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Comparative Analysis of the Effect of Size Reduction on the Drying Rate of Cassava and Plantain Chips

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Abstract: ***The effect of size reduction on the drying rate of cassava (Manihot sp.) and plantain (Musa paradisiacal) chips were analyzed comparatively through physical and statistical operations. In this study, duplicate cassava and plantain chips were used with varying thicknesses of 2mm, 4mm, 6mm and 8mm. The chips were subjected to natural sun drying with ambient temperature of 29^{0}C and artificial tray drying with the following conditions: dry bulb temperature of 60^{0}C, wet bulb temperature of 48^{0}C, air flow rate of 2.0m/s and relative humidity of 52%. The results showed that there was more moisture loss in the tray drying method than the sun drying with distinct difference in their respective moisture contents. The observed result was due to increase in surface area, drying conditions and the drying methods applied in which dried chip was attained at 9 hours of drying time for all thicknesses. The final dried products were found to have high rate of microorganism inhibition and considerable weight loss for cheaper transport and storage.***

Keywords: Size reduction, drying rate, moisture content.

1. Introduction

Size reduction can be referred to as the disintegration of solid substances by mechanical forces without altering their state. This also includes the division of liquids into drops or gases into bubbles. However, the physical and chemical condition of the disintegrated material may alter, particularly when inhomogeneous substances are present. The preparation for separation according to material components, e.g. dressing ores or grinding grain, is therefore one of the classical tasks of size reduction techniques. Different substances such as minerals, ores and coal, grain and cellulose, fertilizers, drugs, plastics and color pigments, to name but a few, must be processed for a wide range of purposes. The state of dispersion of a collective, i.e. the particle size or particle distribution, in many respects determines its properties and behavior. For example, the internal friction, agglomeration behavior, solubility and miscibility, transportability as well as color and taste are all functions of the mean fineness and particle distribution.

Drying is a unit operation aimed at removing nearly all water present in foodstuff. Cassava and plantain are dried when water contained within them is removed into the surrounding air. This drying is associated with water present in both samples for prolonged shelf life of food. Water needs to be removed or reduced to a certain amount which hinders both biochemical and microbial activities, while dehydration denotes drying effected by artificial means; it is usually reserved for artificial drying methods employing a forced draft of conditioned air by mean of fans. The capacity of air for moisture removal depends on its humidity and its temperature.

Cassava (*Manihot esculenta*) is the third-largest source of food carbohydrates for human consumption in the tropics, after rice and maize. Cassava is a major staple food in the developing world. It is one of the most drought-tolerant crops, capable of growing on marginal (or difficult to cultivate) soils. Nigeria is one of the world's largest producers of cassava. Cassava is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy, tuberous root, a major source of carbohydrates. Cassava, when dried to a starchy, powdery (or pearly) extract is called tapioca; its fermented, flaky version is called garri. Cassava chips are the most common form in which dried cassava root are marketed and most exporting countries produce them, it is a rich source of cassava pellet, alcohol, industrial starches and cassava beer [1].

Nigerian cassava production is by far the largest in the world; a third more than production in Brazil and almost double the production of Indonesia and Thailand. Cassava production in other African countries, the Democratic Republic of the Congo, Ghana, Madagascar, Mozambique, Tanzania and Uganda appears small in comparison to Nigeria's substantial output [2]. The Food and Agriculture Organization of the United Nations (FAO) in Rome [2] estimated 2002 cassava production in Nigeria to be approximately 34 million tons. The trend for cassava production reported by the Central Bank of Nigeria mirrored the FAO data until 1996 and thereafter rises to the highest estimate of production at 37 million tons in 2000. The third series provided by the Projects Coordinating Unit (P.C.U) had the most conservative estimate of production at 28 million tons in 2002. PCU data collates state level data provided by the Agricultural Development Programme (ADP) offices in each state. Comparing the output of various crops in Nigeria, cassava production ranks first, followed by yam production at 27 million tons in 2002, sorghum at 7 million tons, and millet at 6 million tons and rice at 5 million tons [2]. Expansion of cassava production has been relatively steady since 1980 with an additional push between the years 1988 to 1992 owing to the release of improved IITA varieties.

The different types of cassava are described by the term cultivars or varieties of cassava which can be distinguished by such features as size, color, shape of leaf, branching habits, color of stem and petiole, plant height, maturity time of the roots, yield, etc. There are also many cultivars described by the nutritive contents; levels and quality of food materials such as starch, protein, minerals etc. of the root, resistance of the plant to certain diseases and weeds; or the climatic and nutrient requirements including fertilizer for maximum yield of the plant [3],[4],[5]. In Nigeria, many varieties are in cultivation apart from the local varieties. Cassava is also classified on the basis of cyanide content into “sweet” and “bitter” varieties. Any variety with cyanide level less than 50 mg/kg is referred to as sweet variety; while those with 100 mg/kg fresh weights and above are referred to as bitter varieties [6]. The bulk of cassava produced in the forest and savannah ecologies of Nigeria are the bitter high cyanide containing varieties.

Cassava chips are unfermented, dry products of cassava. Roots are chipped into smaller sizes for fast drying that also helps the process of detoxification. Cassava can be dried naturally in the sun or artificially in an oven [7] to produce cassava chips that vary in size. They are used mostly in animal feed production but have potential for human consumption although this has not been fully explored [8],[9]. In some West African countries, chips are utilized in the production of flour and starch.

Traditionally, cassava is processed into dry whole roots that have undesirable colour, irregular shapes and are often contaminated with dust. A process technology has been developed for converting freshly harvested cassava into dried cassava chips having at least eighteen (18) months shelf life and cyanogenic glycosides concentrations within the permitted safe limits suitable for export and other uses. In the process technology, the washed, peeled cassava roots are fed into a cassava chipping machine designed to produce chips of regular sizes and shapes. Alternatively, the tubers can be manually cut into round chips of uniform sizes. The shape, size and thickness of the chip influences how fast it dries; diffusion and the rate of drying are fastest in small chips. When chips are thick, the outer layer easily compacts, thereby preventing the free air movement through the mass. Thick slices may appear dry on the surface but their internal moisture content will still be high. Therefore, for effective drying, the chips shape/size and loading rate should permit air and moisture to readily pass through the mass when drying. The optimal chip geometry for natural drying is a bar 5cm x 1cm x 1cm [10].

Plantain (*Musa paradisiaca*) belongs to the family of plants referred to as *Musaceae*. It is a carbohydrate staple in humid tropical zone of Africa, Asia, Central and Southern America. Most of the production of plantain occurs in Central and West Africa, with Uganda and Rwanda together accounting for 41% of all plantain production worldwide [11]. Plantain is a large, herbaceous plant with a rhizome from which the plant is propagated by sprouts or suckers. The stem of the plantain bears fruit only once, dies down, and is replaced by sprouts. Plantains contain more starch and less sugar than dessert bananas and are therefore cooked or otherwise processed before being eaten. They are always cooked or fried when eaten green. At this stage, the pulp is hard and the peel often so stiff, it has to be cut with a knife to be removed. Mature plantains can be peeled like typical dessert bananas; the pulp is softer than in immature, green fruit and some of the starch has been converted to sugar. They can be eaten raw, but are not as tasty as dessert bananas, so are usually cooked. Hence, plantain chips are processed as one of the means of preparing plantain for consumption or as a preservative measure for storage.

Cassava and plantain chips are smaller sizes of dried cassava roots and matured green plantain. The size reduction is mainly for fast drying that also helps in the storage and bulk packaging. The chips can be dried naturally or artificially depending on the factors considered:

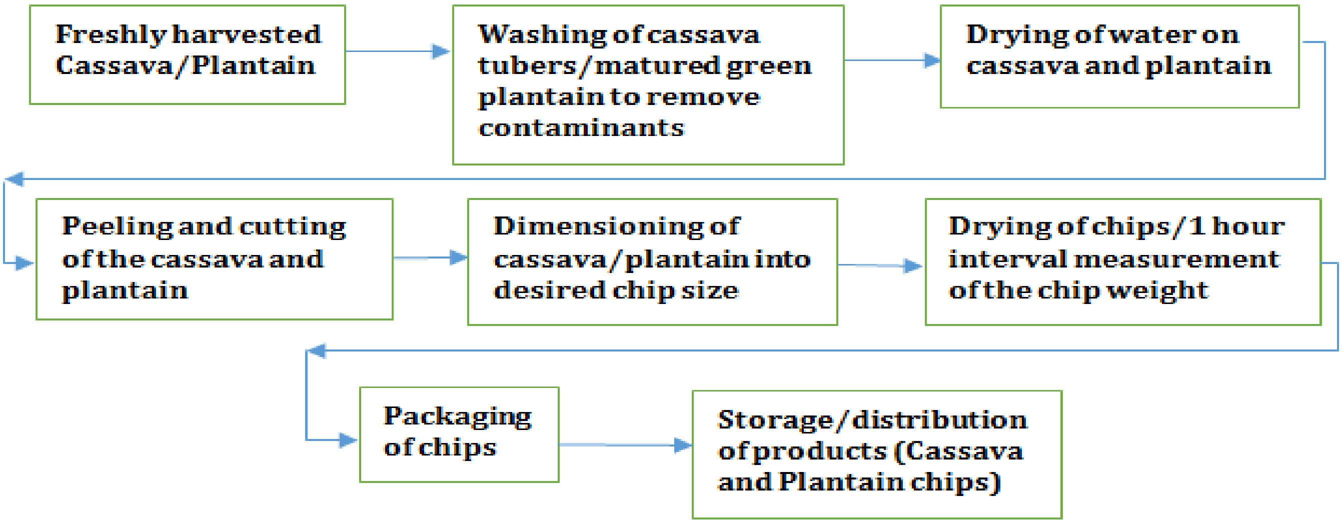
Sun drying is the simplest natural method of drying and traditionally cassava is sun dried in the open air, either on the ground or on a raised platform likewise plantain. The practice involves spreading out freshly sliced cassava roots and green plantain on drying areas or concrete floors of various dimensions with the chips being turned over at intervals with the use of a shovel or rake. The time of drying and chip quality are affected by the chip shape and size. Interrupted sun drying affects the quality of the finished chips.

Oven drying is an artificial means of drying in which the drying atmosphere is under control. Some of the artificial drying methods include drum drying, freeze drying, kiln drying, tunnel drying and cabinet drying. Cabinet drying in which the chips are loaded thinly on a tray is most applicable to solid foods. Fresh air enters the cabinet drawn by the fan through the heater coils and is then blown across the food trays. The rate of drying depends on the chip size, loading density and initial moisture [12]. This artificial method has a great advantage over sun drying and it is more efficient. In oven drying, there is reduction in space and labour requirement compared to sun drying, and the whole operation is independent of the weather. Thus there is better quality control and little chance of mould growth and bacterial contamination. Oven drying for the production of cassava and plantain chips has been carried out at temperatures ranging from 30°C to 170°C with a focus on cyanide removal with respect to cassava. Temperatures less than 100°C gave the most preferred results. After drying the chips are cooled, packed in sacks or polyethylene bags and stored on raised platforms in clean, dry and airy places. Damp and warm environments should be avoided [13]. This work seeks to comparatively and statistically analyze, the effect of drying rate on cassava (*Manihot sp.*) and plantain (*Musa paradisiaca*) chips.

2. Materials and Methods

Cassava and Plantain, the major raw materials used for this research were obtained from Choba main market, Port Harcourt, Rivers state. The cassava tubers and matured green plantain obtained were freshly harvested from farms in Choba community. The equipment used include: micrometer screw gauge, thermometer, digital weight balance, tray dryer, vernier caliper, trays and timer.

The processing of drying food chips followed the method in which mature cassava tuber and green plantain were washed, peeled and chipped using knife, vernier caliper and micrometer screw gauge for taking dimension measurement of the chips and the corresponding surface area were calculated. For tray drying, the tray dryer was switched on and regulated to 60^0C temperature required for the analysis. The fresh air inlet was adjusted to full aperture and the dryer was allowed to attain steady conditions within a stipulated time of 30 minutes and the following records were taken: dry bulb temperature of the heated air, wet bulb temperature of the heated air, and air flow rate. The weights of the chips were measured and recorded as the initial mass of the chips before drying. Afterward, the chip weights were recorded at hourly basis on a digital weighing balance to determine the mass of the moisture loss. The same procedures were taken for sun drying, the ambient temperature was recorded and the chips were carefully placed on a flat surface exposed for sun drying. The drying process is continued for both methods until required time limit is reached. The processing of cassava and plantain chips follows the processing steps below:



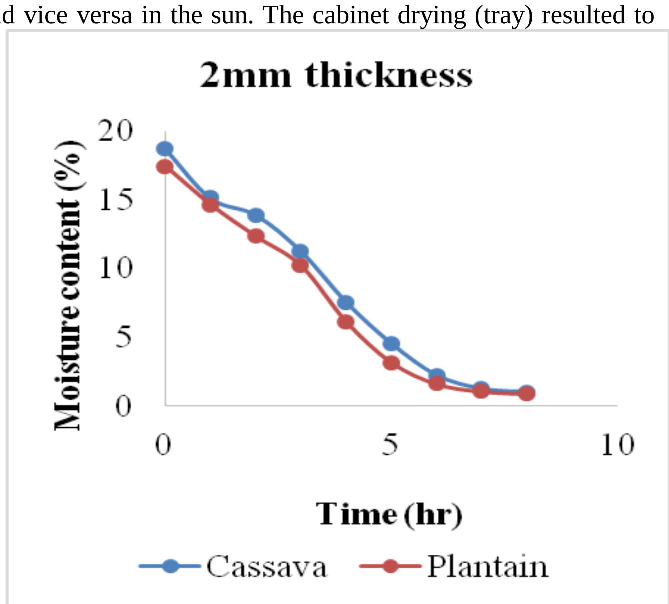
The data obtained from the tray and sun drying experiments which include the weight loss of the chips for every drying hour for different millimeter thicknesses were subjected to statistical analysis (regression analysis). The results showed the significant effect of size reduction on the drying rates of both chips for different drying methods. The statistical analysis include the regression statistics, analysis of variance and the residual outputs.

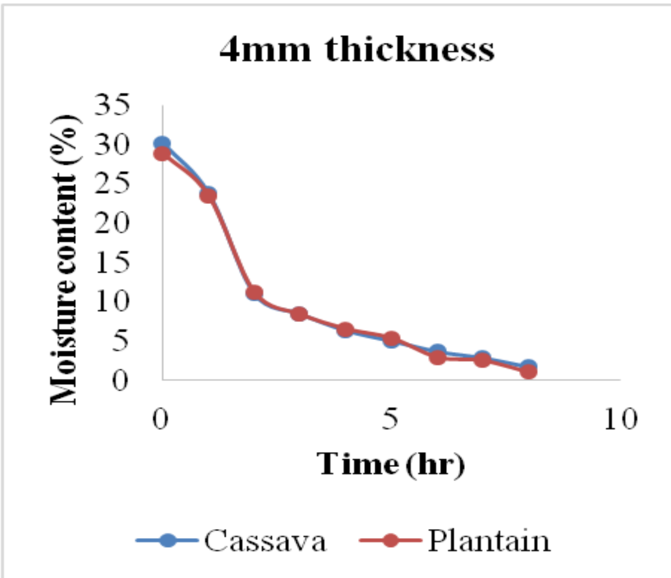
3. Results

The observed difference in the two cases (tray drier and sun mediums) for both food chips can be attributed to size reduction which exposes large surface area, the temperature and medium used for the analysis. Therefore, the rate of moisture loss varies for both mediums as it is high in the tray and vice versa in the sun. The cabinet drying (tray) resulted to little or no change in the colour of the cassava and plantain chips but it was obvious in the sun drying method that the chips were decolourized. The graphs (figures 1 and 2) below also shows that the final moisture contents derived in the tray drying for the 9 hours of drying were lower than the sun drying method which principally determines the equilibrium moisture content point for the cassava and plantain chips.

Drying time could not be extended for more than 9hours for all thicknesses examined for both samples to avoid case hardening as reported by [14]. Case hardening can occur as a result of high temperature and length of exposure which could result to undesirable changes in the chips.

3.1 Figures





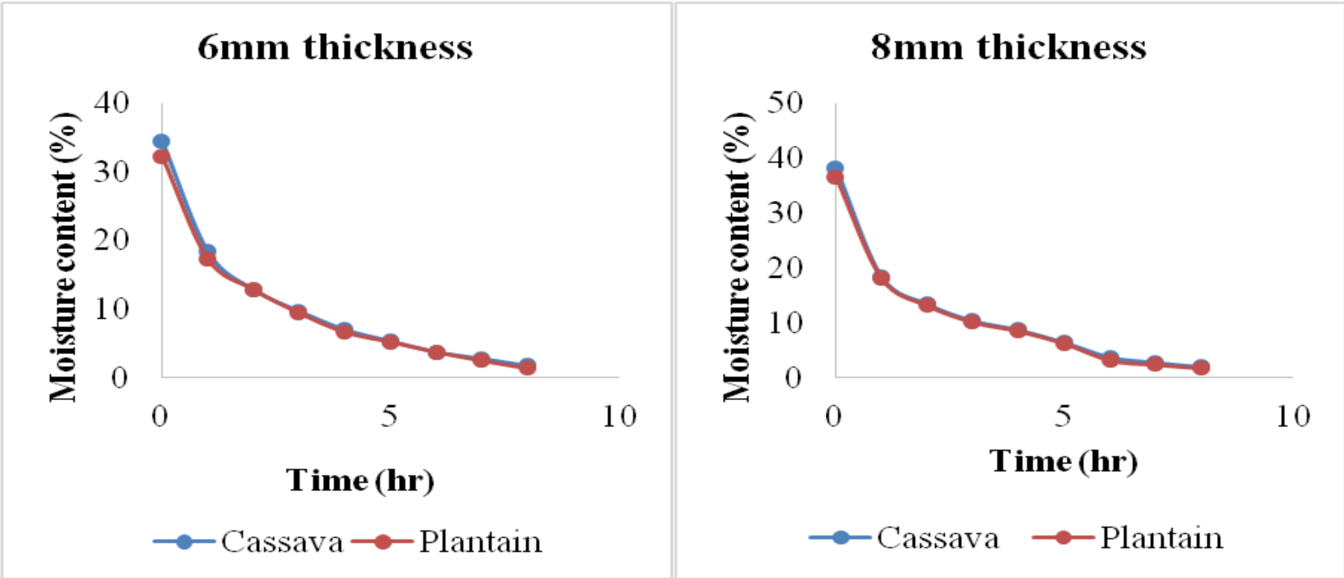


Fig. 1: Graphs of moisture content against time for tray drying

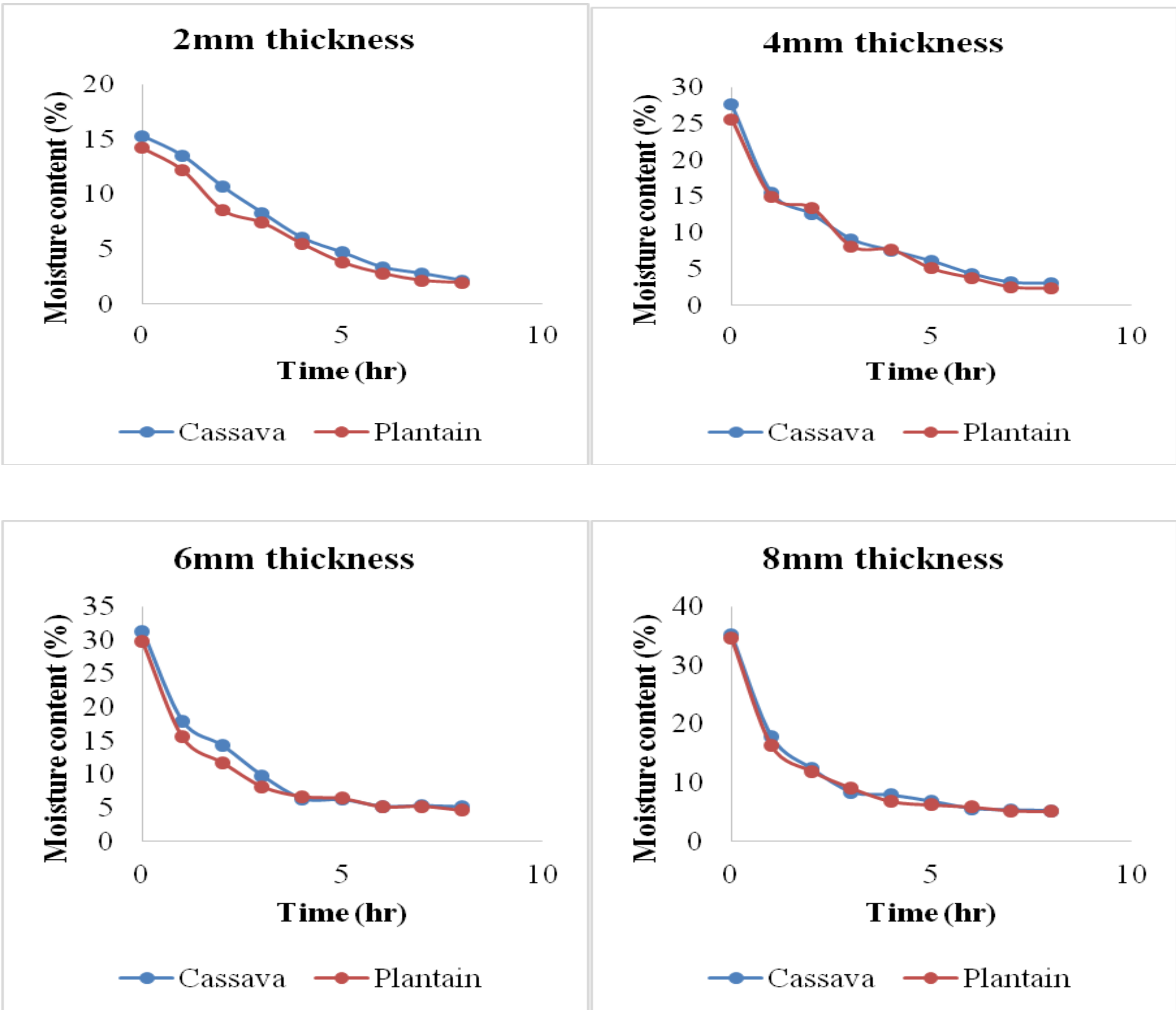


Fig. 2: Graphs of moisture content against time for sun drying

3.2 Tables
Table 1: 2mm thickness chips

Regression Statistics	
Multiple R	0.89415
R Square	0.7995
Adjusted R Square	0.77444
Standard Error	0.77484
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	19.1523	19.1523	31.9007	0.00048
Residual	8	4.80297	0.60037		
Total	9	23.9552			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	7.32418	0.45541	16.0825	2.2E-07	6.274	8.37437
Time (hr)	-0.4818	0.08531	-5.6481	0.00048	-0.6785	-0.2851

Summary output for sun drying – cassava

Regression Statistics	
Multiple R	0.91951
R Square	0.84551
Adjusted R Square	0.82619
Standard Error	0.5802
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	14.7384	14.7384	43.7819	0.00017
Residual	8	2.69305	0.33663		
Total	9	17.4314			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	7.258	0.34101	21.2835	2.5E-08	6.47162	8.04438
Time (hr)	-0.4227	0.06388	-6.6168	0.00017	-0.57	-0.2754

Summary output for tray drying – plantain

Regression Statistics	
Multiple R	0.88679
R Square	0.7864
Adjusted R Square	0.7597
Standard Error	0.63861
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	12.012	12.012	29.4539	0.00063
Residual	8	3.2626	0.40782		
Total	9	15.2746			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	6.36709	0.37535	16.9632	1.5E-07	5.50154	7.23264
Time (hr)	-0.3816	0.07031	-5.4271	0.00063	-0.5437	-0.2194

Summary output for sun drying - plantain

Regression Statistics	
Multiple R	0.91849
R Square	0.84362
Adjusted R Square	0.82407
Standard Error	0.47328
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9.66664	9.66664	43.1565	0.00017
Residual	8	1.79192	0.22399		
Total	9	11.4586			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	6.58836	0.27817	23.6847	1.1E-08	5.9469	7.22982
Time (hr)	-0.3423	0.05211	-6.5694	0.00017	-0.4625	-0.2221

Table 2: 8mm thickness chips

Summary output for tray drying - cassava

Regression Statistics	
Multiple R	0.82376
R Square	0.67858
Adjusted R Square	0.6384
Standard Error	1.8513
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	57.8849	57.8849	16.8893	0.00339
Residual	8	27.4184	3.4273		
Total	9	85.3033			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	10.3484	1.08811	9.51043	1.2E-05	7.83918	12.8575
Time (hr)	-0.8376	0.20382	-4.1097	0.00339	-1.3076	-0.3676

Summary output for sun drying - cassava

Regression Statistics	
Multiple R	0.851727
R Square	0.725438
Adjusted R Square	0.691118
Standard Error	1.687293
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	60.17711	60.17711	21.13735	0.001761
Residual	8	22.77565	2.846956		
Total	9	82.95276			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	10.83527	0.991713	10.92582	4.37E-06	8.548379	13.12217
Time (hr)	-0.85406	0.185765	-4.59754	0.001761	-1.28243	-0.42569

Summary output for tray drying - plantain

Regression Statistics	
Multiple R	0.8279
R Square	0.68541
Adjusted R Square	0.64609
Standard Error	1.66967
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	48.5914	48.5914	17.4301	0.0031
Residual	8	22.3023	2.78779		
Total	9	70.8937			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	9.71455	0.98135	9.89913	9.2E-06	7.45154	11.9775
Time (hr)	-0.7675	0.18382	-4.1749	0.0031	-1.1914	-0.3436

Summary output for sun drying - plantain

Regression Statistics	
Multiple R	0.85489
R Square	0.73084
Adjusted R Square	0.69719
Standard Error	1.54385
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	51.773	51.773	21.7216	0.00162
Residual	8	19.0678	2.38348		
Total	9	70.8409			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	10.3358	0.90741	11.3905	3.2E-06	8.24334	12.4283
Time (hr)	-0.7922	0.16997	-4.6606	0.00162	-1.1841	-0.4002

4. Conclusion

The following conclusions can be made from the results obtained from the study: the quality of cassava and plantain chips obtained in this study revealed that the quality is influenced by several variables which includes air velocity, temperatures of the drying air, size of chips, the surface area of the chip and relative humidity of the atmosphere are very important in achieving results during the drying process. Cassava and plantain chips with small thicknesses considered shows that more moisture is removed at a shorter time because of the short distance travel from within to the surface of the chips. The virtual reality of the traditional processes of drying whereby there is little or no consideration of the thickness and the size of the chips will result in loss of product quality; discoloration of the cassava and plantain chips caused by this removal of moisture from its surface thus aid which in turn propagates microbial and biochemical activities within the chips. The product inside the tray dryer requires lesser frequent attention compare with those in the open sun drying in order to prevent attack from both human and animal. In addition, chips are principally protected from rain, dust or pest .Increase in temperature beyond 50^0C – 70^0C might cause undesirable changes to the chips like case hardening as a result of changes in the biochemical activities within the chips .The mass of water removed totally in the tray drying approach is greater than that of the sun drying and the appearance of the cassava and plantain chips disclose the uniformity and a considerable drying approach in the tray drying than the open sun drying as the latter resulted to discoloration of the product .The natural sun drying method regardless all physical merits derived from the tray drying had a better statistical result (regression analysis) with regards to its coefficient of regression and analysis of variance.

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