Effect of Potassium Carbonate on the Viscosity of Stored Bombax Costatum

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Abstract— **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 calyxes were sun dried to 5.5%wb and reserved for the study. The dried samples were pounded and sieved using sieve of 0.25mm aperture to achieve uniform particle size. 100ml of distilled water was used along with 10g of sample to form slurries of average consistency for all viscosity experiments. Potassium carbonate was reduced into powder and sieved. Dosages of potassium carbonate preservative were computed as percentage of Bombax costatum sample (0%, 3%, 6%, 9%) in grams and blended with the sample, which was package into ceramic, metal, plastic and glass containers and hermitically stored at room temperature, for nine months. The viscosity of samples was determined using the Brookfield viscometer. The result showed that viscosity of Bombax costatum at 5.5%wb decreases with increase in potassium carbonate, with 0% sample presenting the best performance. The result also showed that all containers performed effectively. Both metal and glass recorded 92% performance efficiency. Metal container was rated above glass due to its low coefficient of variation, compared to glass. Plastic and ceramic presented 90% and 87% performance efficiencies respectively, with control exhibiting the least performance efficiency of 36%. Room temperature and relative humidity of the stored environment were recorded throughout the storage duration**

***Index Terms*— Bombax costatum, Potassium carbonate, viscosity and containers**

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,2003). 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.

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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 parameter such as viscosity of *Bombax costatum* is of paramount interest. This study is therefore aimed at investigating the viscosity 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).

It is no longer news that *Bombax Costatum* calyx which is the target of this study losses its viscosity immediately rain sets in, rendering the stored produce useless. The control of this menace through storage is intended. The broad objective of this study is to control viscosity loss of *Bombax costatum* through hermitic storage, and the study is specifically aimed at checking the effect of varying the concentration of potassium carbonates on the viscosity of stored *Bombax costatum* calyx. Potassium carbonate (K_2CO_3) also known as potash or pearl ash is a white salt, soluble in water (insoluble in ethanol), which forms a strongly alkaline solution. Potassium carbonate is used in reactions to maintain anhydrous conditions without reacting with the reactants and product formed. It may also be used to dry some ketones, alcohols, and amines prior to distillation. All carbonated salts are on the FDA generally regarded as safe list. There is no evidence in the available information on calcium carbonate, potassium carbonate, potassium bicarbonate, sodium carbonate, sodium bicarbonate, or sodium sesquicarbonate that demonstrates or suggests reasonable grounds to suspect a hazard to the public when used at normal levels that are now current or that might reasonably be expected in the future (Gernnah and Gbakaan,2013).

MATERIALS AND METHODS

This study was conducted on *Bombax costatum* calyx 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 calyxes were sun dried to 5.5%wb and reserved for the study. The dried samples were pounded and sieved using sieve of 0.25mm aperture to achieve uniform particle size. 100ml of distilled water was used along with 10g of sample to form slurries of average consistency for all viscosity experiments. The potassium carbonate used for the study was obtained from the Gboko main market and ground into powder. Dosages of the preservative were computed as percentage of *Bombax costatum* sample (0%, 3%, 6%, 9%) in grams and blended with the sample, which was package into ceramic, metal, plastic and glass containers.

Quantities and methods of Determination

(b) Moisture Content of *Bombax costatum* Samples

The moisture content (percent wet basis) was determined by air-oven drying method. Wet basis which is expressed in a lot of literature is mostly used by farmers. Apparatus such as electronic weighing balance, crucibles, oven (gallencarp) and thermometer were used to carry out the experiments, while Equations 1 was used for the calculation of moisture content.

$$Moisture\ content(\%) = \frac{weight\ of\ water}{weight\ of initial\ sample} * 100 \quad (1)$$

Akinremi(1999).

(a) Temperature and relative humidity

Temperature at all experiments was 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 relative humidity of both the storage environment and the ambient environment were measured with a hygrometer graduated in percentage.

(d) Viscosity

The viscosity of *Bombax costatum* was determined with the aid of a Brookfield viscometer at selected speed and spindle size of four and five respectively, along with; electric hotplate, beaker, thermometer, distilled water and ice park. The experiment was based on the power law equation presented as equation 2

$$\mu = K\gamma^{n} \quad (2)$$

Where:

μ= apparent viscosity
K= Flow consistency index
γ = Shear rate
n = Flow behaviour index
Gonap (2000)

The experiment was conducted at Room Temperature. Slurries of average consistency were reconstituted across all samples using same volume (100ml) of distilled water and mass (10g) and treated one after the other. The apparatus was energized and viscosity readings were taken. With the aid of spindle and speed indicators, the correct spindle size and speed for the experiment was achieved with ease. Readings were replicated three times at interval of two minutes, using the same spindle and speed, but different portions of the *Bombax costatum* sample.

Storage of *Bombax costatum* samples

Treated samples of *Bombax costatum* were stored hermitically in Metal, Plastic, Ceramic, Glass and Control containers for a period of nine months (Jan 2020 to September 2020). Containers were adequately filled and tapped in order to close up all possible air spaces that could aid microbes to survive in containers and cause damage to the stored material. The viscosity of *Bombax costatum* was determined monthly during the nine months of storage. A wooden cupboard inside the laboratory was used for the storage to provide adequate protection of samples from moisture, excessive heat and animals or insects attack. Temperature and Relative humidity of the storage environment were monitored during storage. Both storage and experiments were conducted at the Advanced Bio-chemistry laboratory of the Benue state University Makurdi. Both performance efficiencies and viscosity losses of containers were calculated using equations 3 and 4

$$Container\ Efficiency\ (\%) = \frac{Output\ viscosity}{input\ viscosity} x100 \quad (3)$$

$$Viscosity\ loss\ (\%) = \frac{Initial\ viscosity - Final\ viscosity}{Inital\ viscosity} x100 \quad (4)$$

To investigate the viscosity of dry sample stored in five different containers (Metal, plastic, ceramic, glass and control) and treated with four dosages of potassium carbonate and control for nine months. 5-containers, 5-treatments and 5-temperature levels were involved. RCBD was used for the experiment. The analysis was done for 5 - containers, 5-treatments and 5-temperature levels as one experimental design (i.e.5 x 5 x 5) in RCBD using SPSS.

RESULTS

Table 1: Average Viscosity of *Bombax costatum* calyx treated with different concentrations of $K_2CO_3$and Stored in Ceramic Containers and control for nine months, and determined at RT degrees Celsius

Month	Potassium carbonate (K_2CO_3 (%)) Treatments and corresponding viscosities(cp)				
	0	3	6	9	Control

Jan.	63481	56340	50115	42817	63481
Feb.	58132	63447	63109	32773	58572
March	50146	43161	42880	29416	47017
April	60148	53199	57309	54130	53524
May	57413	59661	54930	41194	45791
June	53029	47114	44950	40001	33192
July	54270	46050	45480	39110	30673
Aug.	54465	46087	46030	22205	30543
Sept.	55557	50773	46010	29104	23217
Loss (%)	12.48	9.88	8.19	32.03	63.43
Reference value	63481.00	63481.00	63481.00	63481.00	63481.00
SD	8113.97	13416.29	14875.82	28176.63	24511.06
COV	0.1278	0.2113	0.2343	0.4439	0.3861
Max.	63481.00	63447.00	63109.00	54130.00	63481.00
Min.	50146.00	43161.00	42880.00	22205.00	23217.00

Table 2:Average Viscosity of *Bombax costatum* calyx treated with different concentrations of $K_2CO_3$and Stored in Metal Containers and control for nine months, and determined at RT degrees Celsius

Month	Potassium carbonate (K_2CO_3 (%)) Treatments and corresponding viscosities(cp)				Control
	0	3	6	9	
Jan.	63481	53640	50115	42817	63481
Feb.	78011	35632	49150	42591	58572
March	52181	38730	44761	40864	47017
April	62467	55129	46091	39660	53524
May	61047	53008	45651	37143	45791
June	52970	47150	43551	40007	33192
July	53530	47020	40048	38370	30673
Aug.	55488	52524	40046	30494	30543
Sept.	58263	54125	40374	24135	23217
Loss (%)	8.22	-0.90	19.44	43.63	63.43
Reference value	63481.00	63481.00	63481.00	63481.00	63481.00
SD	8474.68	16362.97	19391.38	26778.71	24511.06
CV	0.1335	0.2578	0.3055	0.4218	0.3861
Max.	78011.00	55129.00	50115.00	42817.00	63481.00
Min.	52181.00	35632.00	40046.00	24135.00	23217.00

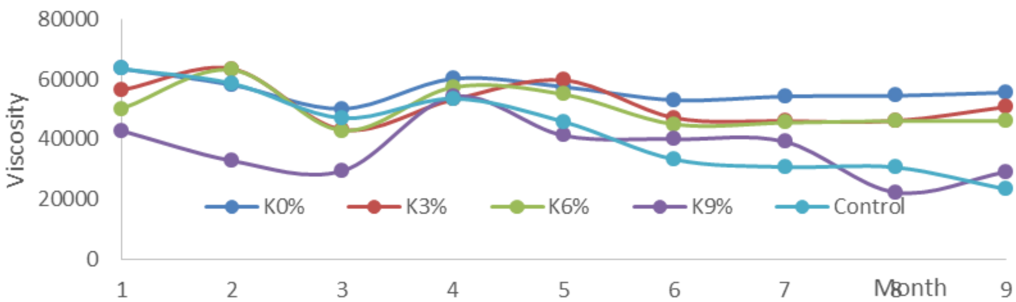
Table 3:Average Viscosity of *Bombax costatum* calyx treated with different concentrations of $K_2CO_3$and Stored in Plastic Containers and controlfor nine months, and determined at RT degrees Celsius

Month	Potassium carbonate (K_2CO_3 (%)) Treatments and corresponding viscosities(cp)				Control
	0	3	6	9	
Jan.	63481	53640	50115	42817	63481
Feb.	76541	63068	49150	25784	58572
March	60857	49816	44761	30714	47017
April	58188	55110	46091	53620	53524

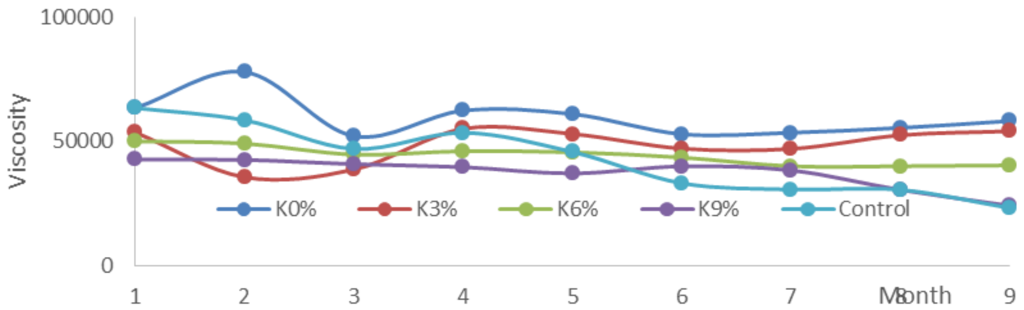
May	56172	54148	45651	48511	45791
June	55701	60185	43551	38272	33192
July	55195	56295	40048	35220	30673
Aug.	55269	52589	40046	37933	30543
Sept.	57643	53933	40374	20280	23217
Loss (%)	9.20	0.55	19.44	52.64	63.43
Reference value	63481.00	63481.00	63481.00	63481.00	63481.00
SD	7375.57	8902.11	19391.38	28276.98	24511.06
CV	0.1162	0.1402	0.3055	0.4454	0.3861
Max.	76541.00	63068.00	50115.00	53620.00	63481.00
Min.	55195.00	49816.00	40046.00	20280.00	23217.00

Table 4:Average Viscosity of *Bombax costatum* calyx treated with different concentrations of $K_2CO_3$and Stored in Glass Containers and control for nine months, and determined at RT degrees Celsius

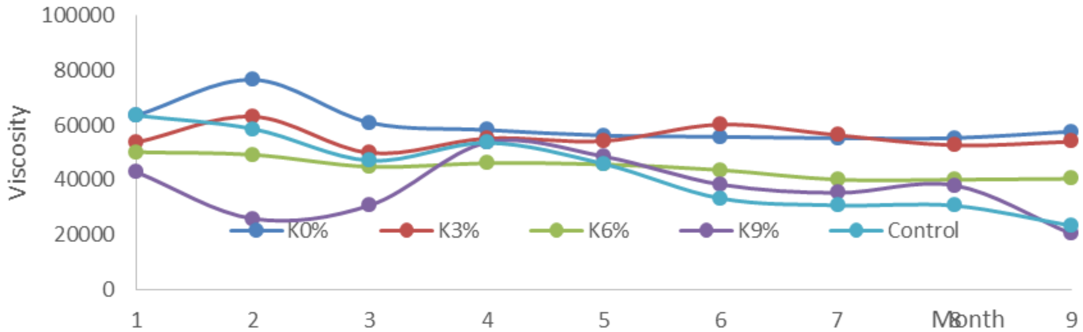
Month	Potassium carbonate (K_2CO_3 (%)) Treatments and corresponding viscosities(cp)				Control
	0	3	6	9	
Jan.	63481	53640	50115	42817	63481
Feb.	59534	63554	44172	33013	58572
March	51793	43091	40085	30130	47017
April	58553	56215	45145	39713	53524
May	56170	56326	44665	37747	45791
June	40132	50749	42071	35194	33192
July	51080	50045	40730	38770	30673
Aug.	56864	49406	40574	30743	30543
Sept.	58548	55570	44259	20420	23217
Loss (%)	7.77	3.40	11.69	52.31	63.43
Reference value	63481.00	63481.00	63481.00	63481.00	63481.00
SD	10525.12	11642.41	20164.11	29872.99	24511.06
COV	0.1658	0.1833	0.3176	0.4706	0.3861
Max.	63481.00	63554.00	50115.00	42817.00	63481.00
Min.	40132.00	43091.00	40085.00	20420.00	23217.00



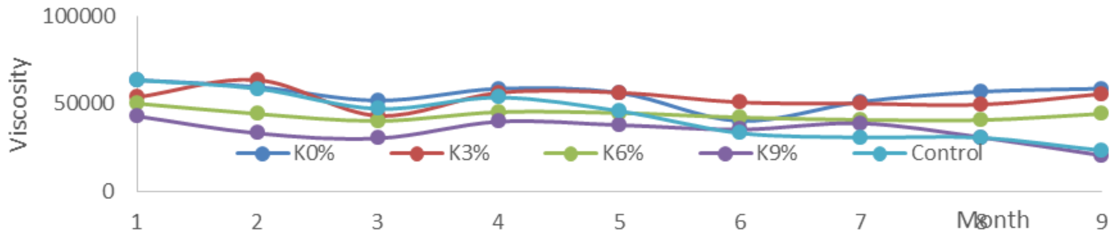
A (ceramic)



B (metal)



C plastic



D (glass)

Fig 1: Plot of viscosity against time to check the effect of varying K_2CO_3concentration on viscosity of *Bombax costatum* calyx stored in (a) ceramic, (b) metal, (c) plastic, (d) glass and control for nine months, determined at RT degree celsius

Table 5: Calculated performance efficiencies (%) of storage containers from viscosity readings at different levels of K_2CO_3 and temperature

Temperature(^{0}C)	K_2CO_3(%)	Ceramic	Metal	Plastic	Glass	Control
20	0	87.13	97.22	84.90	90.62	32.33
	3	92.89	108.40	93.30	82.00	32.33
	6	76.39	91.73	81.27	77.59	32.33
	9	73.08	58.07	65.87	66.69	32.33
RT	0	87.52	91.78	90.80	92.23	36.57
	3	90.12	100.91	100.54	103.60	36.57
	6	91.81	92.54	99.85	88.31	36.57
	9	67.97	56.37	47.36	47.69	36.57
40	0	98.98	112.36	101.18	102.02	38.39
	3	80.36	74.45	82.60	78.75	38.39
	6	83.46	91.51	90.47	80.34	38.39
	9	50.06	39.44	56.60	50.33	38.39
60	0	91.47	88.39	106.24	100.46	30.64
	3	68.36	73.60	73.15	79.13	30.64
	6	58.65	62.24	58.20	58.34	30.64
	9	41.44	34.04	34.59	36.92	30.64
80	0	105.05	87.14	84.57	99.24	34.42
	3	92.24	110.50	95.02	97.27	34.42
	6	73.06	65.60	75.87	66.76	34.42
	9	116.64	147.84	113.43	140.64	34.42

Table 6: Viscosity-losses or gains (%) across containers and treatments due to storage across temperature levels

Temp	K_2CO_3	Ceramic	Metal	Plastic	Glass	Control
20	0	12.87	2.78	15.10	9.38	67.67
	3	7.11	-8.40	6.70	18.00	67.67
	6	23.61	8.27	18.73	22.41	67.67
	9	26.92	41.93	34.13	33.31	67.67
RT(30)	0	12.48	8.22	9.20	7.77	63.43
	3	9.88	3.93	4.27	1.37	63.43
	6	8.19	7.46	0.15	11.69	63.43
	9	32.03	43.63	52.64	52.31	63.43
40	0	1.02	-12.36	-1.18	-2.02	61.61
	3	19.61	25.55	17.40	21.25	61.61
	6	16.54	8.49	9.53	19.66	61.61
	9	49.94	60.56	43.40	49.67	61.61
60	0	8.53	11.61	-6.24	0.46	69.36
	3	31.64	26.40	26.83	20.87	69.36
	6	41.35	37.76	41.80	41.66	69.36
	9	58.56	65.96	65.41	63.08	69.36
80	0	-5.05	12.85	15.43	0.76	64.58
	3	7.76	-10.50	4.98	2.73	64.58
	6	26.94	34.40	24.13	33.24	64.58
	9	-16.84	-47.84	-13.43	-40.64	64.58

Table 7: Coefficient of Variations of containers across treatments and temperatures

Temperature	K_2CO_3	Ceramic	Metal	Plastic	Glass	Contorl
20	0	0.097	0.071	0.153	0.159	0.480
	3	0.178	0.174	0.214	0.296	0.480
	6	0.254	0.208	0.276	0.280	0.480
	9	0.486	0.491	0.588	0.530	0.480
RT(30)	0	0.134	0.116	0.166	0.128	0.386
	3	0.211	0.258	0.140	0.183	0.386
	6	0.234	0.306	0.200	0.308	0.386
	9	0.444	0.422	0.446	0.471	0.386
40	0	0.163	0.156	0.130	0.081	0.352
	3	0.207	0.215	0.167	0.201	0.352
	6	0.158	0.084	0.163	0.138	0.352
	9	0.374	0.362	0.331	0.316	0.352
60	0	0.058	0.107	0.098	0.080	0.333
	3	0.160	0.217	0.225	0.153	0.333
	6	0.247	0.164	0.181	0.274	0.333
	9	0.346	0.461	0.366	0.374	0.333
80	0	0.441	0.234	0.172	0.178	0.342
	3	0.201	0.232	0.168	0.126	0.342
	6	0.189	0.221	0.262	0.293	0.342
	9	0.361	0.354	0.271	0.326	0.342

Table 8: Mean separation values of Viscosity data to investigate the effect of varying Dosages of K2CO3 with viscosity of treated dry Bombax costatum sample before storage, using the Least Significance Difference (LSD).

Dependent Variable: Viscosity						
					95% Confidence Interval for Difference[b]	
(I) K2CO3	(J) K2CO3	Mean Difference (I-J)	Std. Error	p-value	Lower Bound	Upper Bound
K2CO3 0	K2CO3 3	5371.500*	2186.178	.036	426.022	10316.978
	K2CO3 6	9511.500*	2186.178	.002	4566.022	14456.978
	K2CO3 9	14336.000*	2186.178	.000	9390.522	19281.478
K2CO3 3	K2CO3 0	-5371.500*	2186.178	.036	-10316.978	-426.022
	K2CO3 6	4140.000	2186.178	.091	-805.478	9085.478
	K2CO3 9	8964.500*	2186.178	.003	4019.022	13909.978
K2CO3 6	K2CO3 0	-9511.500*	2186.178	.002	-14456.978	-4566.022

	K2CO3 3	-4140.000	2186.178	.091	-9085.478	805.478
	K2CO3 9	4824.500	2186.178	.055	-120.978	9769.978
K2CO3 9	K2CO3 0	-14336.000*	2186.178	.000	-19281.478	-9390.522
	K2CO3 3	-8964.500*	2186.178	.003	-13909.978	-4019.022
	K2CO3 6	-4824.500	2186.178	.055	-9769.978	120.978

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

Table 9: Descriptive Statistics on viscosity of dry *Bombax costatum* samples treated with four dosages of K_2CO_3 and stored in five different Containers for nine months

Dependent Variable: Viscosity					
Container	K_2CO_3	Mean	Std. Deviation	CV	N
Ceramics 1	K2CO3 0	56293.44	3993.429	0.0709	9
	K2CO3 3	51759.11	6922.321	0.1337	9
	K2CO3 6	50090.33	6872.230	0.1372	9
	K2CO3 9	36750.00	9449.756	0.2571	9
	Total	48723.22	10012.704	0.2055	36
Metals 2	K2CO3 0	59715.33	8052.642	0.1349	9
	K2CO3 3	48550.89	7102.345	0.1463	9
	K2CO3 6	45087.44	3500.714	0.0776	9
	K2CO3 9	37342.33	6172.761	0.1653	9
	Total	47674.00	10223.135	0.2144	36
Plastic 3	K2CO3 0	59894.11	6835.566	0.1141	9
	K2CO3 3	55420.44	4007.427	0.0723	9
	K2CO3 6	51355.22	3949.088	0.0769	9
	K2CO3 9	37016.78	10565.807	0.2854	9
	Total	50921.64	10913.461	0.2143	36
Glass 4	K2CO3 0	55128.33	6792.463	0.1232	9
	K2CO3 3	53177.33	5749.142	0.1081	9
	K2CO3 6	43535.11	3138.007	0.0721	9
	K2CO3 9	34283.00	6697.491	0.1954	9
	Total	46530.94	10092.203	0.2169	36
Controls 5	K2CO3 0	42890.00	14103.306	0.3288	9
	K2CO3 3	42890.00	14103.306	0.3288	9
	K2CO3 6	42890.00	14103.306	0.3288	9
	K2CO3 9	42890.00	14103.306	0.3288	9
	Total	42890.00	13485.340	3.1805	36
Total	K2CO3 0	54784.24	10367.263	0.1892	45
	K2CO3 3	50359.56	9073.198	0.1802	45
	K2CO3 6	46591.62	7995.428	0.1716	45
	K2CO3 9	37656.42	9797.114	0.2602	45
	Total	47347.96	11220.581	0.2370	180

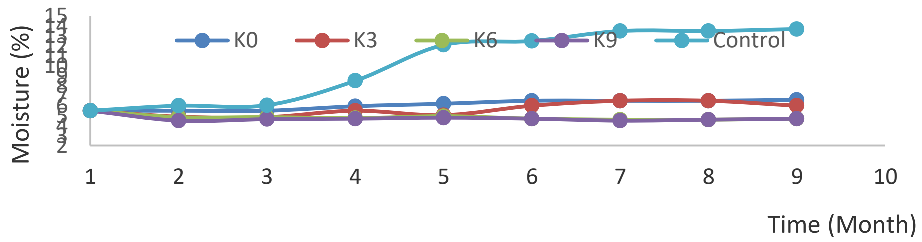
Table 10: Analysis of Variance to investigate the effect of K_2CO_3 and Containers on viscosity of *Bombax costatum* samples stored for nine months.

Dependent Variable: Viscosity						
Source	Type III Sum of Squares	Df	Mean Square	F	p-value	Partial Eta Squared
Corrected Model	8420120376.061[a]	7	1202874339.437	14.656	.000	.374
Intercept	403529295848.273	1	403529295848.273	4916.823	.000	.966
K2CO3	7148969345.750	3	2382989781.917	29.036	.000	.336
Container	1271151030.311	4	317787757.578	3.872	.005	.083
Error	14116236986.667	172	82071145.271			
Total	426065653211.000	180				

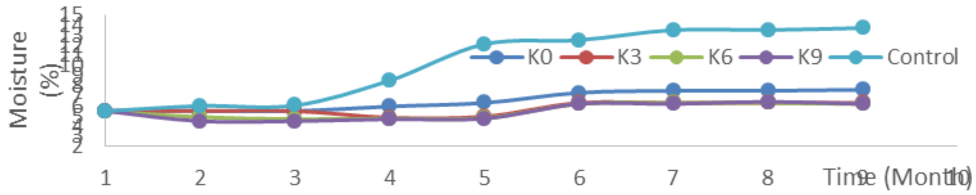
Corrected Total	22536357362.728	179				
R Squared = .374 Both Containers and treatments presented significant effects at 0.05 level of significance						

Table 11 : Table 5:Mean separation values of Viscosity data to investigate the effect of Containers on viscosity of *Bombax costatum* samples stored for nine months, using the Least Significance Difference(LSD).

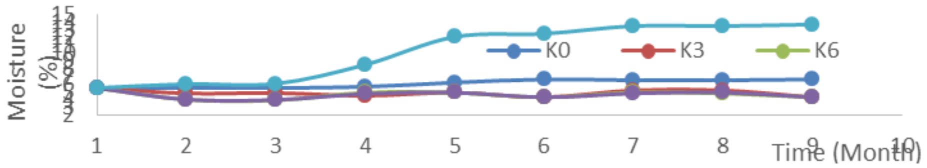
Dependent Variable: Viscosity						
(I) Container	(J) Container	Mean Difference (I-J)	Std. Error	p-value	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Ceramics 1	Metals 2	1049.222	2135.300	.624	-3165.545	5263.990
	Plastic 3	-2198.417	2135.300	.305	-6413.184	2016.351
	Glass 4	2192.278	2135.300	.306	-2022.490	6407.045
	Controls 5	5833.222*	2135.300	.007	1618.455	10047.990
Metals 2	Ceramics 1	-1049.222	2135.300	.624	-5263.990	3165.545
	Plastic 3	-3247.639	2135.300	.130	-7462.406	967.129
	Glass 4	1143.056	2135.300	.593	-3071.712	5357.823
	Controls 5	4784.000*	2135.300	.026	569.233	8998.767
Plastic 3	Ceramics 1	2198.417	2135.300	.305	-2016.351	6413.184
	Metals 2	3247.639	2135.300	.130	-967.129	7462.406
	Glass 4	4390.694*	2135.300	.041	175.927	8605.462
	Controls 5	8031.639*	2135.300	.000	3816.871	12246.406
Glass 4	Ceramics 1	-2192.278	2135.300	.306	-6407.045	2022.490
	Metals 2	-1143.056	2135.300	.593	-5357.823	3071.712
	Plastic 3	-4390.694*	2135.300	.041	-8605.462	-175.927
	Controls 5	-3640.944*	2135.300	.090	-573.823	7855.712
Controls 5	Ceramics 1	-5833.222*	2135.300	.007	-10047.990	-1618.455
	Metals 2	-4784.000*	2135.300	.026	-8998.767	-569.233
	Plastic 3	-8031.639*	2135.300	.000	-12246.406	-3816.871
	Glass 4	-3640.944*	2135.300	.090	-7855.712	573.823
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						



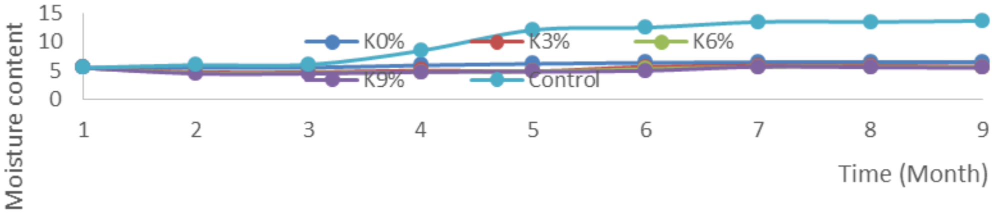
A (Ceramic)



B (Metal)



C (Plastic)



D (Glass)

Figure 2: Plot of moisture content against time to check the effect of Storage environments and K_2CO_3 on Moisture Content of Bombax Costatum calyx-Stored in (A) Ceramic (B) Metal (C) Plastic and (D) Glassand control fornine Months, determined at room temperature.

Table 12: Average Moisture Content of *Bombax Costatum* calyx stored with 0% of K_2CO_3 in different containers and control for nine Months at room temperature.

Container	Jan	Feb	March	April	May	June	July	August	Sept.
Ceramic	5.50	5.50	5.50	5.95	6.20	6.50	6.50	6.50	6.60
Metal	5.50	5.50	5.20	5.30	5.23	5.50	6.30	6.40	6.50
Plastic	5.50	5.50	5.60	5.60	6.20	6.60	6.50	6.60	6.60
Glass	5.50	5.50	5.50	5.80	6.200	6.40	6.50	6.50	6.50
Control	5.50	6.00	6.05	8.50	12.10	12.50	13.50	13.50	13.70

Table 13: Average Temperature and Relative Humidity of Storage Environment during Storage

	Morning		Afternoon		Evening		Average	
Months	Temp. (^0C)	RH (%)	Temp. (^0C)	RH (%)	Temp.(^0C)	RH (%)	Temp. (^0C)	RH (%)
1	28.5	35	29.3	29	29.1	25	28.96	29.67
2	29.2	26	29.7	26	29.4	24	29.43	25.33
3	31.3	26	32.3	44	33.7	49	32.43	39.67
4	30.0	62	32.7	65	33.0	64	31.90	63.67
5	28.5	65	29.0	64	28.7	65	28.73	64.67
6	28.0	68	28.5	66	28.5	66	28.33	66.67
7	28.0	72	28.5	68	28.5	70	28.33	70.00
8	28.0	70	29.5	68	29.0	69	28.83	69.00
9	27.5	74	28.5	68	28.0	72	28.00	71.33

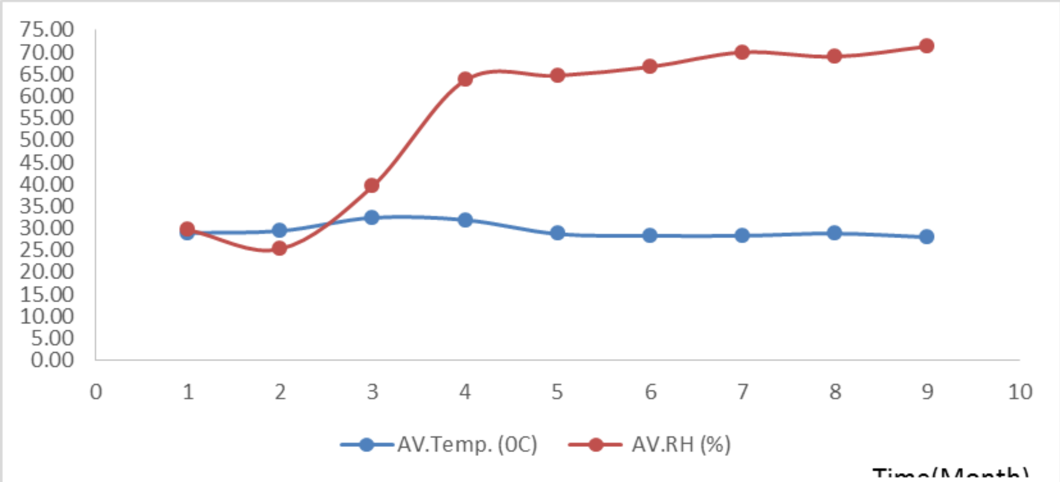


Fig3:Plot of Average Temperature and Relative Humidity of Storage Environment during Storage against time

DISCUSSION

The aim of this study is to control the loss of viscosity of *Bombax costatum* associated with wet season, through hermetic storage. Table1 presents viscosity of dry *Bombax costatum* samples treated with 0%, 3%, 6%,9% of potassium carbonate (K_2CO_3) preservative and control, and stored in ceramic, metal, plastic, glass and open container for nine months. Viscosities of these samples were determined at Room temperature (30ºC) using spindle 4 and shear rates of 5rpm. Oral communication with Hannah A.S. and C.T. Nyikuma(2019) indicates that storage of *Bombax costatum* calyx powder in airtight container helps to maintain its gellation capacity even during rainy season. Hermetic storage which is a similar approach was adopted with incorporation of Potassium carbonate preservative to check its effect on viscosity of *Bombax costatum* and compare with zero treatment and control samples before, during and after storage. Potassium carbonate also known as potash is white salt, soluble in water, which forms a strong alkaline solution. It can be made as the product of potassium hydroxide absorbent reaction with carbondioxide. The resulting potassium hydroxide is then carbonated with carbondioxide to form potassium carbonate. Potassium carbonate is used in reactions to maintain anhydrous conditions without reacting with the reactant and product formed (Tingir, 2003). Four different containers and control were obtained from the market and used for the study. These containers include clay ceramic, Metal, plastic, glass and control (open Calabash). Each container was replicated according to the number of treatments and months (4 treatments* 4containers *9months and 1 control) to avoid the subsequent re-use of already opened containers. All containers were filled to the brim and tapped properly (10 times) to close up all air spaces to minimize the effect of microbes that survive on available oxygen to cause food damage during storage. The choice of K_2CO_3 and dosages, storage containers and method of storage was made in line with literature and existing practices. Gernah(2003) used metal and plastic with K_2CO_3 as treatment using 0%, 5%, 10% and 15% dosages and stored *Bombax costatum* with initial moisture content of 12%wb hermetically for a period of four months (May to August). All containers used for this study are food graded and approved for food storage by the National Agency for Food and Drugs Administration and Control (NAFDAC), and are already in public use. The use of 0%,3%,6% and 9% dosages of potassium carbonate compared to other researchers who used higher percentages of same preservative is to ensure minimum interference with original properties of *Bombax costatum,* and the need to retain organic nature of sample and increase public consumption confidence (Adezwa,2018). The choice of spindle size 4 and speed of 5rpm for measurement of viscosity in this study was based on the wide tolerance and sensitivity of spindle 4 and shear rate of 5rpm to both low and high viscosities. Tables 1 and Figures 1 present average viscosity readings of *Bombax costatum* samples treated with dosages of K_2CO_3 preservative (0%, 3%, 6% and 9%) and stored indoors under five different environmental conditions (Metal, Ceramics, Plastics, Glass and Control) and determined at Room Temperature (30 ºC), and compare the behavior of stored sample with the original or initial sample. Viscosity losses and coefficients of variation due to containers and treatments were also calculated as shown in tables 5 to 6. Tables 1 to 4 and figure 1 present viscosity readings of stored *Bombax costatum* under different levels of preservative (K_2CO_3) across different containers and temperatures.

The actual storage was conducted at room temperature, with temperature fluctuating between 28ºC and 32ºC taken in the morning, afternoon and evening with average of 30ºC. The relative humidity of the storage environment which was equally taken in the morning, afternoon and evening increased from 26% in January to 75% in September, with average of 55.56%. The viscosity of 0% K_2CO_3 sample stored in ceramic, metal, plastic, glass and control at room temperature changed from the initial 63481cp to 55557cp, 58263cp, 57643cp, 58548 and 23217cp respectively. The viscosity of 3% K_2CO_3 sample stored in ceramic, metal, plastic, glass and control at room temperature changed from the initial 56340cp to 50773cp, 54125cp, 53933cp and 23217cp respectively. The viscosity of 6% K_2CO_3 sample stored in ceramic, metal, plastic, glass and control at room temperature changed from 50115cp to 46010cp, 46374cp, 50040cp and 23217cp respectively. The viscosity of 9% K_2CO_3 sample stored in ceramic, metal, plastic, glass and control at room temperature changed from 42817cp to 29104cp, 24135cp, 20280cp and 23217cp respectively. Table 5 presents detail performance efficiencies of Ceramic, Metal, Plastic, Glass and Control across all temperatures and dosages of potassium carbonate. At room temperature, the 0% K_2CO_3 sample presented performance efficiencies for Ceramics, Metal, Plastic, Glass and Control to be 87.52%, 91.78%, 90.80%, 92.23% and 36.57% respectively, while at the same room temperature, 3% K_2CO_3 sample presented performance efficiencies for Ceramics, Metal, Plastic, Glass and Control to be 90.92%, 100.91%,100.54%, 103.60% and 36.57% respectively. The calculated performance efficiencies of storage containers show that all containers performed very effectively at 0% and 3% preservative across at Room temperature, except the control sample which presented a poor performance efficiency.

To check the effect of storage containers on stored samples of *Bombax costatum*, Study at room temperature revealed that samples with 0% and 3% treatments presented high performance efficiencies across all storage containers. At 0% treatment, the performance efficiency of storage containers at room temperature ranged from 87.52% to 92. 23%, and 3% K_2CO_3 treatment at room temperature ranged from 90.12% to 103.64% across all selected containers, except the control which presented a poor performance efficiency of 36.57%. Equally, the coefficient of variation and viscosity loss or gain due to storage were calculated across containers and treatments to check the level of viscosity loss and consistency of storage containers as shown in Tables 5 and 6 respectively. The viscosity losses of sample treated with 0% K_2CO_3 at room temperature for Ceramic, Metal, Plastic, Glass and Control at the end of storage period was calculated to be 12.48%, 8.22%, 9.20%, 7.77% and 63.43% respectively, while the same sample at the same temperature presented coefficient of variation (CV) for Ceramic, Metal, Plastic, Glass and Control to be 0.128, 0.134, 0.116, 0.166 and 0.386 respectively. The viscosity loss or gain and coefficient of variation were also calculated for the 3% K_2CO_3 sample at room temperature. The result presented the calculated viscosity loss for Ceramic, Metal, Plastic, Glass and Control to be 9.88%, 3.93%, 4.27%, 1.37% and 63.43% respectively, while the coefficient of variation of the same sample for Ceramic, Metal, Plastic, Glass and Control was calculated to be 0.211, 0.250, 0.140, 0.183 and 0.386 respectively.

Tables 6 and 7 contain viscosity losses and coefficients of variation for all containers across 0%, 3%, 6%, 9% K_2CO_3 and control during storage. The result of ceramic container for 0%, 3%, 6%, 9% K_2CO_3 treatments and control samples presented viscosity losses and coefficients of variation to be 12.48%, 9.88%, 8.19% 32.03% 63.43 and 0.128, 0.211, 0.234, 0.444, 0.386 respectively. The result for metal at the same treatment regime and temperature for viscosity loss and coefficient of variation were 8.22%, -0.90%, 19.44%, 43.63%, 63.43% and 0.134, 0.258, 0.306, 0.422, 0.386 respectively. Plastic presented the viscosity loss and coefficient of variation at the same temperature and treatment regime to be 9.20%, 0.55%, 19.44%, 52.64%, 63.43% and 0.116, 0.140, 0.306, 0.445, 0.386 respectively. Similarly the viscosity losses and coefficient of variation of glass container for 0%, 3%, 6%, 9% K_2CO_3 treatment and control at room temperature were 7.77%, 3.40%, 11.69%, 52.31%, 63.43% and 0.166, 0.183, 0.318, 0.471, 0.386 respectively. The study presented good and consistent performance at 0% and 3% K_2CO_3 across all containers except the control sample.

The result showed that viscosity decrease with increase in the concentration of potassium carbonate across all containers. The good performance of all containers, except control at 0% and 3% K_2CO_3 treatments at room temperature equally agrees that viscosity of *Bombax costatum* is better enhanced at low percentage of K_2CO_3 . Considering the respective performance efficiencies and coefficients of variation of containers at room temperature, it was observed that metal and glass containers stood out with low viscosity loss and low coefficient of variation across months, followed by plastic and lastly ceramic. The control sample that represented the actual problem of the study recorded huge viscosity loss. For the Comparing the performance of all the storage containers at 0% K_2CO_3, it was observed that metal container achieved 91.78% efficiency with 0.134 coefficient of variation, followed by glass which achieved 92.30 efficiency with 0.166 coefficient of variation, followed by plastic which achieved 90.8% efficiency with 0.116 coefficient of variation, ceramic achieved 87.52% efficiency and 0.128 coefficient of variation, and lastly the control which recorded 36.57% efficiency and 0.386 coefficient of variation. Both metal and glass recorded approximately 92% performance efficiency, but with metal having low coefficient of variation, it can be concluded that it is more consistent and is be rated above glass. Tables 8 to 11 present statistical analysis covering descriptive, ANOVA and mean separation, which agrees that samples with lower percentage of potassium carbonate presented higher viscosity across all containers. Both ANOVA and mean separation showed that both treatments (K_2CO_3) and containers have significant impact on viscosity of *Bombax costatum* at 5% level of significant. The result in Table 12 showed that all containers provided effective sealing and barrier from external moisture, as the level of moisture increase after nine months of storage was still within the acceptable moisture level for storage of flours. Except the control which showed substantial increase in moisture due to deliberate exposure to the room atmosphere. According to the result, metal provided more effective sealing, followed by glass, ceramic and lastly plastic. The effective performance of metal and glass containers is in agreement with result obtained for viscosity, as determined in this study. The low percentage of moisture (5.5%wb) of *Bombax Costatum* calyx used for this study is in agreement with Mkaanem (2018) for leafy and calyx materials, especially for the purpose of storage. The supposition that moisture affects some functional properties of *Bombax Costatum* is justified by value of viscosity of sample exposed to the room environment, which absorbed more moisture than the sealed containers that were adequately protected from moisture invasion, as shown by the moisture content of the control sample. Table13 contains relative humidity and room temperature of the storage environment. The data presented temperature with a horizontal trend for the nine months of storage, with relative humidity rising sharply at the fourth month. The effect of increased relative humidity manifested to increase moisture and viscosity decay at the fourth, especially with the control.

Conclusion

Based on the result obtained in this study, it can be declared that hermitic storage is the appropriate method of storage for dry calyx of *Bombax costatum*. All the four containers used for the study performed effectively, with metal performing best, followed by glass, plastic and lastly ceramic. The control, which represent the actual problem performed worst.

The result presented viscosity of *Bombax costatum* as decreasing with increase in potassium carbonate preservative. It can therefore be concluded that fully dried *Bombax costatum* can be hermitically stored without potassium carbonate preservative in any of the four containers(ceramic, metal, plastic and glass) at room temperature.

REFRENCES

[1] 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.

[2] Gernah D.I and P. Gbakaan (2003): 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.

[3] 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.

[4] Jorge M. And H. Morale (2015): Evaluating biocompatible barrier films as encapsulant of medical micro devices. Research gate:www.researchgate.net

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

[6] 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.

[7] Mkaanem D.P (2018). Solar drying of agricultural produce, principles and processes 1st Ed integrity pub. Abuja, Nigeria, pp 18-26.

[8] Nyikuma C.T. (2019): A Bombax costatum trader in Gboko, Benue state, Nigeria.