THE EFFECTS OF DRYING ON SOME SELECTED ENGINEERING PROPERTIES OF SOAKED BROWN-SPECKLED AFRICAN YAM BEAN SEEDS

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ABSTRACT

This research investigated the effects of drying on some selected engineering properties of soaked brown-speckled African yam bean seeds. The research was borne out of the fact that a number of process parameters like soaking time, drying, etc, have not been linked to the engineering properties of soaked brown-speckled African yam bean seeds and as a result, it becomes overwhelmingly important to investigate whether any such relationship exists between them. Freshly harvested brown-speckled African yam bean seeds purchased from the market were subjected to manual cleaning, soaking in water for 90minutes, 180minutes, 270 minutes, 360minutes, 450minutes and 540minutes and drying of the soaked samples at a fixed temperature of 60^0C for 5hours. For each process parameter, the engineering properties of the samples (brown-speckled African yam bean seeds) were taken and the data generated was plotted against soaking time. The variations observed in each process parameter as soaking time increased could not in any way be interpreted as the desired link hence the use of statistical techniques to analyse the data to show whether drying has any significant influence on the engineering properties of soaked brown-speckled African yam bean seeds. The results of the statistical analysis showed that the chosen process parameters significantly influenced some of the engineering properties the brown-speckled African yam bean seeds. This implies that brown-speckled African yam bean seeds unloaded from a dryer and conveyed for further processing would ultimately cause equipment adjustment due to the significant changes that have taken place in its sizes, mass, true density, volume, bulk density and porosity.

Keywords: African Yam Bean, Engineering Properties, Soaking time, Drying.

INTRODUCTION

African yam bean (*Sphenostylis sternocarpa)* is a leguminous crop which belongs to the family of Fabaceae and genus sphenostylis (Ojukwu et al., 2012). It is a bean that comes in different colours such as black, white, grey and brown. Irrespective of specie, the African yam bean plant is an annual crop whose seeds are usually contained in pods just like cowpea (Asoiro and Ani, 2011). The pods are often born on climbing stems whose leaves are wide and shaped like a heart. On a single stem, a number of pods are spaced apart at different points along it. These pods (where the leguminous seeds are held) together with the edible tubers (which contain classified nutrients good for human consumption) that look like elongated sweet potatoes are harvested from 150 to 240 days after sowing (Ecocrop, 2009; Ezueh, 1984). African yam bean is an underutilized food legume crop grown in most parts of the hot and humid tropical regions of Africa. It is mostly cultivated at middle and low altitudes. In Nigeria alone, extensive cultivation of the crop has been reported in the eastern, western and southern parts of Nigeria. Although the crop is not as popular as the other major legumes, it is very rich in protein and other healthy food minerals like potassium and phosphorous (Frank-Peterside et al., 2002). The protein content in African yam bean ranges between 21 and 29% whereas, the tuber contains about 2 to 3 times the amount in potatoes and higher than those in yam. In recent years, African yam bean is increasingly becoming an attractive food crop owing to its very high protein content. This is even as many recent research efforts (Nwosu, et al., 2014; Njoku et al., 1989; Abbey and Berezi, 1988) are consistently been tailored towards making the crop an alternative to the regular cowpea by aiming to improve on its processing qualities such as producing seeds with softer seed coats as well as having the product being cooked at considerably short periods of time as against the normal four-hour period required to cook the seeds to levels which can be consumed by humans.

LITERATURE REVIEW

Processing of African yam bean often involves a number of unit operations and this depends on the kind of end product desired from the product (Asoiro and Ani, 2011). For some certain African yam bean seeds whose end products are moi-moi and flour, soaking and drying will inevitably be one of the major unit operations respectively. Interestingly, the quality of the end products will, to a large extent, depend on the appropriateness of the process parameters involved such as the duration of time for which the African yam bean seeds should be soaked before grinding to form the thick paste used in making of the moi-moi as well as issues relating to the drying characteristics of the African yam bean seeds (Frank-Peterside et al., 2002; Nwosu, et al., 2014; Njoku et al., 1989). Going by these views, it becomes pertinent to observe that since some process parameters play a major role in the desirability of an end product and as such, a lot of emphases is being placed on its optimization, would it be fairly consistent if it is assumed that having similar process parameters as inputs may also show some influence on the engineering properties of African yam bean seeds? Or would the values of the engineering properties of African yam bean seeds obtained during experimentation depend on the use of individual process parameter? Or still, could it be that the engineering properties of African yam bean seeds depend on the use of combined process parameters such as soaking and drying? And if so, would it be significant? These questions point to the fact that a lot still needs to be done if the quest to have African yam bean as a popular legume with unlimited applications is to be fulfilled. It is based on this that this research is initiated with a view to providing meaningful answers to a myriad of questions that have continued despite many previous research efforts aimed at solving such problems. To achieve this, the following objectives were considered: to determine the engineering properties of freshly harvested brown-speckled African yam bean seeds such as: length, width, thickness, geometric mean diameter, mass, volume, sphericity, true density, bulk density, porosity, angle of repose and coefficient of static friction; to determine the engineering properties of soaked brown-speckled African yam bean; to determine the engineering properties of samples of brown-speckled African yam bean seeds that will be soaked for different times before it is subjected to drying at a fixed temperature of 60^0C for 5hours; to determine the effect of soaking and drying on those selected engineering properties of soaked brown-speckled African yam bean seeds using statistical analysis.

METHODOLOGY

Experimental procedures

Mature seeds from freshly harvested brown-speckled African yam bean pods were bought at mile 3 market, Port Harcourt, Rivers State. The seeds were cleaned manually to remove all foreign matter such as dirt, pieces of stones, and broken seeds. The cleaned seeds were then soaked in water for 90minutes, 180minutes, 270 minutes, 360minutes, 450minutes and 540minutes and were labelled as Treatment A, B, C, D, E, and F respectively. Soaked and well-drained samples of African yam bean seeds were subjected to oven air dryer at 60^oC for 5hours. The engineering parameters in consideration were critically determined for unsoaked, soaked and dried African Yam Bean seeds. This will be achieved by using Table 1.

Table 1: Experimental Procedure for the Determination of the Engineering Properties of Brown-speckled AYB seeds

S/N	Input Parameter	Response Parameter	Response Parameter Code
1	Unsoaked AYB (freshly harvested)	Length, Width, Thickness, Geometric mean diameter, Sphericity, Mass, Volume, True density, Bulk density, Porosity, Static coefficient of friction and Angle of Repose.	Engineering Properties (B-s1)
2	Soaked AYB	Length, Width, Thickness, Geometric mean diameter, Sphericity, Mass, Volume, True density, Bulk density, Porosity, Static coefficient of friction and Angle of Repose.	Engineering Properties (B-s2)
3	Dried AYB	Length, Width, Thickness, Geometric mean diameter, Sphericity, Mass, Volume, True density, Bulk density, Porosity, Static coefficient of friction and Angle of Repose.	Engineering Properties (B-s3)

At the end of these experiments, three (3) different statistical analyses were done so that statistical analysis (1) involved a comparison between the engineering properties of unsoaked brown-speckled AYB seeds and the engineering properties of soaked brown-speckled AYB seeds; statistical analysis (2) involved a comparison between the engineering properties of unsoaked brown-speckled AYB seeds and the engineering properties of dried brown-speckled AYB seeds while the statistical analysis (3) involved a comparison between the engineering properties of soaked brown-speckled AYB seeds and the engineering properties of dried brown-speckled AYB seeds. For the purpose of clarity, the foregoing is put in tabular form as shown in Table 2.

Table 2: Statistical Analysis and Expected Outcome

S/N	Statistical Analysis	Components of the Analysis	Expected Statistical Outcome
1	Statistical analysis 1	Comparison between (B-s1) and (B-s2)	It is either statistically significant or not statistically significant
2	Statistical analysis 2	Comparison between (B-s1) and (B-s3)	It is either statistically significant or not statistically significant
3	Statistical analysis 3	Comparison between (B-s2) and (B-s3)	It is either statistically significant or not statistically significant

Where (B-s1), (B-s2) and (B-s3) represents the engineering properties of the Unsoaked brown-speckled AYB seeds, Soaked brown-speckled AYB seeds and Dried brown-speckled AYB seeds respectively.

The experiment was done for three (3) replicates and the average result was recorded. The results obtained from the various experiments were subjected to further statistical analysis to ascertain whether the combined use of soaking and drying as input process parameters has any significant influence on the selected engineering properties of brown-speckled African yam bean seeds. The experimental determinations for each input process parameter were carried out at the Department of Food science and technology Laboratory, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, between July 27, 2015, to October 8, 2015.

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Experimental Determinations

Determination of Soaking Time of African Yam Bean Seeds

Soaking is a unit operation utilized mostly in processing and preservation to cause some targeted alterations in a product such as changes in the outcomes of certain constituents which are considered to be very important to the process like starch yield and moisture content (Princewill and Ogwo, 2016). Soaking is mainly characterized by the duration in which the biological material is submerged in water and the amount of water that it can absorb into its cells. The duration in which the biological material is allowed to stay submerged in water is called soaking time while the amount of water the product absorbs during such a time as compared to the amount of water it had in it before it was soaked is called rehydration ratio. On account of this, soaking time is preferably chosen as the process parameter to be used in this research work. Hence, soaking times of 90minutes, 180minutes, 270 minutes, 360minutes, 450minutes and 540minutes were used as the period for which the African yam bean seeds were completely submerged in water before it was drained. A stopwatch was used to determine the various soaking times.

Determination of Drying Responses of African Yam Bean Seeds

At the end of each soaking time, a sample is drawn from the lot and weighed. Let the weight of this sample be denoted as $(w_i)_{t=0}$. At the end of the weighing process, the sample is inserted into the dryer (oven) at 60°C for actual drying. The drying condition at which the sample is to be dried is denoted as $\{[(MC_{wb})_{i[\text{A, B, C, D, E, and F}]}], \text{T}_{60^o C}\}$. After every 1hour, the sample is withdrawn from the oven and its weight was taken. Let the subsequent weights of the sample undergoing drying be denoted as $(w_f)_{\text{t=10, 20, 30,...n}}$. For each subsequent weight of the sample, the new moisture content will be attained. Let the subsequent moisture content, after the initial moisture content of the sample, be denoted as $[(MC_{wb})_f]_{\text{t=10mins,20mins,30mins,...n}}$. The product is dried for 5hours. At the end of this period, the experiment is terminated and the dried sample is withdrawn from the oven for the determination of the engineering properties of the seeds.

Determination of moisture content

The air oven drying method was used for the moisture content determinations. Moisture content is an expression of the percentage of water contained in a wet sample. According to Mohsenin (1980) the moisture content of a given sample of biological material can be expressed mathematically as:

$$MC_{wb} = \frac{w-d}{w}$$

However, since our focus is to determine the initial moisture content, the equation is modified and can be written as:

$$(MC_{wb})_i = \left(\frac{w_i - d}{w_i}\right)$$

Where,

$(MC_{wb})_i$ The = initial moisture content of the sample

w_i The = initial weight of the sample

d = oven dry weight of the sample

As the drying process proceeds, it will be impractical to draw samples for moisture content determination using oven drying method after every 1hour of drying; hence the need to develop a mathematical solution through which the moisture content can be determined continuously without resorting to oven drying method. The equation through which the subsequent moisture content of the samples will be determined is given as:

$$\left[\left(MC_{wb}\right)_f\right]_{t=10\text{mins}} = \left[\left(MC_{wb}\right)_i\right]_{t=0} + \frac{[d]_{T=0}\left[\left(w_f\right)_{t=10\text{mins}} - \left(w_i\right)_{t=0}\right]}{\left(w_f\right)_{t=10\text{mins}} \times \left(w_i\right)_{t=0}}$$

Determination of Sample Weight

In this experiment, the weights of the initial moisture content of the sample and the subsequent moisture content determination are achieved by the use of an electronic weighing balance with 0.1mg readability.

Determination of Drying

There are various drying methods but in this research work, the air oven drying method was used. The method consist of weighing an empty moisture Can and loading it with samples of African yam bean seeds which was soaked in water for 90minutes, 180minutes, 270 minutes, 360minutes, 450minutes and 540minutes and labelled as Treatment A, B, C, D, E, and F respectively. Each treatment was subjected to oven drying at 60^{o}C. After every 1 hour, the sample is withdrawn from the oven and allowed to cool in a desiccator for 5mins and the subsequent weight is taken. From the value obtained, the subsequent moisture content was calculated. This process was continuously used to obtain the subsequent sample weights and the subsequent moisture contents throughout the 5hour drying period.

Determination of Engineering Properties of African Yam Bean Seeds

An Italian made light digital vernier calliper with a sensitivity of 0.001mm was used to obtain the size [length or major diameter (a), width or minor diameter (b) and thickness or intermediate diameter (c)] of each unit seed of 10 seeds sampling. A single seed was placed within the external jaws of the vernier calliper and the thumb screw adjusted until the seed is just firmly held before taking its reading. The applied force on the adjustable thumb screw of the vernier calliper was manually controlled in order to minimize damage to the sample due to excessive compressive force. The process was done for three (3) replications and the average result calculated and recorded.

Geometric mean diameter was determined for each given input process parameter by using the average measurements of the length, width and thickness taken for each unit seed of 10 seeds sampling and substituting it into the expression presented by Mohsenin (1980): $D_g = (abc)^{\frac{1}{3}}$. Where D_g is the Geometric Mean Diameter?

Sphericity was calculated using the expression by Mohsenin (1980): $\phi = \frac{(abc)^{\frac{1}{3}}}{a}$.

Mass was determined by weighing each unit seed of 10 seeds sampling on an electronic scale with an accuracy of 0.01g. The experiment was repeated thrice and the average value of the mass was used. The volume of each unit seed of 10 seeds sampling was calculated from the expression presented by Mohsenin (1980):

Volume = (Sphericity)^3×volume of the smallest circumscribing sphere

Where the volume of the smallest circumscribing sphere = $\frac{\pi}{6} \times a^3$

True density of each unit seed of 10 seeds sampling was determined by dividing the mass of a single African yam bean seed with the volume of that particular single seed. This ratio was suggested by Mohsenin (1980) and it is expressed mathematically as:

$$\text{True density} = \frac{\text{Mass of a single African yam bean seed}}{\text{Volume of that particular seed}}$$

Bulk density was determined by using a standard measurement procedure in which bulk seeds were poured from a standard height of 15cm into a standard container (20cmx20cmx10cm) at a constant rate. The cone formed by the grains above the standard container was then levelled with a hard 30cm meter rule without compacting the bulk grains. Mathematically:

$$\text{Bulk density} = \frac{\text{Mass of a bulk seeds in the box}}{\text{Volume of the box}}$$

This method has been used by (Princewill and Ogwo, 2014; Princewill and Ogwo, 2016 and Gebreselassie, 2012).
A mathematical equation for which the porosity is a function of the bulk density and true density has been suggested by several research workers (Ogunjimi et al., 2002; Ozguven and Vursavus, 2005; Princewill and Ogwo, 2016) as a practical means of determining the porosity of bulk seeds. It is, however, stated as: $\varepsilon = 100\left(1 - \frac{\rho_b}{\rho_s}\right)$ and was used in this work to determine the porosity of bulk African yam bean seeds. The terms $(\varepsilon, \rho_b, \rho_s)$ used in the equation denote porosity, bulk density and true density respectively.
The static coefficient of friction was determined by using the method described by Vikash et al (2013). The following equation was used to calculate the static coefficient of friction:

$$\text{SCF}(\mu) = \frac{\text{Limiting frictional force}}{\text{Normal reaction}}$$

The angle of repose was measured by using a hollow wooden box filled with the seeds and then mounted on a tilting table top as described by Igbeka et al (2006). The value for the angle of repose for each input process parameter was obtained by reading off the angle on a protractor mounted at the side of the tilting table when the hollow wooden box filled with the seeds is just about to slide. This experiment was replicated three (3) times.

RESULTS

A research was carried out to investigate the influence of some input process parameters on the engineering properties of brown-speckled African yam bean seeds. In carrying out this research, both direct and indirect measuring tools were used to obtain several observations which represent the response parameters of the brown-speckled African yam bean seeds such as the size, geometric mean diameter, mass, sphericity, volume, true density, bulk density, porosity, coefficient of static friction and angle of repose. Considering the fact that composite input process parameters such as the ones used in this research work have not been checked against the engineering properties of brown-speckled African yam bean seeds, one might think that the product would have responses that would not differ significantly. However, this notion became irrelevant when the findings of this research work proved otherwise. Tables 1, 2 and 3 show the experimental results for un-soaked, soaked and dried brown-speckled African yam bean seeds while figures 1-9 show the graphical representations of the different response parameters and are presented below. Statistical analysis to evaluate the combined influence of soaking and drying on the engineering properties of brown-speckled African yam bean seeds are presented in Tables 4-12.

Table 1: Average values of some selected engineering properties of brown-speckled African yam bean seeds arising from samples subjected to 0 (mins) of soaking (un-soaked AYB) and 0hr of drying

duration of soaking (mins)	Length (mm)	width (mm)	thickness (mm)	Geometric Mean Diameter (mm)	Sphericity	Mass (g)	Volume (cm^3)	True Density (g/cm^3)	Bulk Density (g/cm^3)	Porosity	Static Coefficient	Angle of Repose
0.00	7.74	6.92	5.84	6.79	1.16	0.26	0.16	1.59	0.90	43.24	0.72	20.55

(soaked AYB) and 0hr of drying

duration of soaking (mins)	Length (mm)	width (mm)	thickness (mm)	Geometric Mean Diameter (mm)	Sphericity	Mass (g)	Volume (cm^3)	True Density (g/cm^3)	Bulk Density (g/cm^3)	Porosity	Static Coefficient	Angle of Repose
90	8.24	7.09	6.19	7.12	1.15	0.36	1.89E-01	1.90	0.79	58.45	0.72	25.22
180	8.69	7.26	6.54	7.44	1.14	0.39	2.16E-01	1.81	0.76	57.90	0.70	26.18
270	8.67	6.71	6.03	7.05	1.17	0.45	1.84E-01	2.45	0.69	71.84	0.82	30.2
360	11.87	7.77	6.89	8.60	1.25	0.59	3.33E-01	1.77	0.71	59.96	0.73	26.65
450	11.08	8.76	7.99	9.19	1.15	0.73	4.06E-01	1.80	0.69	61.62	0.80	28.39
540	10.75	8.02	7.31	8.57	1.17	0.74	3.30E-01	2.24	0.74	67.00	0.83	29.39

duration of soaking (mins)	Length (mm)	width (mm)	thickness (mm)	Geometric Mean Diameter (mm)	Sphericity	Mass (g)	Volume (cm^3)	True Density (g/cm^3)	Bulk Density (g/cm^3)	Porosity	Static Coefficient	Angle of Repose
90	8.14	7.32	6.95	7.45	1.07	0.43	0.22	1.98	0.77	61.17	0.54	18.80
180	8.16	7.38	7.04	7.51	1.07	0.42	0.22	1.89	0.76	59.83	0.53	19.78
270	7.52	6.58	5.84	6.61	1.13	0.34	0.15	2.25	0.73	67.51	0.75	27.71
360	9.46	8.53	6.24	7.96	1.27	0.52	0.26	1.97	0.66	66.54	0.74	27.12
450	11.35	7.59	6.94	8.42	1.21	0.62	0.31	1.98	0.70	64.66	0.81	28.66
540	10.59	7.59	6.9	8.22	1.19	0.60	0.29	2.07	0.68	67.09	0.77	27.17

Geometric Mean Diameter

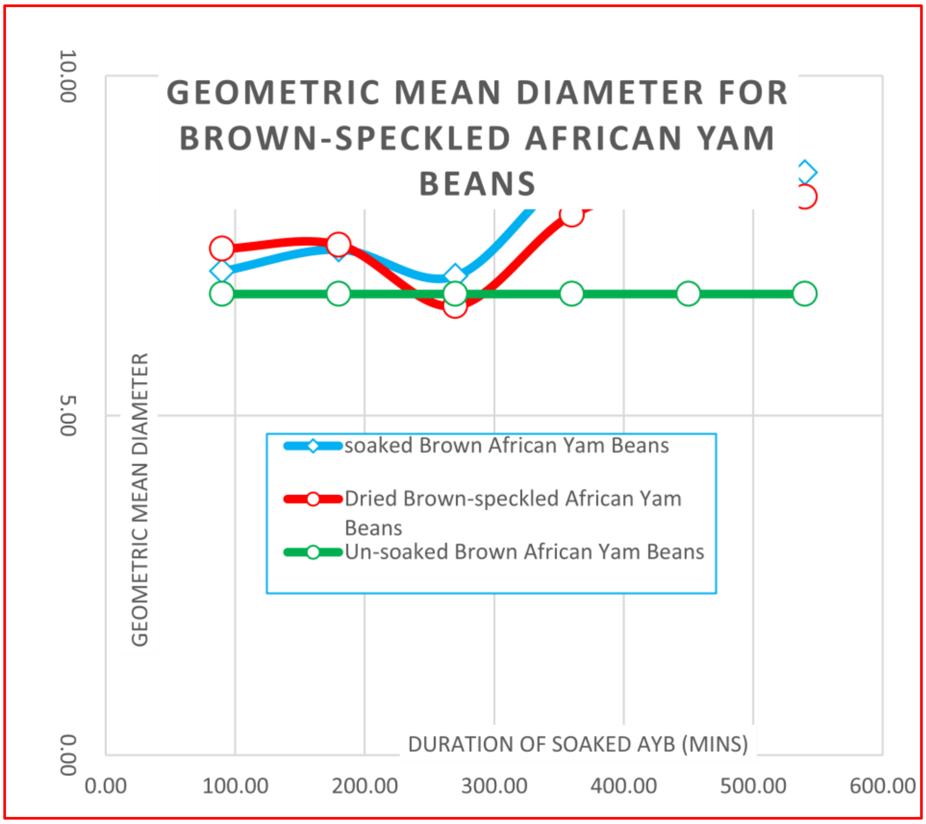

Figure 1: Geometric mean diameter response graph for samples subjected to un-soaked, soaked and dried process conditions.

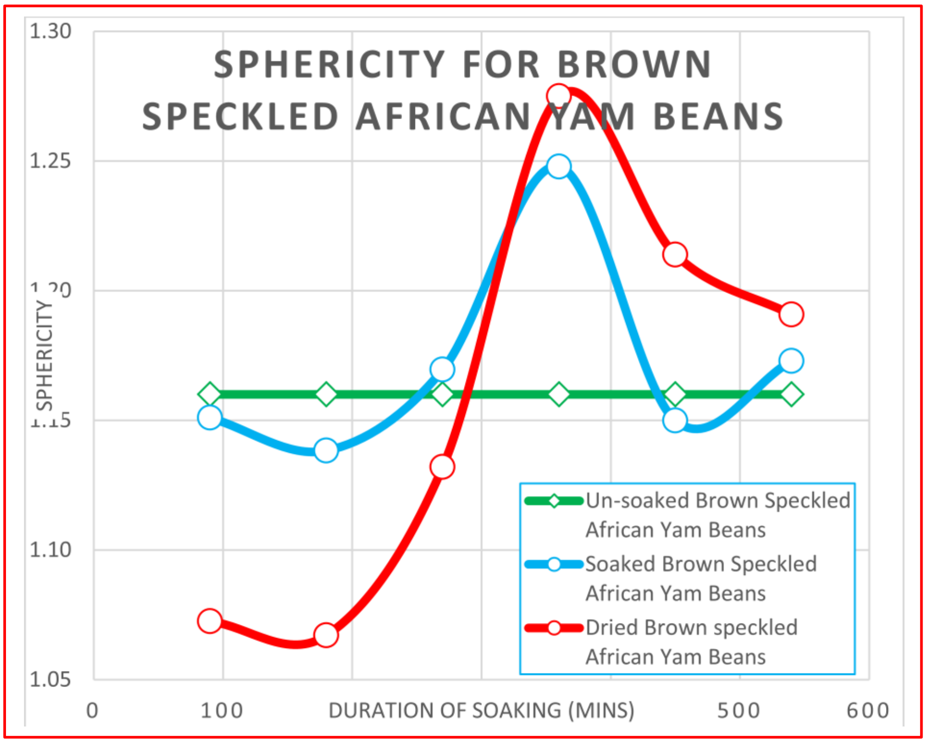

Figure 2: Sphericity response graph for samples subjected to un-soaked, soaked and dried process conditions.

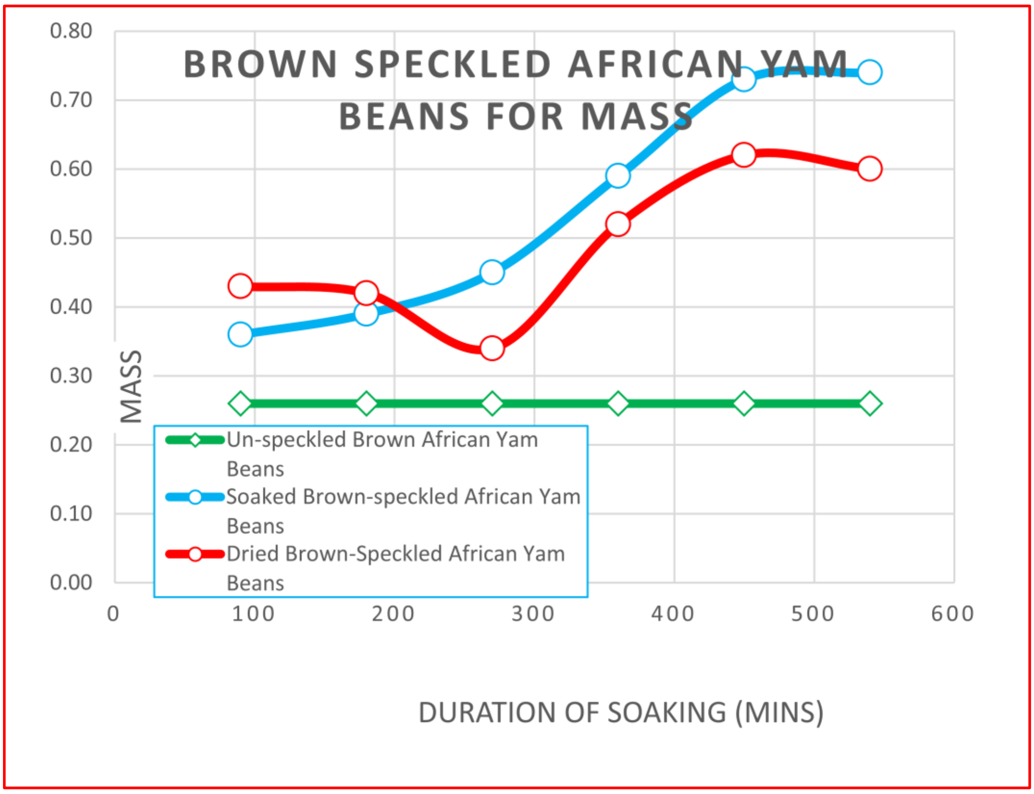

Figure 3: **Mass response graph for samples subjected to un-soaked, soaked and dried process conditions**

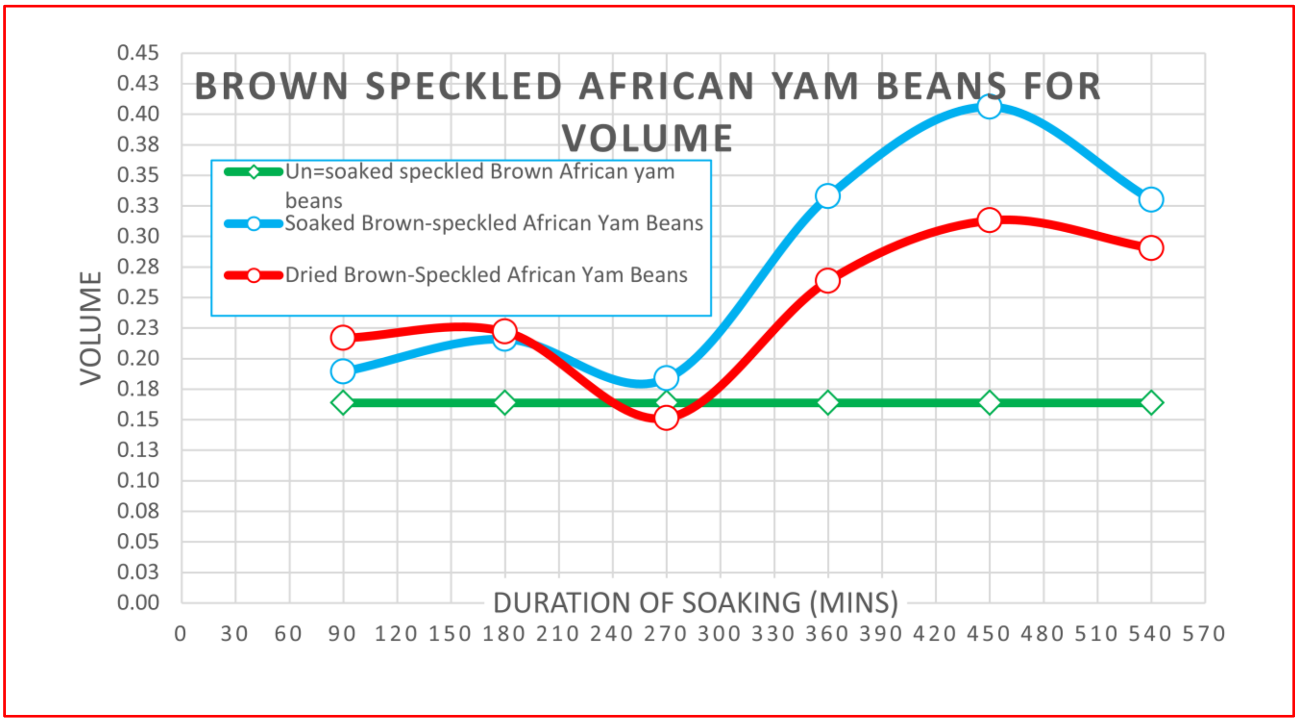

Figure 4: **Volume response graph for samples subjected to un-soaked, soaked and dried process conditions.**

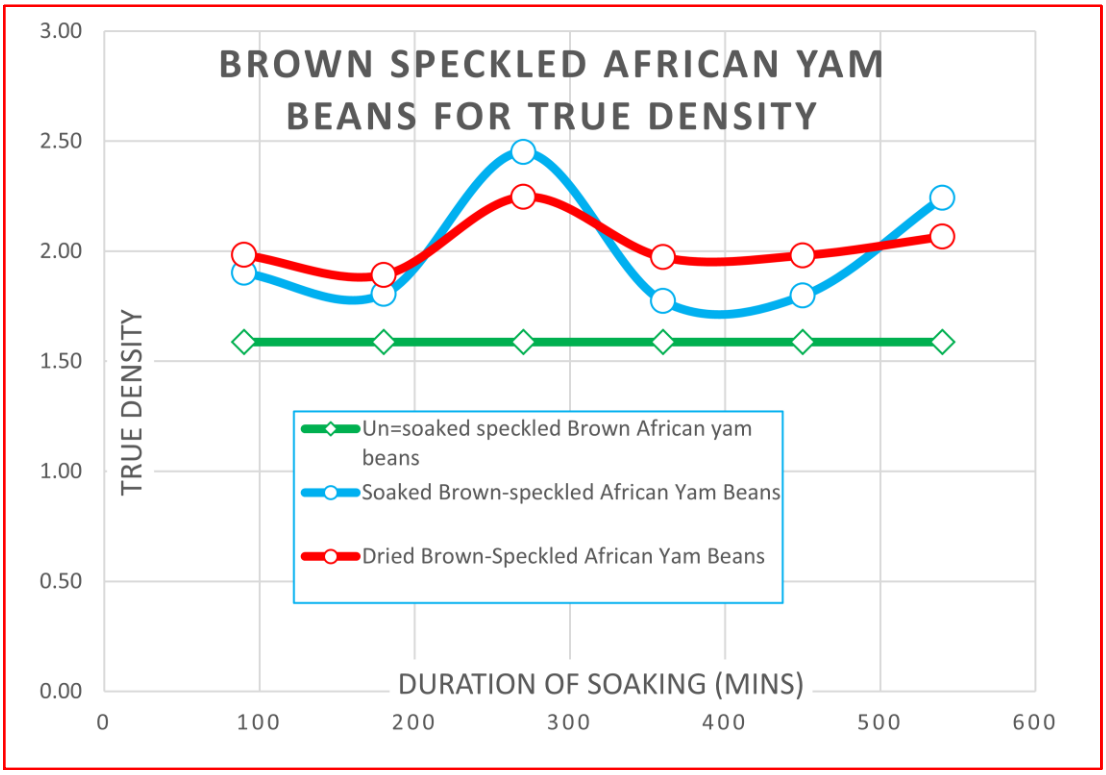

Figure 5: **True density response graph for samples subjected to un-soaked, soaked and dried process conditions.**

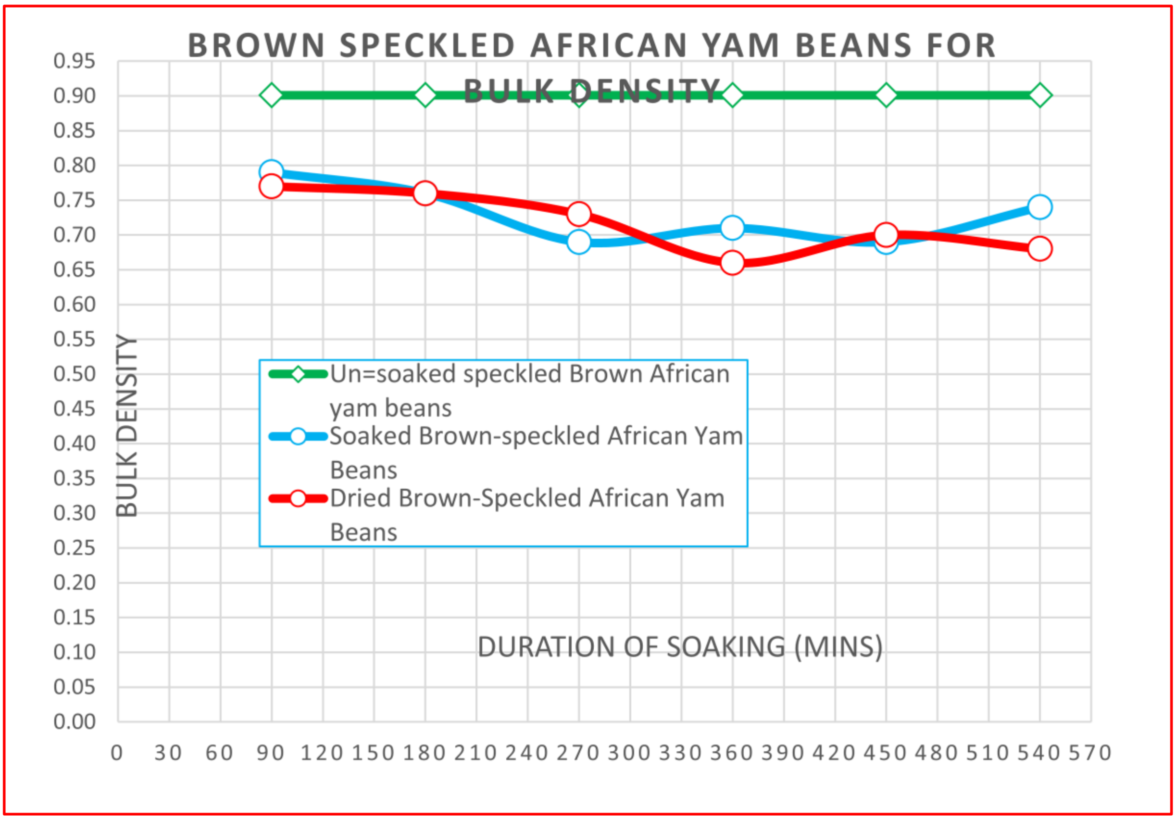

Figure 6: **bulk density response graph for samples subjected to un-soaked, soaked and dried process conditions.**

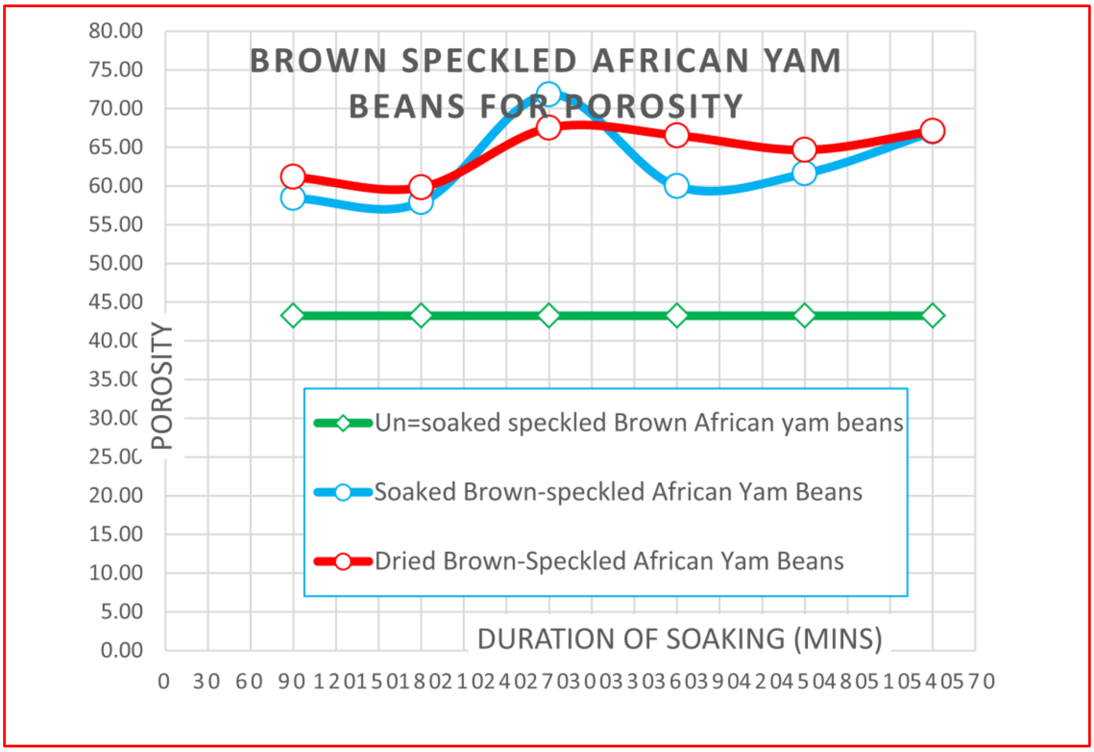

Figure 7: **Porosity response graph for samples subjected to un-soaked, soaked and dried process conditions**

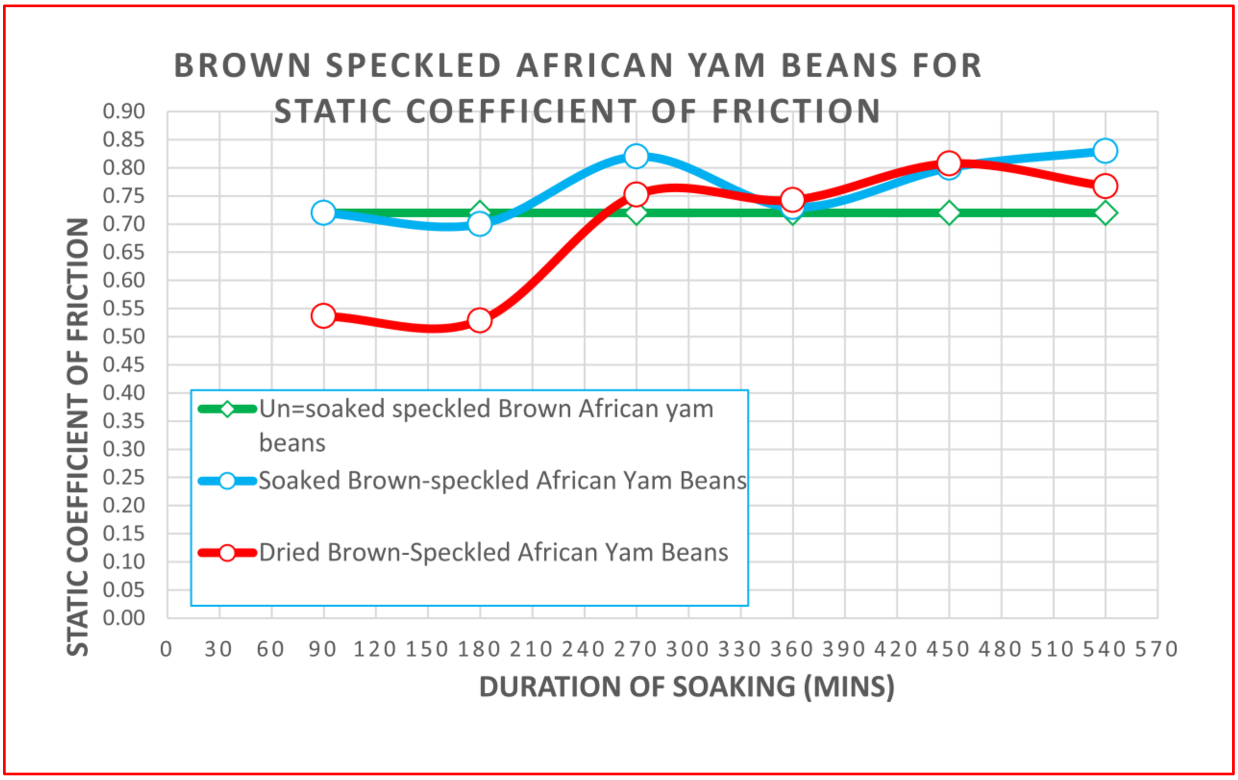

Figure 8: **Porosity response graph for samples subjected to un-soaked, soaked and dried process conditions.**

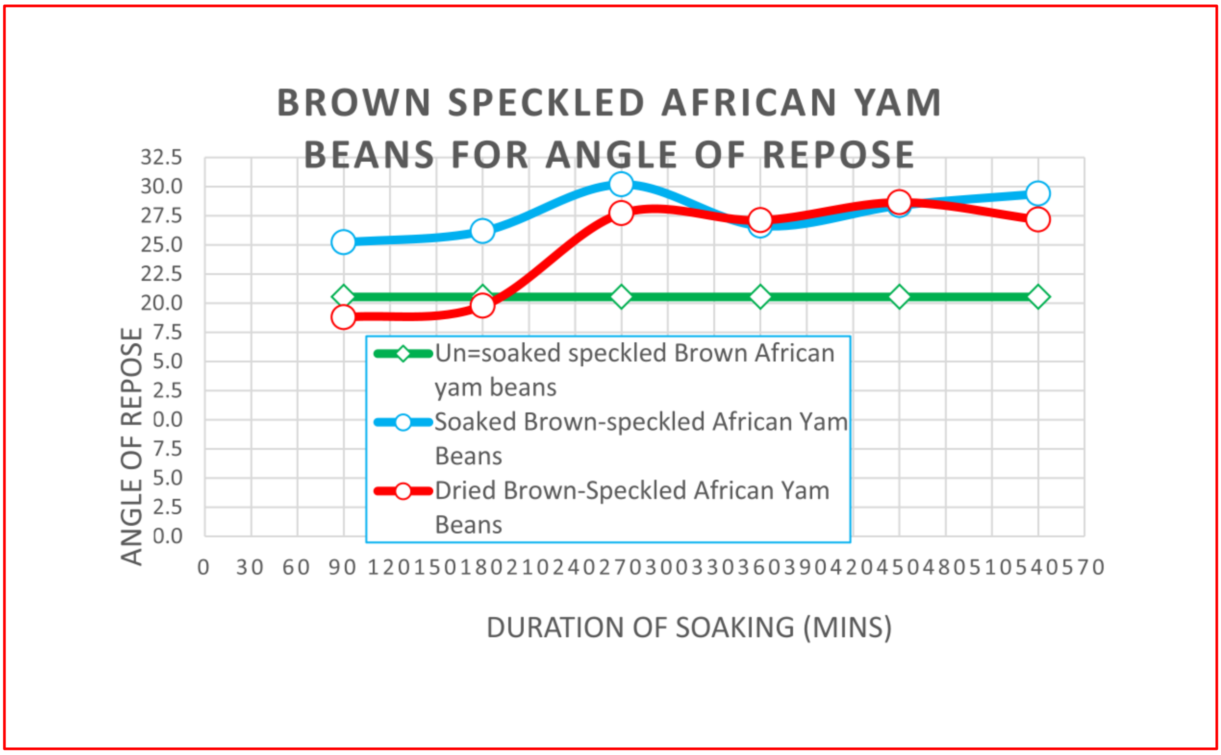

Figure 9: Angle of Repose graph for samples subjected to un-soaked, soaked and dried process conditions.

Table 4: Expected Statistical Outcome of Geometric Mean Diameter Analysis

Components of the Analysis	Absolute mean difference	DFW	MSW	1/N1+1/N2	Alpha	$t_{v,a}$	LSD	Expected Statistical Outcome
Comparison between (B-s1) and (B-s2)	1.21	15.00	0.41	0.33	0.05	2.13	0.79	Significant
Comparison between (B-s1) and (B-s3)	0.91	15.00	0.41	0.33	0.05	2.13	0.79	Significant
Comparison between (B-s2) and (B-s3)	0.30	15.00	0.41	0.33	0.05	2.13	0.79	Not Significant

Table 5: Expected Statistical Outcome of Sphericity Analysis

Components of the Analysis	Absolute mean difference	DFW	MSW	1/N1+1/N2	Alpha	$t_{v,a}$	LSD	Expected Statistical Outcome
Comparison between (B-s1) and (B-s2)	0.01	15.00	0.003	0.33	0.05	2.13	0.07	Not Significant
Comparison between (B-s1) and (B-s3)	0.00	15.00	0.003	0.33	0.05	2.13	0.07	Not Significant
Comparison between (B-s2) and (B-s3)	0.01	15.00	0.003	0.33	0.05	2.13	0.07	Not Significant

Table 6: Expected Statistical Outcome of Mass Analysis

Components of the Analysis	Absolute mean difference	DFW	MSW	1/N1+1/N2	Alpha	$t_{v,a}$	LSD	Expected Statistical Outcome
Comparison between (B-s1) and (B-s2)	0.28	15.00	0.013	0.33	0.05	2.13	0.14	Significant
Comparison between (B-s1) and (B-s3)	0.23	15.00	0.013	0.33	0.05	2.13	0.14	Significant
Comparison between (B-s2) and (B-s3)	0.06	15.00	0.013	0.33	0.05	2.13	0.14	Not Significant

Table 7: Expected Statistical Outcome of True Density Analysis

Components of the Analysis	Absolute mean difference	DFW	MSW	1/N1+1/N2	Alpha	$t_{v,a}$	LSD	Expected Statistical Outcome
Comparison between (B-s1) and (B-s2)	0.41	15.00	0.032	0.33	0.05	2.13	0.22	Significant
Comparison between (B-s1) and (B-s3)	0.44	15.00	0.032	0.33	0.05	2.13	0.22	Significant
Comparison between (B-s2) and (B-s3)	0.03	15.00	0.032	0.33	0.05	2.13	0.22	Not Significant

Table 8: Expected Statistical Outcome of Volume Analysis

Components of the Analysis	Absolute mean difference	DFW	MSW	1/N1+1/N2	Alpha	$t_{v,a}$	LSD	Expected Statistical Outcome
Comparison between (B-s1) and (B-s2)	0.11	15.00	0.004	0.33	0.05	2.13	0.08	Significant
Comparison between (B-s1) and (B-s3)	0.08	15.00	0.004	0.33	0.05	2.13	0.08	Significant
Comparison between (B-s2) and (B-s3)	0.03	15.00	0.004	0.33	0.05	2.13	0.08	Not Significant

Table 9: Expected Statistical Outcome of Bulk Density Analysis

Components of the Analysis	Absolute mean difference	DFW	MSW	1/N1+1/N2	Alpha	$t_{v,a}$	LSD	Expected Statistical Outcome
Comparison between (B-s1) and (B-s2)	0.17	15.00	0.001	0.33	0.05	2.13	0.04	Significant
Comparison between (B-s1) and (B-s3)	0.18	15.00	0.001	0.33	0.05	2.13	0.04	Significant
Comparison between (B-s2) and (B-s3)	0.01	15.00	0.001	0.33	0.05	2.13	0.04	Not Significant

Table 10: Expected Statistical Outcome of Porosity Analysis

Components of the Analysis	Absolute mean difference	DFW	MSW	1/N1+1/N2	Alpha	$t_{v,a}$	LSD	Expected Statistical Outcome
Comparison between (B-s1) and (B-s2)	19.55	15.00	13.635	0.33	0.05	2.13	4.54	Significant
Comparison between (B-s1) and (B-s3)	21.22	15.00	13.635	0.33	0.05	2.13	4.54	Significant
Comparison between (B-s2) and (B-s3)	1.67	15.00	13.635	0.33	0.05	2.13	4.54	Not Significant

Table 11: Expected Statistical Outcome of the Static Coefficient of friction Analysis

Components of the Analysis	Absolute mean difference	DFW	MSW	1/N1+1/N2	Alpha	$t_{v,a}$	LSD	Expected Statistical Outcome
Comparison between (B-s1) and (B-s2)	0.05	15.00	0.006	0.33	0.05	2.13	0.10	Not Significant
Comparison between (B-s1) and (B-s3)	0.03	15.00	0.006	0.33	0.05	2.13	0.10	Not Significant
Comparison between (B-s2) and (B-s3)	0.08	15.00	0.006	0.33	0.05	2.13	0.10	Not Significant

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Table 12: Expected Statistical Outcome of Angle of Repose Analysis

Components of the Analysis	Absolute mean difference	DFW	MSW	1/N1+1/N2	Alpha	$t_{v,a}$	LSD	Expected Statistical Outcome
Comparison between (B-s1) and (B-s2)	0.05	15.00	0.006	0.33	0.05	2.13	0.10	Not Significant
Comparison between (B-s1) and (B-s3)	0.03	15.00	0.006	0.33	0.05	2.13	0.10	Not Significant
Comparison between (B-s2) and (B-s3)	0.08	15.00	0.006	0.33	0.05	2.13	0.10	Not Significant

DISCUSSION

Geometric Mean Diameter

Figure 1 shows the graph of geometric mean diameter as plotted against soaking time for samples of African yam bean seeds that were subjected to different process parameters such as unsoaked (0mins of soaking and 0hrs of drying), soaked (90-540mins of soaking and 0mins of drying) and dried (90-540mins of soaking and 5hrs of drying). It was observed that the soaked and dried curves increased between 90-180mins of soaking time but decreased between 180mins and 270mins soaking period. However, the geometric mean diameter for the process parameters under consideration showed an increase between 270-450minutes of the soaking period while a slight drop in the response parameter was observed between 450-540minutes. Remarkably, it was further observed that at about 270 minutes of soaking time, the dried curve decreased below the un-soaked curve. These behaviours indicate that a better drying effect on brown African Yam beans could be achieved when the product is soaked for 270 minutes before it is being dried.

Sphericity

Figure 2 shows plotted values of sphericity for samples subjected to different process parameters such as unsoaked (0mins of soaking and 0hrs of drying), soaked (90-540mins of soaking and 0mins of drying) and dried (90-540mins of soaking and 5hrs of drying). The results indicate that there was an increase in sphericity between 180 to 360minutes as the soaking time increased but it began to decrease thereafter. It thus appears, however, that drying may have contributed significantly to the changes observed in the sphericity of samples of African yam bean seeds subjected to soaking and drying.

Mass

Average values of mass as reported in Tables 1, 2 and 3 are plotted against soaking time and it is shown in Figure 3. The figure shows that the mass increased steadily throughout the soaking period for soaked brown-speckled African yam bean seeds while it showed variable behaviour for the dried samples. The reason for this behaviour is not fully known but the decrease observed in the mass of the dried brown-speckled African yam bean seeds is not unexpected.

Volume

The volume of each African yam bean seeds sample subjected to the three preferred process parameters are plotted against soaking time and it is as shown in Figure 4. A detailed look at the figure reveals that the volume increased during the period of 90 to 180 minutes of soaking time for the soaked and dried curves of samples of brown-speckled African yam bean seeds. Continuing, the volume decreased from 180 to 270 minutes of soaking time for the soaked and dried curves of the brown-speckled African yam bean seeds. However, changes in the volume was observed as the volume increased during the period of 270 to 450 minutes before decreasing slightly during the 450 to 540 minutes soaking time of soaking time for the soaked and dried curves of the brown-speckled African yam bean seeds. At 270 minutes of soaking time, the drying curve has a minimum volume below the volume of the un-soaked curve at the same soaking time. The results suggest that the water adsorbed by the seeds during soaking plus a certain fraction of the moisture held by the seeds before drying were removed during drying, thus implying that at 270 minutes of soaking time that there was no significant soaking effect on the volume of brown-speckled African yam bean seeds.

True Density

The true density of samples of African yam bean seeds subjected to several process parameters is as shown in Figure 5. The figure reveals that the true density of brown-speckled African yam bean seeds has a bell-like shape signifying that its value rises and peaks before it falls again. From the graph, it can be noted further that the rise and fall behaviour of the true density of African yam bean seeds could be continuous if the samples were soaked beyond 540mins. The reason for this behaviour is not known but further research by comparing the data obtained in this work with those to be obtained for other seeds or the seeds of some other species of the bean could be a pointer in that regard.

Bulk density

Tables 1, 2 and 3 show average values of bulk density for brown-speckled African yam bean seeds samples at the three specified process parameters. A combine plot of these values of bulk density against soaking time is shown in Figure 6. The results show that the bulk density decreased as the soaking time increased. The results further reveal that the bulk densities of brown-speckled African yam bean seeds for un-soaked were higher than the soaked and dried conditions as soaking time increased. The reason for this behaviour could be attributed to the high values of porosity of encountered during soaked and drying conditions of the beans.

Porosity

Average values of porosity as obtained from Tables 1, 2 and 3 are plotted against soaking time and it is shown in Figure 7. The combined plot of the response parameter for each process parameter indicates that high values of porosity were recorded during the soaked and dried conditions of brown-speckled African yam bean seeds. From the figure, it can be seen that continuous changes in the values of porosity were observed during 90-540mins of soaking time for soaked and dried brown-speckled African yam bean seeds before it peaked at 270mins. Since the values of porosity for soaked and dried conditions were higher than those obtained for un-soaked condition at the correspondent soaking time, it suggest that the combine use of soaking and drying as input process parameters may have some influence on the observed response parameter. Besides, another reason for this behaviour can be attributed to the fact that during soaking, the seeds increase in its sizes thus leading to an increase in porosity of the seeds. Consequently, when a sample of the soaked seeds is subjected to a preferred drying condition, the seeds decrease in its sizes but never shrinks to the sizes of its unsoaked condition hence the porosity of each dried sample remained higher than those of the unsoaked samples.

Static coefficient of friction

Experimental results for the static coefficient of friction for brown-speckled African yam bean seed samples subjected to three (3) separate process parameters are plotted against soaking time and it is shown in Figure 8 above. From the figure, it can be seen that the static coefficient of friction increased as the soaking time increased. But during the soaking period of 90 to 200 minutes for soaked condition and 90 to 255 minutes for the dried condition, the values of static coefficient of friction were below those obtained for the seeds under un-soaked condition. However, beyond 180mins of soaking time the values of static coefficient of friction for the soaked and dried conditions began to increase. An explanation that supports this behaviour can be derived from the fact that increase in soaking time causes a simultaneous increase in the ability of the seeds to stick to surfaces it comes into contact with due to its carbohydrate content thus resulting to higher values of static coefficient of friction of brown-speckled African yam bean seeds during those conditions.

Angle of repose

Figure 9 shows a plot of average values of the angle of repose against soaking time. The values used in the plot were obtained from Tables 1, 2 and 3. Both the Tables and Figure 9 provide numerical evidence that the angle of repose increased steadily as soaking time increased. A rapid increase in the values of the angle of repose was observed between 90 to 270 minutes of soaking time for the soaked and dried conditions of samples of the brown-speckled African yam bean seeds though its values for the dried condition of the seeds were initially lower than those obtained for the unsoaked condition at the corresponding soaking time (i.e. at the same soaking time) during 90 to 200 minutes of soaking time. The reason for this behaviour follows closely to the views earlier expressed about the static coefficient of friction of the brown-speckled African yam bean seeds.

Statistical Analysis to Determine Whether the Combined Use of Soaking and Drying as Input Process Parameters has any Significant Influence on the Selected Engineering Properties of Brown-speckled African Yam Bean Seeds

Tables 4-12 show the results of the statistical analysis to determine whether the combined use of soaking and drying as composite input process parameters have some influence on the selected engineering properties of brown-speckled African yam bean seeds. The results of the statistical analysis showed that the chosen process parameters significantly influenced some of the engineering properties the brown-speckled African yam bean seeds. This implies that brown-speckled African yam bean seeds unloaded from a dryer and conveyed for further processing would ultimately cause equipment adjustment due to the significant changes that have taken place in its sizes, mass, true density, volume, bulk density and porosity.

CONCLUSIONS

This study investigated the influence of drying on some selected engineering properties of soaked brown-speckled African yam bean seeds. Un-soaked, soaked and dried conditions were chosen as input parameters and the response of samples of African yam bean seeds during each of those conditions were taken as output parameters. The response parameters

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measured during each condition were plotted against soaking time. The plot showed variations of each response parameter during each condition as soaking time increased without giving any clear indication as to how each of those conditons influenced the preferred response parameters. This, however, prompted the use of statistical method to help indicate whether the combine use of a processing and a preservation parameters like soaking and drying, respectively, as composite input parameters contributes significantly to the changes observed in the response parameters of interest. From the results of the statistical analysis obtained, it has been shown that soaking and drying has some effect on the selected engineering properties of brown-speckled African yam bean seeds.

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REFERENCES

Abbey, B.W. & Berezi, P.E. (1988) Influence of Processing on the Digestibility of African Yam Bean (*Sphenostylis stenocarpa*) Flour. Nutrition Reports International, 32: 819-827.

Asoiro, F. U., & Ani, A. O. (2011) Determination of Some Physical Properties of African Yam Beans. The Pacific Journal of Science and Technology, 12(1).

Ecocrop (2009). Ecocrop database. FAO. Retrived from: http://ecocrop.fao.org/ecocrop/srv/en./home

Ezueh, M. I. (1984) African Yam Bean as a Crop in Nigeria. World Crops. 36(6): 199-200.

Frank-Peterside, N., Dosumu, D. O. & Njoku, H. O. (2002) Sensory Evaluation and Proximate Analysis of African Yam Bean *(Sphenostylis stenocarpa* Harms) Moi moi. J. Appl. Sci. Environ. Mgt. 6(2): 43-48.

Gebreselassie, T.R. (2012) Moisture Dependent Physical Properties of Cardamom (*Elettaria Cardamomum M*.) Seed. Agric Eng Int: CIGR Journal. 14(1): 108-115.

Igbeka, J. C., Arinze, E. A., & Ajibola, O. O. (2006) Engineering Properties of Biomaterials. In A textbook on Agricultural Post harvest Engineering. Chapter 3, 26-33.

Mohsenin, N. N. (1980) Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York, London Paris.

Njoku, H. O., Eli, I. & Ofuya, C. O. (1989) Effect of Pre-treatment on the Cooking Time of the African Yam Bean (*Sphenostylis Stenocarpa*). Journal of Food Science. 54: 43-47.

Nwosu, J. N., Onuegbu, N. C., Ogueke, C. C., Kabuo, N. O. & Omeire, G. C. (2014) Acceptability of Moin-moin Produced from Blends of African Yam Bean (*Sphenostylis stenocarpa*) and Cowpea (*Vigna unguiculata*). Int. J. Curr. Microbiol. App. Sci. 3(5): 996-1004.

Ofuya, C.O., Njoku, H.O. & Eli, O. (1991) Development of Cheese-like Product from the African Yam Bean. Food Chem. 39:197-204.

Ogunjimi, L. A. O., Aviara, N. A. & Aregbesola, O. A. (2002) Some engineering properties of locust bean seed. Journal of food engineering. 55:95 – 99.

Ojukwu, M., Olawuni, I. A., Ibeabuchi, C. & Amadikwa, C. (2012) Physical, Proximate and Functional Properties of 'Nsama' A Local Variety of African Yam Bean (Sphenostylis stenocarpa) Grown in Southern States in Nigeria. African Journal of Food Science and Technology. 3(10): 260-267.

Ozguven, F. & Vursavus, K. (2005) Some Physical, Mechanical and Aerodynamic Properties of Pine (*Pinus Pinea*) Nuts. J. Food Eng. 68:191-196.

Princewill, O. P. and Ogwo, E. E. (2014) The Effect of Soaking Time on some Engineering Properties of Brown-speckled African yam bean. International Journal of Engineering and Technology, 4(12):700 - 708.

Princewill, O. P. & Ogwo, E. E. (2016). The Effect of Soaking Time on Some Selected Engineering Properties of White African Yam Bean. International Journal of Engineering and Technology, 6(2):69 - 77.

Vikash, K., Raushan, K., Dinesh, R., Vishal, K. & Anjani, K. (2013). Influence of Moisture Content and Grade on Engineering Properties of Makhana. Advances in Applied Science Research. 4(6):29-35.