Effects of Blanching and Stabilization on the Rheological Evaluation of Products from African Star Apple (Chrysophyllum albidium) Peels and Cotyledons.

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Abstract

The focus of this work is fruit (Afrian star apple (Chrysophyllum albidium) peels and cotyledon) product formulation where understanding rheology is critical in optimizing product development efforts, processing (blanching and stabilization) methodology and final product quality. The peels and cotyledons were blanched at 1000C for 2, 4 and 6 mins, wet milled with water in 1: 1.5 ratio, sieved with muslin cloth to obtain the extracts which were pasteurized at 800C for 10mins and stabilized with 0.2, 0.4, 0.6, 0.8 and 1.0 (g/litre) concentrations of carboxy methyl cellulose (CMC) and pectin each. A preliminary study was done on the African star apple ("udara") peels and cotyledons by ranking to determine the best two stabilized samples from each of the three batches of 2, 4, and 6 mins blanched. Based on the overall acceptability of the panelists, six samples were selected for further study together with their respective controls making a total of twelve samples coded as follows: peel extract control samples A1, B1 and C1 of 2, 4 and 6 mins blanching respectively, cotyledon extract control samples A2, B2 and C2 of 2, 4 and 6mins blanching respectively, stabilized peel extract samples D1, E1 and F1 of 2, 4, and 6 mins blanching respectively, and stabilized cotyledon extract samples D2, E2 and F2 of 2, 4, and 6 mins blanching respectively. Blanching considerably reduced the viscosity while stabilization increased the viscosity. Rheological characterization of "udara" peel and cotyledon samples were found to be shear thinning – pseudoplastic behaviour of non-Newtonian fluid.

Key words: African star apple, blanching, effects, products, stabilization, rheological, evaluation.

Index words: African star apple, effects of blanching and stabilization, peels and cotyledons, products, rheological evaluation.

INTRODUCTION

Rheology is often defined as the science of flow and deformation, the study of rheology covers a whole field that is associated with flow of fluids, granular materials or powders and solid food products (Onwuka, 2003; Faith, 2004). The texture of foods has a substantial influence on consumer's perception of quality and during chewing (or mastication), information on the changes in texture of a food is transmitted to the brain from sensors in the mouth, from the sense of hearing and from memory, to build up an image of the textural properties of the food. The term rheology was coined by Eugene C. Bingham, a professor at Lafayette College in 1920, from a suggestion by a colleague, Markus Reiner (Steefe, 1996). The experimental characterization of a material's rheological behavior is known as rheometry, although the term rheology is frequently used synonymously with rheometry, particularly by experimentalists. Theoretical aspects of rheology are the relation of the flow/deformation behaviour of material and its, internal structure (example; the orientation of polymer molecules), and the flow deformation behaviour of materials that cannot be described by classical fluid mechanics or elasticity. It is also concerned with establishing predictions for mechanical behavior (on the continuum mechanical scale) based on the micro or nanostructure of the material example the molecular size and architecture of polymers in solution or the particle size distribution in a solid suspension. Materials with the characteristic of fluid will flow when subjected to a stress which is defined as the force per unit area. Much of theoretical rheology is concerned with associating external forces and torques with internal stresses and internal strain gradients and velocities (Schowalter, 1978; Bird *et al.*, 1989., Faith, 2001). Food rheology is important in the manufacture and processing of food products, it is generally referred to as the material science of food and it is defined as the study of the rheological properties of food that is the consistency and flow of food under tightly specified conditions. Understanding rheology of food is critical in optimizing product development, process methodology, final product quality and chemical analysis as well as result interpretation.

However, the consistency, degree of fluidity and other mechanical properties are important in understanding how long food can be stored, how stable it will remain, and in determining food texture. The acceptability of food products to the consumer is often determined by food texture, such as how spreadable and creamy a food product is. Rheology attribute such as texture of food, has a substantial influence on the consumer's perception of quality and mouth feel during chewing and mastication (Fellows, 2000). The interest in product formulation is growing and stimuli acting various research activities to identify and evaluate the chemical (nutritional) and rheological properties of fruits extracts and their potential application in fruit drink production. Thus, the rheological properties of fruit (African star apple) products are

important factors that determine the sensory properties such as mouth feel, texture and consistency. One can therefore think of food rheology as the material science of food.

Viscosity

Viscosity is an important characteristic of liquid foods in many areas of food processing. For example the characteristic mouth feel of food products such as tomato ketchup, cream, spread, syrup, etc, is dependent on their consistency of viscosity. The viscosity of many liquids changes during heating, cooling, concentration among others and this has important effects on, for example, the power needed to pump these products (Fellows, 2(Viscosity may be thought of as a liquid's internal resistance to flow. The force that moves the liquid is known as the *Shearing force* or shear stress and the velocity gradient is known as the shear rate. For all liquids, viscosity decreases with an increase in temperature but for most gase increases with temperature (Lewis, 1990).

MATERIALS AND METHODS

Procurement of Raw Materials

The healthy fruits of *Chrysophyllum albidum* were collected from uncultivated and cultivated farmlands respectively, located at South Eastern part of Nigeria.

Instrument for Laboratory Analysis

All instruments used for this study were obtained from the Department of Mechanical Engineering, University of Nigeria, Nsukka and they are all of analytical quality.

METHODS: Sample Preparation

The fruits were thoroughly washed with water, to remove extraneous materials such as dirt, separated into pulp, peel and seeds which were further cracked to reveal the white cotyledon. Different processing methods were applied as shown in Fig. 1.

Production of Extracts from Blanched Seeds and Peel Pulps

The cotyledon and peel were divided into three equal parts each and steam blanched at 100°C for 2mins, 4mins and 6mins, wet milled to produce their respective pulps which were blended with water in 1:1.5 ratios producing their extract yield respectively. These extracts were pasteurized at 80°C for 10mins and stabilized with 0.2, 0.4, 0.6, 0.8 and 1.0 (g/litre) concentrations of carboxy methyl cellulose (CMC) and pectin each. A preliminary study was done on the African star apple ("udara") peels and cotyledons products by ranking to determine the best two stabilized samples from each of the three batches of 2, 4, and 6 mins blanched. Based on the overall acceptability of the panelists, six samples were selected for further study together with their respective controls making a total of twelve samples coded as follows: peel extract control samples A_1, B_1 and C_1 of 2, 4 and 6 mins blanching respectively, cotyledon extract control samples A_2, B_2 and C_2 of 2, 4 and 6mins blanching respectively, stabilized peel extract samples D_1, E_1 and F_1 of 2, 4, and 6 mins blanching respectively, and stabilized cotyledon extract samples D_2, E_2 and F_2 of 2, 4, and 6 mins blanching respectively. They are thereafter bottled for further analysis.

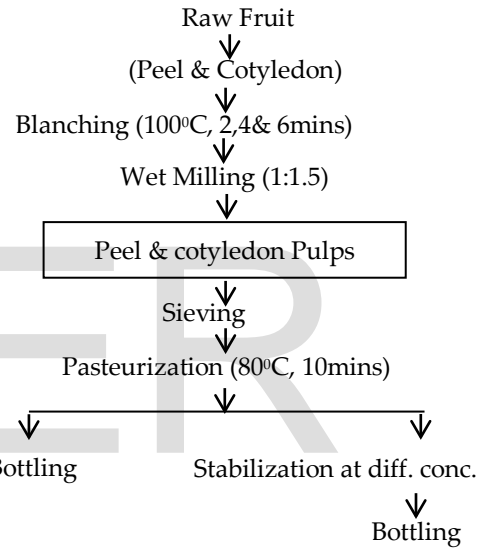

Fig. 1: Production of udara products.

SAMPLE ANALYSIS

Viscosity Determination

This determination was done using the Ferranti Portable Viscometer – model VL as described in Bentleys Textbook of Pharmaceutics by Davies (1956). Model VL is for low viscosities with the inner cylinder combination. The outer cylinder was fitted to ensure that the location spring lies flat against the side of the shaft. The knurled knob which is left of the handle was rotated clockwise to "lock" the inner spindle inserting the guard ring up the inside of the outer cylinder and pressing home firmly. Inner cylinder was chosen as the appropriate size to just cover the viscosity ranges required. The spindle was inserted inside the guard ring and the inner cylinder was rotated slowly maintaining a light upward/until the inner spindle pin was located on its restraining slot. The cylinder was then pressed home until the ball end engages the retaining spring. The inner spindle was unlocked and the cylinders were immersed

with 200mls or sample to be tested. Determinations were made with the top of the outer cylinder just covered by the liquid. five different speeds ranging from one to 5 were utilized; their respective gears were switched on. The main supply required was 200 – 250 volts, 50 cycles. To facilitate the plotting of the flow curves the gears were changed without stopping the motor. Viscosity in poises, at a given speed and cylinder combination, was obtained by multiplying the instrument reading by the appropriate multiplying factor given on the calibration chart as illustrated in the equation below.

$$\mu = IM$$

Where; μ is viscosity, I is instrument reading and M is multiplying factor.

Sheer rate and shear stress:

This was measured by the method of Halek and Paik (1989) using an instrument, Universal Testing Machine. The food sample to be analysed was placed between a fixed plate and a moving probe. The measurement of shear strain and stress of the sample was taken as it was compressed. Shear stress in poises/sec at a given speed and cylinder combination was obtained by multiplying the viscosity (μ) by the appropriate multiplying shear rate given on the calibration chart of the instrument as illustrated in equation below;

$$\tau = \mu\left(du/dy\right)$$

Where; τ is shear stress,μ is viscosity and du/dy is shear rate

RESULTS AND DISCUSSION

Effect of blanching and stabilization on viscosity of "udara" samples:

The results of test of viscosity, shear rate and shear stress of the samples are presented in Table 1.

Generally from Table 1, the gear speed was directly proportional to the instrument reading and inversely proportional to the multiplying factors, while viscosities of the peel, control samples A_1, B_1 and C_1increased from gear 1 to 3, and decreased afterwards, unlike viscosities of other samples that decreased uniformly. The resultant shear rate and shear stress also decreased as the gear speed was increased. The decreased viscosities of the control peel samples (A_1, B_1, and C_1) and seed (A_2, B_2, and C_2) with blanching treatment were as a result of increased heat treatment from 2, 4 and 6 mins. for samples A_1 and A_2, B_1, and B_2 and C_1 and C_2respectively which is in accordance with the report of Onwuka (2003) that the parameter μ, viscosity is very important in food processing since it changes significantly during heating, homogenization, etc and very much so in industrial fermentation. Fellows (2000) also reported that the viscosity of many liquids changes during heating, cooling, concentration, etc and this has important effects on the power needed to pump these products.

Onwuka (2003) also observed that temperature as other parameters involved in processing of food and non-food system affects viscosity. Lewis (1990) also reported that viscosity for all liquids decreases with an increase in temperature but increases with temperature for most gases.

The effect of stabilization (CMC and pectin) on the other hand was observed on the stabilized samples of D_1, E_1 and F_1 for peel, and D_2, E_2 and F_2 for cotyledon extracts. The stabilizer (CMC) functions as a thickener and has optimum pH range of 3 – 10 (Trudso, 1991). Therefore, the improved consistency of "udara" products could be attributed to the formation of highly viscous system with CMC which caused diffusion resistance that reduced the mobility of the reactants. Since "udara" cotyledon and peel extracts particles are negatively charged, addition of food gums (CMC) with negative charge is expected to increase the electrostatic repulsive forces between particles. Yamasaki *et al*., (1964) reported that negatively charged colloids (like sodium alginate, CMC and Arabic gum) in concentrations as low as 0.03%, completely inhibit apple juice clarification and thus increases its viscosity.

Pectin (white to light brown powder) is also a stabilizer which functions as a gelling agent and thickening agent in food and has optimum pH range of 1.5 – 3.5 (Buchanan *et al*., 2000) and its typical level as a food additive are between 0.5% - 10% which is about the same amount of pectin as in fresh fruit. Therefore the increased viscosities of stabilized samples could be attributed also to its formation of highly viscous systems with pectin when compared to control samples. Generally, viscosity of stabilized seed extracts of D_2, E_2 and F_2 were higher than that of the peel extracts of D_1, E_1, and F_1 respectively. This could be due to higher macromolecules (e.g. starches, proteins and gums), colloidal materials like emulsions, paste and suspensions present in the cotyledon extract. However, although the shear rate was constant for all the samples, shear stress of stabilized and control samples of cotyledon extracts were higher than those of the peel extracts.

Viscosity which is liquid's internal resistance to flow and this liquid "udara (cotyledon and peel extract) can be envisaged as having series of layers and when it flows on a surface (testing equipment), the uppermost layer flows fastest and drags the next layers along at a slightly lower velocity and so on through the layers until the one next to the surface was stationery. The force that moves the liquid ("udara" samples) was known as the shearing force or shear stress (τ) while the velocity gradient is known as the shear rate or strain (λ). From Table 1, when shear stress was plotted against shear rate, the "udara" peel and cotyledon samples showed a non-linear relationship as illustrated in Fig. 2 and Fig. 3, respectively. This is in agreement with the report of Fellows (2000) that a plot of shear stress against shear rate gives a non-linear relationship for non-simple liquids and thus is termed non-Newtonian fluid while a plot of shear stress against shear rate gives a linear relationship for most simple liquids and gases and is termed Newtonian fluids. Onwuka (2003) reported that Newtonian fluids obey Hook's law while non-Newtonian fluids obey.

Fig 2 shows a pseudoplastic non-Newtonian (non-linear relationship) of udara peel extracts as a result of effects of blanching and stabilization on these extracts. As expected increase in blanching time resulted in decreased viscosity as the shear rate increases in all the samples both controls (A_1, B_1, and C_1) and stabilized ones (D_1, E_1, and F_1). It was observed that stabilized samples had higher viscosity as a result of stabilization when compared with control samples. When shear stress of these samples were plotted against their appropriate shear rates a very well defined rheological behaviour of pseudoplastic fluid were observed. It was also observed that since the peel extracts are diluted solutions with naturally low viscosity, reductions in viscosity with increasing shear rate was relatively minor. This behaviour was attributed to the alignment of transiently elongated coils in the direction of flow during shear (Morris *et al.*, 1981). There is a continuous replacement of macromolecules in the network at low shear rate (Y) values and resulted in little or no change in viscosity. By increasing the shear rate the number of cross linked macromolecules decreases and viscosity was reduced.

On the other hand, Fig. 3 shows a pseudoplastic behaviour of non-Newtonian rheological model as a result of effects of blanching and stabilization on all the cotyledon extracts of "udara" except for sample C_2 that its behaviour was similar to that of dilatants fluid even though its viscosity decreases as the shear rate increases with increase in time of blanching similar to other seed samples. Just like peel extract samples; cotyledon extract samples of A_1, B_1, C_1, (controls) had lower viscosity compared with D_2, E_2 and F_2 (stabilized) respectively. Cotyledon extracts having higher concentrated solutions than that of the peel extracts, behave quite differently because its macromolecules coils form an entangled network structure (Graessley, 1974). Thus as concentration of these cotyledon extracts increases by addition of stabilizers (Pectin and CMC), the movement of macromolecules was restricted. This behaviour attributed to the formation and breaking of hydrogen bonds, was also noted in galactomanan and polyacrilamide solutions (Kulicke and Porter, 1980).

It was also detected that at low shear rate, all cotyledon and peel samples showed higher viscosity. The non-Newtonian range depends not only on the molecular weight, but on weight distribution and type and extension of polymer branching (Bagley, 1992). Finally, cotyledon and peel extracts with added CMC and pectin are highly pseudoplastic at elevated shear rate values, due to the destruction of intermolecular associations (Da Silva *et al.*, 1992), and the major stabilizing effect of CMC and pectin should be mainly due to its greater electro negativity, which leads to major particle repulsion and avoids agglomeration.

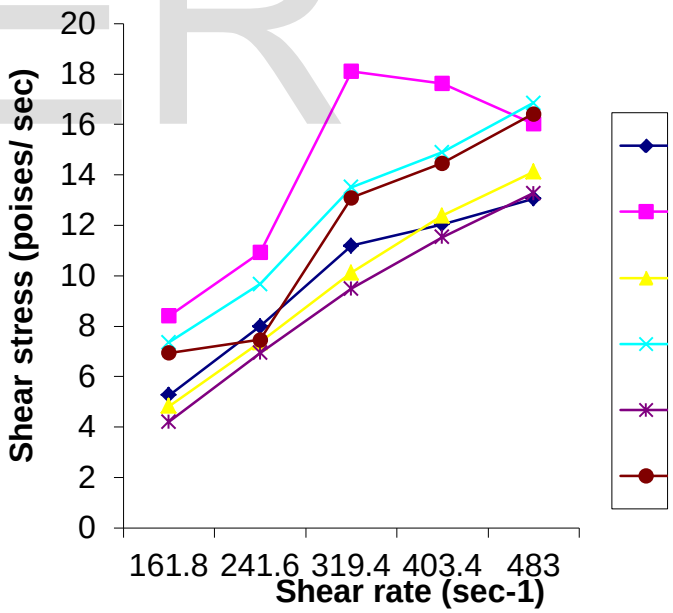

Fig. 2: Viscosity of "udara" peel extracts

Key

A_1 - 2mins blanched unstabilized extract of "udara" peel.

B_1- 4mins blanched unstabilized extract of "udara" peel.

C_1- 6mins blanched unstabilized extract of "udara" peel.

D_1- 2mins blanched stabilized extract of " udara" peel with 1.0 (g/liter) of CMC.

E_1- 4mins blanched stabilized extract of "udara" peel with 1.0 (g/liter) of pectin.

F_1- 6mins blanched stabilized extract of "udara" peel with 1.0 (g/liter) of pectin.

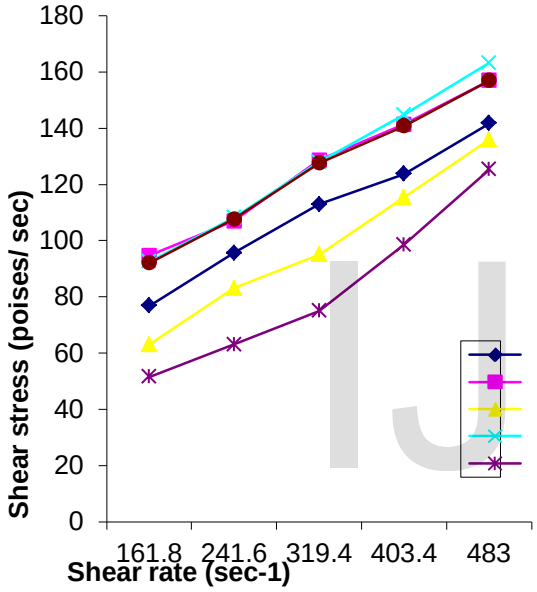

Fig. 3: Viscosity of "udara" seed extracts samples

Key

A_2- 2mins blanched unstabilized extract of " udara" cotyledon.

B_2- 4mins blanched unstabilized extract of " udara" cotyledon.

C_2- 6mins blanched unstabilized extract of " udara" cotyledon.

D_2- 2mins blanched extract of " udara" cotyledon stabilized with 1.0 (g/liter) of pectin.

E_2- 4mins blanched extract of " udara" cotyledon stabilized with 1.0 (g/liter) of CMC.

F_2- 6mins blanched extract of " udara" cotyledon stabilized with 1.0 (g/liter) of CMC.

Table 1: Effects of Blanching, Stabilization and Speed variation on the Rheological Properties of "Udara" samples.

Model (VL) Inner cylinder	Speed/ Gear	Samples	Instrument Readings	Multiplying factors	Viscosities (poises)	Shear rate (sec^{-1})	Shear stress (poises/ sec)
A	1	Control A1	2.5	0.013	0.03250	161.8	5.26
	2		3.8	0.0087	0.03306	241.6	7.99
	3		5.3	0.00661	0.03506	319.4	11.19
	4		5.7	0.0052	0.02984	403.4	12.04
	5		6.2	0.00436	0.02703	483.0	13.06

A	1	D_1	4.0	0.013	0.0520	161.8	8.41
	2		5.2	0.0087	0.04524	241.6	10.93
	3		7.0	0.00661	0.04627	319.4	18.11
	4		8.4	0.0052	0.04368	403.4	17.62
	5		9.1	0.00436	0.03968	483.0	16.03
A	1	Control A2	36.5	0.013	0.47450	161.8	76.77
	2		45.5	0.0087	0.39585	241.6	95.64
	3		53.5	0.00661	0.35364	319.4	112.95
	4		59.0	0.0052	0.30680	403.4	123.76
	5		67.3	0.00436	0.29343	483.0	141.73
A	1	D_2	45.0	0.013	0.5850	161.8	94.65
	2		50.9	0.0087	0.44283	241.6	106.99
	3		60.9	0.00661	0.40255	319.4	128.57
	4		67.4	0.0052	0.35048	403.4	141.38
	5		74.8	0.00436	0.32482	483.0	156.89
A	1	Control B1	2.3	0.013	0.0299	161.8	4.84
	2		3.5	0.0087	0.03045	241.6	7.36
	3		4.8	0.00661	0.03173	319.4	10.13
	4		5.9	0.0052	0.03068	403.4	12.38
	5		6.7	0.00436	0.02921	483.0	14.12
A	1	E_1	3.5	0.013	0.04550	161.8	7.36
	2		4.6	0.0087	0.04002	241.6	9.67
	3		6.4	0.00661	0.04230	319.4	13.51
	4		7.1	0.0052	0.03692	403.4	14.90
	5		8.0	0.00436	0.03488	483.0	16.85
A	1	Control B2	30.0	0.013	0.39000	161.8	63.10

	2		39.5	0.0087	0.34370	241.6	83.03
	3		45.0	0.00661	0.29750	319.4	95.01
	4		55.0	0.0052	0.28600	403.4	115.37
	5		64.5	0.00436	0.28122	483.0	135.83
A	1	E_2	44.0	0.013	0.57200	161.8	92.55
	2		51.5	0.0087	0.44810	241.6	108.25
	3		60.6	0.00661	0.40060	319.4	127.95
	4		69.0	0.0052	0.35880	403.4	144.74
	5		77.5	0.00436	0.33790	483.0	163.21
A	1	Control C1	2.0	0.013	0.02600	161.8	4.21
	2		3.3	0.0087	0.02871	241.6	6.94
	3		4.5	0.00661	0.02970	319.4	9.49
	4		5.5	0.0052	0.02860	403.4	11.54
	5		6.3	0.00436	0.02750	483.0	13.27
A	1	F_1	3.3	0.013	0.04290	161.8	6.94
	2		4.5	0.0087	0.03915	241.6	7.46
	3		6.2	0.00661	0.04098	319.4	13.09
	4		6.9	0.0052	0.03588	403.4	14.47
	5		7.8	0.00436	0.03400	483.0	16.42
A	1	Control C2	24.5	0.013	0.31850	161.8	51.53
	2		30.0	0.0087	0.26100	241.6	63.06
	3		35.5	0.00661	0.23465	319.4	74.95
	4		47.0	0.0052	0.24440	403.4	98.59
	5		59.5	0.00436	0.25942	483.0	125.30

A	1	F_2	43.8	0.013	0.56940	161.8	92.13
	2		51.2	0.0087	0.44544	241.6	107.62
	3		60.4	0.00661	0.39924	319.4	127.62
	4		67.1	0.0052	0.34892	403.4	140.75
	5		74.5	0.00436	0.32482	483.0	156.89

Key: F2- stabilised 6mins blanched extract of "udara" cotyledon with 1.0 (g/liter) of CMC.

A_1- unstabilised 2mins blanched extract of "udara" peel; A2- unsterilized 2mins blanched extract of "udara" cotyledon.

B_1- unstabilised 4mins blanched extract of "udara" peel; B2- unstabilised 4mins blanched extract of "udara" cotyledon.

C_1- unstabilised 6mins blanched extract of "udara" peel; C2- unstabilised 6mins blanched extract of "udara" cotyledon.

D_1- stabilised 2mins blanched extract of "udara" peel with 1.0 (g/liter) of CMC; D2- stabilised 2mins blanched extract of "udara" cotyledon with 1.0 (g/liter) of pectin; E_1- stabilised 4mins blanched extract of "udara" peel with 1.0 (g/liter) of pectin; F1- stabilised 6mins blanched extract of "udara" peel with 1.0 (g/liter) of pectin;

CONCLUSIONS

It was observed that stabilized samples had higher viscosity as a result of stabilization when compared with control samples. When shear stress of these samples were plotted against their appropriate shear rates a very well defined rheological behaviour of pseudoplastic fluid (non – Newtonian model) were observed. It was also observed that since the peel extracts are diluted solutions with naturally low viscosity, reductions in viscosity with increasing shear rate was relatively minor when compared with cotyledon extracts. Data obtained from this study demonstrated that food processing by blanching and pasteurization reduces the viscosity of "udara" products while stabilization improves their viscosity.

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