated but protected by local people for many uses as food, medicine and other economic importance. It is common in Savannah Zones of West Africa and Central African Republic. Its calyx are collected, processed and reconstituted into slurry for production of soup and thickener. The soup produced from the slurry is popularly called genger by the Tiv people of Nigeria. Flow behavior index and flow consistency index of Bombax costatum prepared in three samples were determined at four temperature levels of 30°C,40°C,50°C and 60°C and four levels of shear rate 6,12,30 and 60rpm using the Brookfield viscometer. The flow behavior index was obtained to lie between 0.280 and 0.308 while the flow consistency index lied between 35.280 and 47.140. The effect of temperature on viscosity of samples was investigated and found that viscosity for all samples, decreased with increase in temperature within temperature range of 30°C and 60°C. This confirms that Bombax costatum exhibits shear thinning and is pseudoplastic in nature. The experimental design used for the study is Completely Randomized Design (CRD) using SPSS. Regression analysis was also done for all linearly related properties.

Key words: Rheology, Bombax costatum, Pseudoplastic, flow consistency index flow behavior index and viscosity.

I. INTRODUCTION

Bombax costatum is a deciduous, open savannah woodland tree; it is a species from the Bombaceae family with bombax as Genus name. Bombax costatum is common in the savanna zones of West Africa and Central Africa Republic. It is 3 – 30m high and up to 1m in girth and does well on stony soils (Gernnah and Gbakaan,2013). It produces flowers from November to February and then fruits from February to June. During Hamattan season (from November to March) when most crops are harvested, the flowers become loosened from the stalk and fall freely with little blow of wind (Tingir, 2003). The petals are detached from the calyx which is then dried and ground into powder and stored for reconstitution into soup. Because of the ability of the powder to form a gel when mixed with water, it can be classified as a food gum. Food gums are high molecular weight polymeric compounds, mostly carbohydrates which are characterized by their ability to give highly viscous solution at low concentration (Muhammad et, al 2017). Traditionally foods such as pounded yam and cereals moulded foods are eaten along with slimming soups such as okra, ewedu, ogbono, okoho, ager and stews that are prepared to facilitate the movement of food along the digestive track. One additional of such very popular soups in Nigeria is Genger which is produced from the flowers of the plant Bombax costatum both in fresh and dry form, which is the focus of this study. Bombax costatum in Tiv land is a delicacy with high viscosity or gelling capacity from November to March. During the wet season, from April to October, Genger does not gel at all because it losses its viscosity and when this happens, it becomes inedible and wasteful. Due to wide acceptability and popularity of the soup, the need to produce data that will aid its handling, processing and storage is gaining prominence. Rheological parameters such as flow behaviour index and flow consistency index of Bombax costatum are of paramount interest. This study is therefore aimed at investigating the rheological properties of Bombax costatum for the purpose of achieving quality of finished product. Measurement of viscosity is often very important for quality control, particularly on products that we expect to be of a particular consistency (Mkavga, 2004).

A number of food processing operations depend heavily, upon rheological properties of the product because this has a profound effect upon the quality of the finished product (Satimehin et. al, 2003). For fluid foods, viscosity is a widely used rheological parameter and its relationship with shear rate has been used to classify food into Newtonian and non-Newtonian with distinguished subclasses such as plasticity, pseudoplastic, dilatant, Bingham and Bingham pseudoplatic (Sopade and Cassumu, 1992). The relationship between the stress (i) required to induce a given rate of shear (dv/dr) defines the rheological behaviour of a fluid. For a Newtonian fluid, the shear stress is directly proportional to the rate of shear (Akinremi, 1999).

The term viscosity can only be correctly applied to such fluids where the shear stress required to induce flow is directly proportional to the rate of shear. For fluids that deviate from this behaviour, the term "apparent viscosity" is used as an index of fluid consistency. Instruments used for evaluating the flow characteristics of fluids are called viscometers.

The specific objectives of the study is to determine the flow behavior index and flow consistency index of Bombax costatum, and to investigate the effect of temperature and share rate on viscosity of Bombax costatum

II. MATERIALS AND METHODS

This study was conducted on three samples of Bombax costatum (wet, fairly dried and fully dried) obtained from Yandev Community of Gboko Local Government Area of Benue State, Nigeria. Flowers were collected from a chosen tree as they dropped without the influence of any human activity. Petals were manually detached using hands while the calyx were reserved for the study. These samples were studied at the moisture contents of 82%wb, 28%wb and 10%wb respectively in order to investigate the effect of varying moisture content on Viscosity of Bombax costatum. These materials were pounded and sieved with sieve of 0.25mm aperture to achieve uniform particle size. Equal volume of distilled water was used along witha equal mass of sample to form slurries for the three samples. Temperatures at all experiments were measured using the mercury in glass thermometer graduated in degree celcius ($^\circ$C). The thermometer head was always positioned to keep contact with the body to be measured. Samples were always stirred for even distribution of heat during measurements. The moisture content (percent wet basis) was measured by oven-air method. Apparatus such as electronic weighing balance, crucibles, oven (gallencarp) and thermometer were used to carry out the experiment, while Equation (2) as reported by Akinremi(1999) was used for the calculation of moisture content.

$$\text{Moisture content} = \frac{\text{weight of sample } (w_s) - \text{constant weight } (w_c)}{\text{weight of sample } (w_s)} *100\% \ldots..(1)$$

Bulk densities of the test samples at 82%wb,28%wb and 10%wb were determined using the tapping method. Equation 2 as reported by Gernnah and Gbakaan, (2013) was used.

$$\text{Density} = \frac{\text{mass (g)}}{\text{volume } (\text{cm}^3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Flow behavior index and flow consistency index of <u>Bombax</u> <u>costatum</u> were determined using the method reported by Gonap,(2000)

$$\tau = K\gamma^n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where:

τ= Shear stress
K= Flow consistency index
γ = Shear rate
n = Flow behaviour index

For non-newtonian fluids equation 4 was used

$$\tau = K\gamma^{(n-1)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$\log\tau = \log k + (n-1)\log\gamma \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Gonap, (2000)

The experiment was conducted at four temperature levels (30°C, 40°C, 50°C and 60°C) using four selectable speeds (6, 12, 30 and 60 rpm) of the Brookfield viscometer. Slurries were reconstituted for the three samples using same volume of distilled water and mass of sample across the three samples and treated one after the other. Each sample was heated above the required temperature level in a calorimeter cup on a hot plate and cooled to the desired temperature, while being monitored with a thermometer. The slurry just enough to cover the immersion groove of the spindle shaft was immediately transferred into the viscometer cup already maintained at the corresponding temperature level in a water bath. The apparatus was energized with the viscometer guard leg on and viscosity readings were taken.

These were replicated three times at the interval of two minutes each.

Conversion factor = Viscoreading x 10^{-3}(NS/M^2)

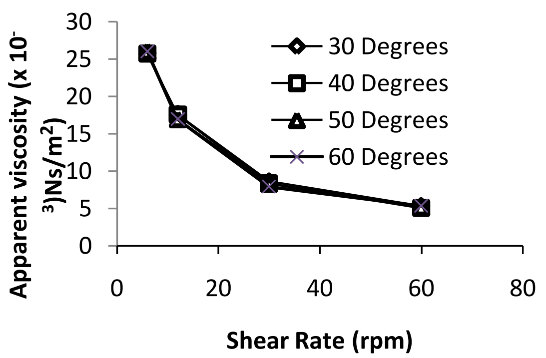
Experimental Design and Statistical Analysis:

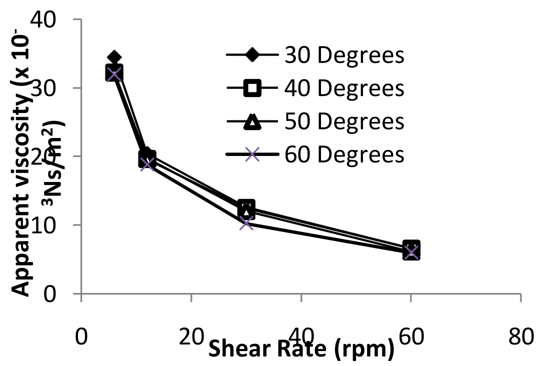
Analysis was done for 3 - sample level, 4-shear rates and 4-temperature levels as one experimental design (i.e. 3 x 4 x 4) in CRD using SPS. The least square means were separated by LSD. Linear regression analysis was also carried out for all linearly related properties.

III. RESULTS

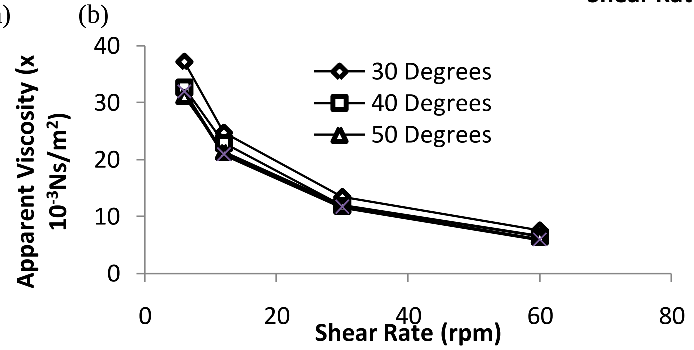
Table 1: Temperature (^{0}C) and corresponding apparent viscosity (NS/M^2) versus share rate (rpm) of Bombax costatum samples.

Sample	ShearRate (RPM)	Temperature (^{0}C) and corresponding viscosity			
		30	40	50	60
82%wb	6	25.807	25.730	25.990	26.060
(wet)	12	17.441	17.562	17.948	16.964
	30	8.600	8.355	8.331	7.903
	60	5.293	5.060	5.180	5.347
28%wb	6	34.483	32.183	32.33	31.953
(fairly dried)	12	20.442	19.625	19.726	18.783
	30	12.648	12.474	12.054	10.265
	60	6.643	6.610	6.160	5.993
10%wb	6	37.217	32.697	31.187	31.943
(fully dried)	12	24.726	22.474	21.383	20.93
	30	13.432	11.912	11.976	11.95
	60	7.543	6.480	6.563	5.950





(a) (b)

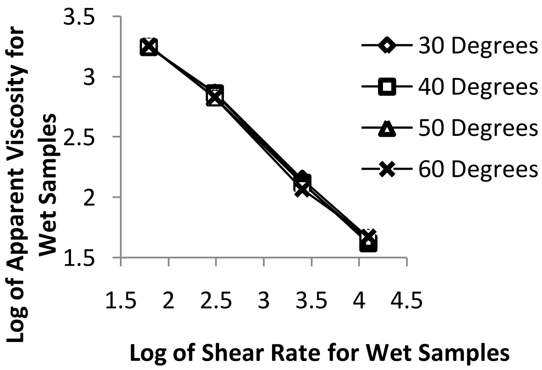


(c)

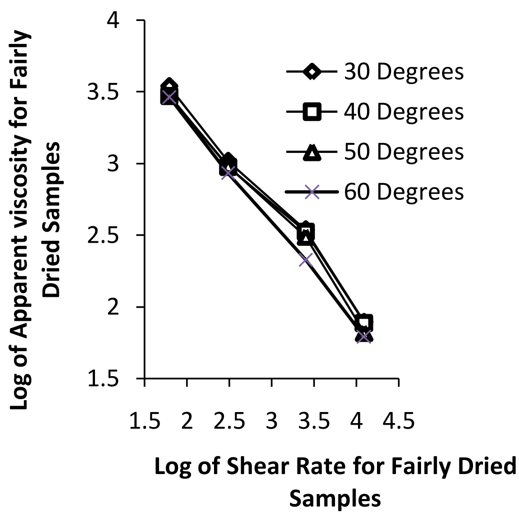
Fig 1: Effect of shear rate on viscosity of Bombax costatum at (a) 82%wb,(b) 28%wb and (c) 10%wb for different temperature levels

TABLE 2: Results Obtained from Plot of a viscosity Versus Shear Rate For all Samples of Bombax Costatum

Sample(M.C%wb)	Temperature	Regression Eqn.	Standard Dev.	R^2	Standard Error
82	30	Y = -0.34 x + 23.61	9.26	0.81	4.63
	40	Y = -0.35 x + 23.54	9.34	0.81	4.67
	50	Y = -0.34 x + 23.28	9.35	0.77	4.68
	60	Y = -0.34 x + 23.45	9.42	0.79	4.71
Av			9.34	0.80	4.67
28	30	Y= -0.44x + 29.23	12.03	0.81	6.01
	40	Y=-0.41x+ 29.00	11.01	0.79	5.51
	50	Y= -.42x0 +28.72	11.3	0.81	5.65
	60	Y= -0.41x +28.01	11.45	0.80	5.72
Av			11.45	0 .80	5.72
10	30	Y = -0.49x+ 33.94	13.05	0.82	6.53
	40	Y = -0.44x +30.47	11.68	0.85	5.84
	50	Y = -0.41x +28.85	10.84	0.84	5.42
	60	Y = -0.43x + 29.16	11.36	0.83	5.68
Av			11.73	0.84	5.86

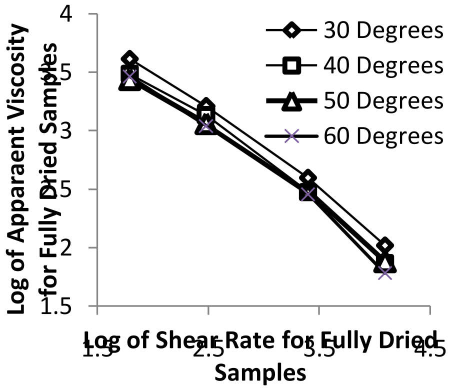


(a) Wet sample (10%wb)



(b)Fairly dried sample (28%wb)

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 365-374 www.ijaem.net ISSN: 2395-5252



(c) Fully dried sample (82%wb)

Fig 2: Plot of log of apparent viscosity against log of share rate for the three samples.

Table 3 Results obtained from the regression analysis performed on plot of log of viscosity versus log of share rate at varying temperature across samples.

Sample	(M.C%wb)	Temperature	Regression Eqn.	n	K	R^2	Power Law
	82	30	Y = -0.70 x + 1.56	0.30	36.31	0.99	$\tau = 36.31\gamma^{0.30}$
		40	Y =- 0.72x + 9.51	0.28	35.48	0.99	$\tau = 35.48\gamma^{0.28}$
		50	Y = -0.71x + 1.56	0.29	34.67	0.99	$\tau = 34.67\gamma^{0.29}$
		60	Y = -0.71x + 1.54	0.29	34.67	0.99	$\tau = 34.67\gamma^{0.29}$
	Av			0.29	35.28	0.99	
	28	30	Y = -0.69x + 1.68	0.31	47.86	0.98	$\tau = 47.86\gamma^{0.31}$
		40	Y = -0.66x + 1.67	0.34	46.77	0.99	$\tau = 46.77\gamma^{0.34}$
		50	Y = -0.70x + 1.65	0.30	44.67	0.99	$\tau = 44.67\gamma^{0.30}$
		60	Y = -0.72x + 1.64	0.28	43.65	0.99	$\tau = 43.65\gamma^{0.28}$
	Av			0.31	45.74	0.99	
	10	30	Y = -0.69x + 1.70	0.31	50.12	0.99	$\tau = 50.12\gamma^{0.31}$
		40	Y = -0.70x + 1.68	0.30	47.86	0.99	$\tau = 47.86\gamma^{0.30}$
		50	Y = -0.67x + 1.65	0.33	41.67	0.98	$\tau = 44.67\gamma^{0.33}$
		60	Y = -0.72x + 1.64	0.28	45.91	0.99	$\tau = 45.91\gamma^{0.28}$
	Av			0.31	46.39	0.99	

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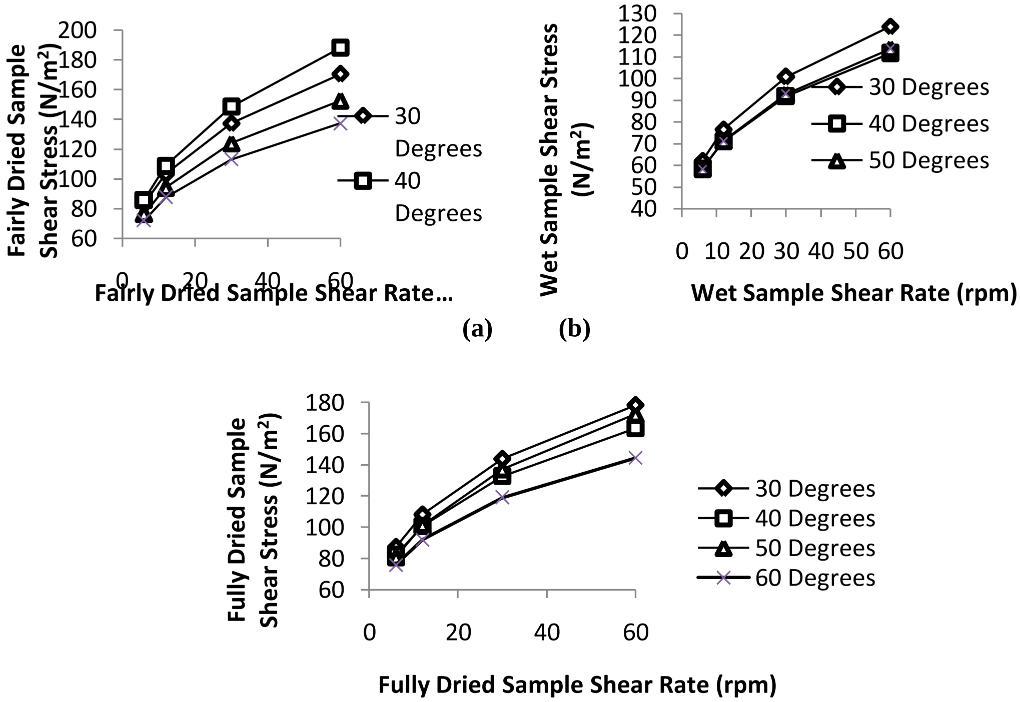
TABLE 4: The Effect of Moisture Content and Temperature of the Samples on calculated Shear Stress at Varying Shear Rates

		Shear Rate			
Samples(MC%wb)	Temp. (°C)	6	12	30	60
82	30	62.154	65.201	100.731	124.014
	40	58.596	71.147	91.955	111.652
	50	58.293	71.272	92.965	113.663
	60	58.293	71.212	92.965	113.663
28	30	83.406	103.400	137.366	170.294
	40	86.008	108.865	148.658	188.165
	50	76.465	94.139	123.923	152.567
	60	72.089	87.532	113.131	137.362
10	30	87.345	108.282	143.853	178.336
	40	81.925	100.861	132.773	163.462
	50	80.687	101.425	137.235	172.507
	60	75.821	92.061	118.987	144.474



(a) (b)

(c)

Fig 3: Effect of shear stress on shear rate of bombax costatum samples at (a) 82%wb,(b)28%wb and(c)10%wb moisture contents at different temperature levels

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TABLE 5: Result of Plot of Shear Stress Against Shear Rate for Samples of Bombax Costatum

Sample (MC%wb)	Tem (°C)	Linear regression	R^2
82	30	y = 61.13 + 1.10x	0.96
	40	y = 59.25 + 0.96x	0.96
	50	y = 61.14 + 1.04x	0.96
	60	y = 60.18 + 1.03x	0.95
28	30	y = 81.84 + 1.55x	0.96
	40	y = 83.70 + 1.82x	0.96
	50	y = 75.21 + 1.35x	0.96
	60	y = 71.22 + 1.16x	0.96
10	30	y = 85.70 + 1.62x	0.96
	40	y = 80.59 + 1.45x	0.96
	50	y = 75.91 + 1.45x	0.96
	60	y = 74.58 + 1.21x	0.96

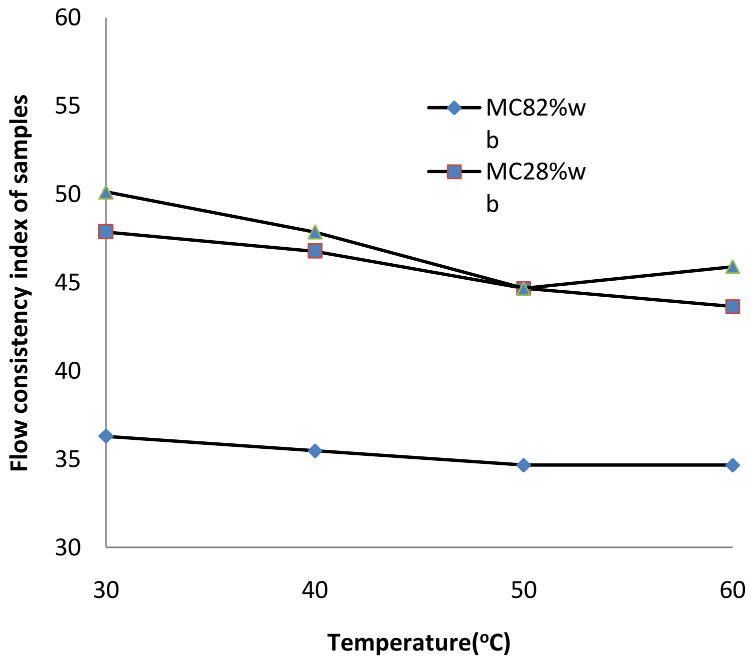

Fig4: Plot of flow consistency index versus temperature of samples at varying moisture contents.

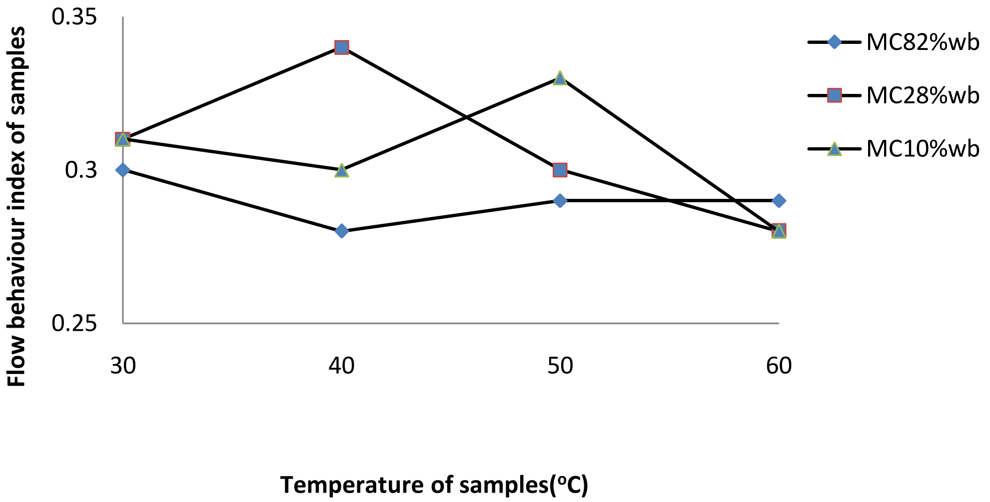

Fig 5:Plot of flow behaviour index versus temperature of samples at varying moisture

TABLE 6: Results Obtained from Plot Of Consistency Index and Flow Behaviour Index VS Temperature for Samples of Bombax Costatum

Plot	Sample(MC%wb)	Regression equation	R^2
Consistency index vs temp	82	$y = -0.057x + 37.86$	0.89
	28	$y = -0.147x + 52.36$	0.98
	10	$y = -0.158x + 54.25$	0.74
Flow behavior index vs temp	82	$y = -0.000x + 0.29$	0.10
	28	$y = -0.001x + 0.37$	0.45
	10	$y = -0.000x + 0.33$	0.14

TABLE 7: Anova to Investigate the Effect of Varying Shear Rate on Viscosity of Genger Across all Samples Considered at 5% Level of Significance.

		Sum of sq	df	mean	F	Sig
Wet Sample App. viscosity $X10^{-3}NS/m^2$	**Between groups**	**1047.091**	**3**	**349.030**	**5292.692**	**0.00**
	Within groups	**0.791**	**12**	**0.660**		
	Total	**1047.882**	**15**			
Fairly dried sample App. Viscosity $X10^{-3}NS/m^2$	**Between groups**	**1571.114**	**3**	**523.705**	**667.314**	**0.00**
	Within groups	**9.418**	**12**	**0.785**		
	Total	**1580.531**	**15**			
Fully dried sample App. Viscosity $X10^{-3}NS/M^2$	**Between groups**	**1654.449**	**3**	**551.483**	**194.111**	**0.00**
	Within groups	**34.093**	**12**	**2.841**		
	Total	**1688.542**	**15**			

Table 8: Average Bulk density of Bombax costatum samples

Smple	Bulk Density(kg/m^3)
Wet (82 %wb)	688
Fairly dried (28%wb)	586
Fully dried (10%wb)	516

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 365-374 www.ijaem.net ISSN: 2395-5252

IV. DISCUSSION

Table 1 shows the average results of Apparent Viscosity against shear rate at different temperatures and moisture contents. It can be seen that all samples followed the same rheological pattern. Alkali et,al (2009) and Alobo and Arueya,(2017) reported that chemical composition affects rheological behaviour of food materials. The similarity in the rheological behaviour of all the samples is therefore not surprising, since they all have the same chemical composition, though there were variations in their moisture contents.

From Figure 1, it can be seen further that viscosity decreased with increased in shear rate. This phenomenon is called shear thinning effects and it is the characteristic behaviour of pseudoplastic fluids, the phenomena has been reported to be widely common with most hydrocolloidal solutions and food pastes with sensitive structure Gernnah and Gbakaan, (2013). This may be due to increased alignment of the fluid molecules in the flow direction which resulted to reduced resistance to flow and, hence, reduced viscosity. Table 2 presents regression analysis for fig 1. Figure 5 also revealed that apparent viscosity as indicated by consistency index decreased with increasing temperature. Similar trends were observed by Alakali and Ijabo, 2003 for tomato pastes, Alakali et al., (2001) for canarium oil and Satimehin et al., (2003) for palm oil. The observed increasing temperature resulting to decreasing viscosity can be attributed to increase in molecular kinetic energy brought about by increased temperature, which hasten alignment of molecules in the flow direction. The trend has been reported for many food materials in literature (Sopade and Kasumu, 1992, Satimehin et al (2003) and Abubakar and Barminas, (2017).

The log-log relationship between apparent viscosity and shear rate for the three Bombax costatum samples is shown in Figure 2. This demonstrates the application of power law equation especially on linearization by least square regression as shown in Table 3. Mean flow behaviour index for the three samples ranged from 0.280 to 0.305 with standard deviation ranging from 0.003 to 0.021 and mean consistency index between 35.282 and 47.140 with standard deviation ranging from ±0.784 to ±2.381. The model is appropriate ($R^2 \geq 0.98$) in describing the rheological behaviour of Bombax costatum. It can also be noted that the flow behaviour index(n) for Bombax costatum has not been affected by change in temperature (Figure 4 and table 6). Similar findings have also been reported by Alakali et al (2009), Sopade and Kassumu (1992). The implication of this is that temperature does not affect the pseudoplastic characteristic of Bombax costatum.

Table 4, figure 3, and table 5 revealed that shear stress of all samples increased with increased in shear rate at a given temperature ($R^2 \geq 0.95$). Comparing the shear stress – shear rate relationship with the classification chart shown by Mohsenin (1986), it was further confirmed that Bombax costatum is non-newtonian.

Varying shear rate and viscosity at fixed temperature ($p>0.05$), analysis of variance presented a significant effect at all temperatures across samples as can be seen in Table 7. The significant effect noticed in varying shear rate and viscosity of samples also confirms the results in Figure 1, which shows that the flow consistency index of samples at moisture contents of 82%wb, 28%wb and 10%wb are different and affected by level of shear rate and percentage of moisture, with 82%wb highest, followed by 28%wb and lastly 10%wb sample. However flow behavior index and temperature of samples did not produce any defined pattern as can be seen in Figure 3.

Table 8 presents bulk density of wet, fairly dried and fully dried samples to be 688kg/m^3, 586 kg/m^3 and 516 kg/m^3 respectively.

PRACTICAL APPLICATION

The results obtained in this work would be useful in flow system analysis and in the processing of this product and it will constitute essential data for the design of process and equipment for industrial application involving the flow of Bombax Costatum. Knowledge of the flow behaviour index (n) and the consistency index (k) of Bombax Costatum is important for efficient design and accurate simulation of its momentum transfer processes and systems. Specifically in solving transport and pumping problems of Bombax costatum, the generalized Reynoid equation and Bernoulli Equation can be applied using the results obtained in this work.

V. CONCLUSIONS

The following conclusions are made:

(a) Apparent viscosity decreased with increasing shear rate indicating shear thinning behaviour.
(b) The flow behaviour index did not show major change with temperature and it values were generally below +1, hence Bombax costatum can be said to exhibit pseudoplastic behaviour and is non-newtonian.

(c) Both apparent viscosity and consistency index of Bombax costatum were found to decrease with increasing temperature indicating that it varies with temperature according to Arrhenius relationship.

REFERENCES

[1]. Abubakar U.D and J.T Baminars (2017). Evaluation of Bombax Costatum calyx hydrogel as a otential insuline delivery system, British journal of Appliedl science and Tech. 20(6). 1-9, http://www.sciencedomain.org/review-history/19013.

[2]. Akinremi ,O. M. (1999). Determination of the Thermal and rheological properties of palm oil relevant to processing: Unpublished M.Eng. Thesis submitted to the Department of Agricultural Engineering, University of Agriculture Makurdi.

[3]. Alakali ,J.S., Ijabo O.J. and Satimehin A.A. (2001) Rheological characterization of oil. Journal of Sustainable Tropical Agricultural Research. Treasure publishers, Nigeria volume 5, pp. 57 – 58

[4]. Alakali, J. S. and Ijiabo O. J. (2003). Effect of Processing methods on the viscosity, PH, and Colour of Tomato Pastes. Journal of Sustainable tropical Agricultural Research. Treasure Publishers Vol. 2 pp 220 – 233.

[5]. Alakali, J. S., Irtwange S. V. and Mkavga M. (2009). Rheological characteristics of food gum (cissus polunea) African Journal of Food Science Vol. 3 (9): 237 – 242.

[6]. Alobo A. P. and Arueya G. L. (2017): Physical, functional and chemical properties of Grewia venusta (ururu) mucilage extract. International food research Journal 24(5): 2107-2115.

[7]. Gernah D.I and P. Gbakaan (2013): Effect of potassium carbonate (K_2CO_3) on the viscosity and related physic-chemical properties of Genger (Bombax Costatum) conrrent research in Nutrition and food science. Vol 1 (1), 77-82.

[8]. Gonap, P. K. (2000). Some Physical and Engineering properties of Canarium Oil. Preceding of the first International Conference and Millennium General Meeting of the Nigerian Institution of Agricultural Engineers. Vol. 22, PP. 52 – 53.

[9]. important soup material of middle belt states of Nigeria. Unpublished thesis Department of Food Science and Technology University of Agriculture Makurdi.

[10]. Mkavga, M. (2004). Rheological Characteristics of cissus populnea (Okoho). Unpublished B. Eng. Thesis, Agricultural Engineering Department University of Agriculture Makurdi Eng.

[11]. Mohsenin, N. (1986). Physical properties of plants and animals materials vol. 1. Structure, Muhammad Z. H., A. A. Ambi, A. Ahmed and E. A. Ayeni (2017): Pharmaceutical standardization of Bombax costatum pellegr and vuillet stem bark (Bombacaceae): Nigeria Journal of pharmaceutical sciences vol.16.No2. P61-67. physical characterization and mechanical properties. Science publishers West Port NY Pp. 899 – 900. pure applied science 6(2): 291 – 297.

[12]. Satimehin, A. A., Akinremi O. M. and Ijabo O. J. (2003). Rheological behaviour of palm oil. J. semi-liquid foods, Kunumzaki and Kunun Gyada. Nigeria Food Journal 10: 23 – 33

[13]. Sopade, P. A.and Kassumu A. J. (1992). Rheological characteristics of Nigerian liquid and

[14]. Tingir, J. N. (2003). Proximate Composition and Functional Properties of Bombax Costatum) an

[15]. Toledo, R. T. (1980). Fundamentals of Food Process Engineering. AV I Publishing Company, West Port Comm. Pp. 226.