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Effects of Oven-Drying on the Viscosity of Okra(*Abelmoschus Esculentus)*

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Abstract

The effects of drying on the viscosity of Okra (*Abelmoschus esculentus*) fruit were evaluated, using a falling ball viscometer. Results show that, at 95% confidence level, drying had a significant influence on viscosity, density and Reynolds number of Okra suspension. Viscosity values obtained ranged from 0.34cP to 0.972cP for dried Okra as against 0.676cP to 2.84cP for the fresh Okra at corresponding mixing concentrations of 100g to 400g respectively. This implies that, glycan, which is responsible for the viscosity of Okra reduces in quality as Okra is dried. Therefore, the hypothesis that okra suspension either fresh or dried would obey stokes law was verified.

Keywords: Drying; Fall velocity; Fall time; Reynolds number; okra; Viscosity

Introduction

Okra (*Abelmoschus esculentus*) is one of the most widely consumed and deliberately cultivated vegetables known to mankind. It is scientifically proven to be rich in energy, protein, niacin, ascorbic acid, calcium and other vitamins [1]. The amino acid composition of Okra seed protein discovered to be similar to that of Soybean [2]. The high percentage of linoleic acid (42%) makes Okra seed oil desirable and the amino acid pattern of the protein renders it an adequate supplement to legume or cereal-based diets [3-5]. This nutritious vegetable thrives well in both temperate and tropical countries. Thus, Nigeria, India, Pakistan, Egypt and Ghana are the leading producers of Okra worldwide.

Okra is cherished in the African cuisine because of its soup making characteristics which is scientifically called viscosity. The viscosity of aqueous Okra suspension and the gum-like consistency which is desirable in soup is as a result of the presence of a chemical substance called glycan [6]. However, being an agricultural produce, Okra is highly perishable and seasonal, and to make it available all year round, several preservation methods has been adopted. This includes slicing the Okra fruit and sun drying until brittleness is attained [7]. The sun-dried product is then milled into powder for future use. Although sun-drying may be cheap, its drawbacks are well documented in literature [8,9]. They therefore recommended solar or hot-air drying as the best preservation methods. However, the effects of these preservation methods on the viscosity of Okra need to be desired because the viscosity of foods determines mouth feel, ease of swallowing, pourability and pumping needs. It is therefore the objective of this study to evaluate the effect of oven-drying on the viscosity of Okra using a falling ball viscometer.

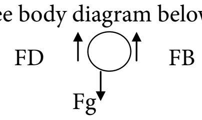
Materials and Methods

Sample preparations

Freshly harvested Okra (*Abelmoschus esculentus*) fruits were purchased from the Amassoma market in Bayelsa State, Nigeria, in November, 2012. All foreign materials were sorted out and the remnant sliced and divided into 3 groups (A, B and C). Each group containing 300g of sliced Okra fruits were then placed on flat plate sample holders and dried in the hot air oven dryer at 600C. The samples were weighed at regular intervals with a Camry Digital scale (EK 5350) until a constant weight was achieved in all samples at 1hour and 20minutes. The moisture content for the 3 samples were then determined and the average recorded. The dried Okra were then grinded into powder using mortar and pestle and stored in a polyethylene bag to prevent hygroscopic tendencies. Then, the remaining undried fresh Okra fruits weighing 900g were also grinded using same mortar in preparation for the analysis proper.

Theory of falling ball viscometer

Falling ball viscometers are simple long vertical tubes with sufficient diameter to permit the fall under gravity of a spherical ball. They operate on the fundamental principle of measuring the time for a ball to fall through the liquid under gravity. The falling ball is subjected to gravitational force, drag force and buoyancy force as displayed in the free body diagram below.



Balancing the forces, we get

Gravitational force (F_g) = Drag force (F_D) + Buoyancy force (F_B) …………………… (1)

$$\frac{\pi D_p^3 \rho_p g}{6} = \frac{\pi D_p^3 \rho_f g}{6} + C_d \pi D_p^2 \rho_f V^2 \quad \text{……………………} (2)$$

D_p = Diameter of the ball (m)

ρ_p = Density of the ball (kg/m3)

ρ_f = Density of the fluid (kg/m3)

C_d = Drag coefficient

V = Velocity of the ball, m/s

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t = Time, s

At equilibrium during the fall (at stokes region), we get

$$\frac{d\upsilon}{dt} = 0$$

This implies that, drag coefficient, $C_{d=}\frac{24}{\text{Re}}$

Where Reynolds number, Re is

$$\text{Re} = D_p \rho_f V/\mu \quad \ldots\ldots(3)$$

And μ= Viscosity

Substituting into equation (2) we get

$$\frac{\pi D_p^3 \rho_p g}{6} = \frac{\pi D_p^3 \rho_f g}{6} + \frac{6\pi D_p \mu V}{2} \quad \ldots\ldots(4)$$

Solving we get

Viscosity, $\mu = \frac{2r^2(\rho_p - \rho_f)g}{9V}$ ……..(5)

Therefore, it is possible to determine the dynamic viscosity of the Okra mixture if the terminal velocity of the falling ball is calculated.

Procedure

Using a Digital Caliper, the diameter of the spherical ball was determined, and result divided by 2 to obtain the radius of the ball. The ball density was then determined by measuring its mass and volume. The dried Okra powder was then mixed with water at 1000C in the following ratios based on the available equipment size;

100g of Okra powder: 1000ml of water

200g of Okra powder: 1000ml of water

300g of Okra powder: 1000ml of water

400g of Okra powder: 1000ml of water

These mixing ratios were repeated for the freshly blended Okra paste, and the mixturesvigorously stirred and separately put into a 2000ml graduated cylinder of known length and diameter. A convenient starting point of 5cm below the surface of the liquid and ending point of 5cm above the bottom was marked to ensure the stokes region. The distance between the starting and ending points was measured with a calibrated plastic ruler and the result called the "fall distance". The spherical ball was then dropped and the stopwatch started immediately the ball crossed the starting point, and stopped immediately it crossed the ending point. The fall time which is the time taken for the ball to fall through the fall distance was recorded. The density of the Okra mixture was then determined and the velocity of fall calculated. This procedure was repeated for all mixing ratios for both the dried and fresh Okra and the data plugged into the respective equations to obtain the desired parameters. This procedure was also applied by various authors for different fluids [10-12].

Results and Discussions

A summary of the measured and determined parameter are presented in (Tables 1and 2).

Effect of drying on density of mixture

As shown in (Table 2), the density of the dried Okra mixture changed from 0.93g/cm^3 to 1.87g/cm^3 for a mixing ratio of 100g to 400g per 1000ml of water respectively. However, for fresh Okra at the same mixing ratio, density changed from 0.95g/cm^3 to 2.27g/cm^3. Figure 1 reveals the graphical behaviour of density for both the dried and fresh Okra mixture as the concentration (grams) increased. It shows a polynomial relationship exist between density values of dried and fresh Okra against mixing ratios. These density values are comparable to those of milk (1.02-1.05g/cm^3) and olive oil (0.92g/cm^3)

Effect of drying on ball fall time

The ball fall time for the various mixtures of dried and fresh Okra is indicated in Table 2. It is evident from data provided that, fall time increased as the quantity of Okra added increases in both cases.

For the dried Okra and at a mixture of 100g, a fall time of 5 seconds was noted. The fall time then increased to 18.32 seconds at 400g mixture. In like manner, a fall of 10 seconds was observed for fresh okra at a mixture of 100g, but later increased to 51.32 seconds at a mixture of 400g. This behaviour, which is similar in both cases, could be attributed to density difference in the various mixing ratios. More so, a plot of the means of the fall time for both cases was conducted and results (Figure 2) show that polynomial models exist for the fall time between the dried and fresh Okra and mixing ratios. Results obtained here agree with the findings of other scientist on the ball fall time for sucrose solution [10].

S/N	Parameter	Values
1	Spherical ball diameter	0.9cm
2	Spherical ball weight	2g
3	Spherical ball volume	0.382 cm^3
4	Height of graduated cylinder	38 cm
5	Diameter of cylinder	6.7cm
6	Density of spherical ball	5.24g/cm^3
7	Weight of empty beaker	41g
8	Fall distance	28cm

*Moisture contents of samples A,B andC were 9.92,10.1 and 10.1% respectively

Table 1: Measured parameters.

	Dried Okra				Fresh Okra			
	100g	200g	300g	400g	100g	200g	300g	400g
Densityof mixture	0.93 ± 0.01	0.95 ± 0.1	1.43 ± 0.05	1.87 ± 0.1	0.95 ± 0.9	1.03 ± 0.1	1.55 ± 0.2	2.27 ± 0.1
Fall time (s)	5 ± 0.3	7 ± 0.5	10.63 ± 1.3	18.32 ± 0.6	10 ± 1.4	15 ± 0.5	29.44 ± 0.7	51.32 ± 3.1
Fall velocity (cm/s)	5.6 ± 0.02	4 ± 0.7	2.63 ± 0.04	1.53 ± 0.2	2.8 ± 0.6	1.8 ± 0.4	0.95 ± 0.9	0.55 ± 0.1
Viscosity (cP)	0.34 ± 0.06	0.47 ± 0.63	0.63 ± 0.1	0.97 ± 0.04	0.67 ± 0.1	0.99 ± 0.1	1.83 ± 1.3	2.84 ± 0.2
Reynolds number	100.63 ± 3.1	53.7 ± 2.5	40.05 ± 2.8	19.72 ± 1.2	52.73 ± 0.3	12.98 ± 3.0	5.37 ± 1.4	2.92 ± 2.6

Table 2: Experimentally determined parameters.

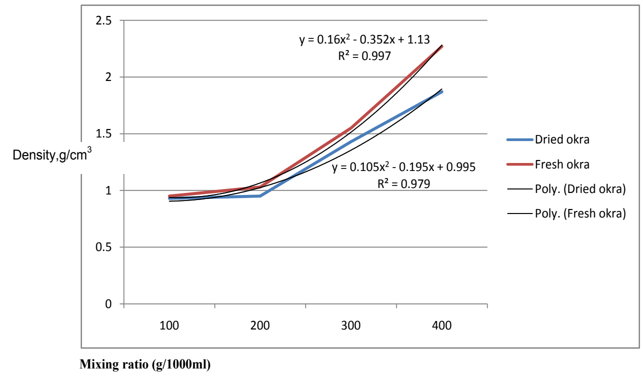

Figure 1: Effect of drying on the density of okra.

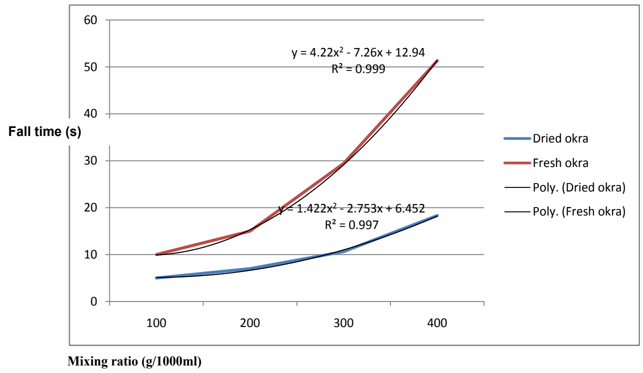

Figure 2: Effect of drying on the ball fall time.

Effect of drying on fall velocity

The fall velocity which is otherwise called the terminal velocity, atstoke's region, tends to decrease as the mixing ratio increased for both dried and fresh Okra. At a mixture of 100g dried Okra, a fall velocity of 5.6cm/s was recorded. This value then decreased to 1.53cm/s at 400g dried Okra mixture. Similarly, for fresh Okra, a fall velocity of 2.8cm/s was obtained at a mixture of 100g and 0.55cm/s at 400g mixture. This decrease in fall velocity which is more noticeable in fresh Okra may be as a result of both density and concentration differences. A plot of fall velocity values of both dried and fresh Okra as against mixing ratios is indicated in Figure 3 and the attendant relationship between both appears polynomial. The observations made tend to concur with the findings of other authors (11,12).

Effect of drying on viscosity

Viscosity, which is the desired parameter, is one of the fundamental qualities that characterize flow behavior. It is, indeed, a measure of a fluid's ability to resist motion when a shearing stress is applied. Data from(Table 2) shows that viscosity, generally, increased with increase in mixing ratio for both dried and fresh Okra. For dried Okra and at 100g mixture, a 0.34cP was recorded. But this viscosity value increased to 0.97cP at 400g mixture. A similar behavior was noted for fresh Okra as viscosity changed from 0.67cP to 2.84cP at 100g and 400g mixtures respectively. This implies that the fresh Okra mixtures are more viscous and could be as a result of the unaltered viscosity prompting chemical called glycan. The presence of glycan tends to increase the cohesive forces between molecules. However, the dry Okra mixtures showed lower viscosities at the various mixing ratios implying that glycan content was drastically reduced in the drying process. Results from a statistical analysis conducted on viscosities of both dried and fresh Okra mixtures showed a significant difference at 95% confidence levels. A graphical behavior of viscosity with mixing ratios for both cases as indicated in Figure 4 agrees with the works of[13,14] and also similar to the viscosities of milk(2.0g/cm^3) and cocoa butter (0.5g/cm^3)

Effect of drying on Reynolds Number

Reynolds number is a dimensionless parameter that is used to indicate the degree of turbulence in a flow regime. Information provided in Table 2 shows that, Reynolds number generally decreased with increase in mixing ratio for both dried and fresh Okra. At 100g mixture of dried Okra, a Reynolds number of 102.63 were achieved. This value then decreased to 19.72 at a corresponding mixing ratio of 400g. A similar negative trend was observed for fresh Okra as Reynolds number decreased from 52.73 to 2.92 at the respective mixing ratios of 100g and 400g. Results therefore reveal that, Reynolds number observed in fresh Okra was by far lower than those of dried Okra. This could be as a result of the high glycan content in fresh Okra, which is known to boost the resistance to flow.A plot conducted for Reynolds numbers of both cases shows that a logarithmic relationship exists between dried okra and mixing ratio. For fresh okra, a power series tends to dominate in the relationship as revealed in Figure 5. These findings are in concord with those of authors [12].

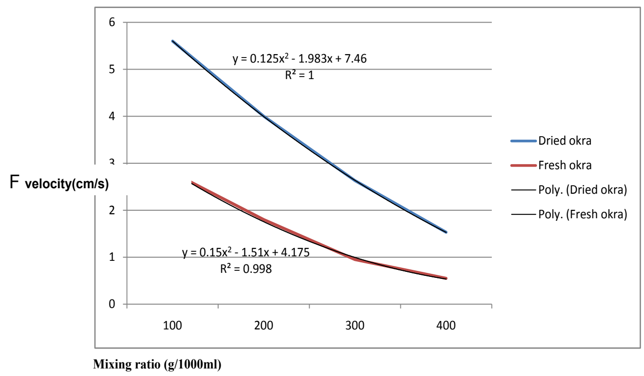

Figure 3: Effect of drying on fall velocity.

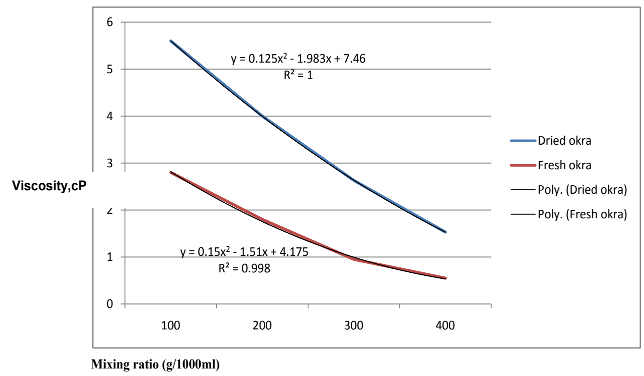

Figure 4: Effect of drying on viscosity of okra.

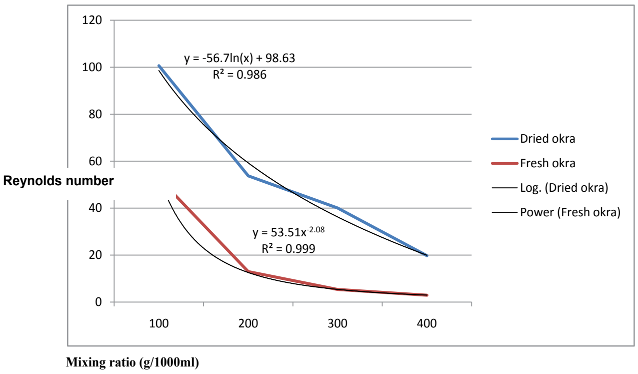

Figure 5: Effect of drying on Reynolds number of okra suspension.

Conclusions

The effects of oven-drying on some flow characteristics of Okra were evaluated. Data shows that viscosity, density and fall time were significantly reduced by drying. Conversely, Reynolds number and ball fall velocity were found to increase as Okra is dried and grinded to powder.

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