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Research Article

Comparison of Moisture Removal Rate for Five Samples of Sliced Staple Food Using Multipurpose Convective Cabinet Dryer

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Abstract: This paper is aimed at studying the rate of moisture removal from samples of staple food using a multipurpose convective cabinet dryer. A multipurpose convective cabinet dryer is designed, fabricated and used to study the moisture removal rate of sliced yam, bitter yam, cocoyam, cassava and plantain (A, B, C, D and E respectively) placed in a single layer. These food samples were obtained from eastern part of the country. The samples were dried from initial moisture content of 60.1%, 72.7%, 70.9%, 64.4%, 61.4%, respectively to final moisture content of 0% in five different trays at $60^{O}C$ air temperature and 2.5m/s air velocity and the weight losses were taken. The moisture removal rate was found to decrease with time and drying process occurred at falling rate period. From the plot of the mass against drying time, it was observed that in general, the reductions in mass of the sliced samples occur at falling rate period. This indicates that the moisture removal from the samples is controlled by the mechanism of diffusion.
Keywords: Multipurpose convective cabinet dryer, weight losses, moisture contents.

INTRODUCTION

Preamble

In Nigeria, just like several other developing nations, agriculture is considered a factor for growth and development. The country is blessed with a landmass of 98.3million hectares of which 72% is considered suitable for agricultural production [1]. However, the method of growth in food production is very low, amount to 2.5% per annum. This poor growth has been attributed to the level of agricultural preservation in the country [2]. Her poor record of food preservation has led to improper management of agricultural produce and this impinged on the growth of food production.

As one of the tropical sub region, Nigeria lies within the equator and is blessed with abundant solar energy all the year round [4]. Most of the agricultural products are harvested during the peak period of raining season and so preservation is difficult and hence most of these products perish. These products can be preserved and stored so that they can be of economic importance both to the farmer and the entire populace.

History had shown that food preservation have come a long way with drying reported to be one of the oldest methods of conservation [4]. In rural communities and particularly among the poor people, sun drying has been one common means of food preservation. This method is un-hygienic since these agricultural products are easily contaminated by animal droppings and consequent infestation by fungal and bacteria. This method also prolongs drying and may result in the deterioration of the quality of the products. Moreover, more labour is involved as the products are watched to prevent attacks from birds and animals and are moved in and out during the day and night and from rain.

Drying is probably the oldest and the most important method of food preservation practiced by humans [5, 6]. It is one of the main post-harvest operations for biological materials [7], since it has great effects on the quality of the dried products. Most agricultural products can be preserved after drying [8]. Moreover, the main purpose of drying the products is to allow longer periods of storage, minimize packaging requirements and reduce shipping weights [9]. The traditional open sun drying method utilized widely by rural farmers has inherent limitations; high product losses ensue from inadequate drying which results to fungal attacks, insects, birds and rodents encroachment, unexpected down pour of rain and other weathering effects [10]. In such conditions, multipurpose convective cabinet dryers increasingly appear to be attractive as viable alternative to open sun drying, where a quicker and controlled dying process can be achieved, and the products are well protected during the process. Therefore the introduction of low cost and locally manufactured multipurpose convective cabinet dryer offers a promising alternative to reduce the tremendous post harvest losses. A low temperature multipurpose convective cabinet dryer has therefore been fabricated which will be appropriate for drying agricultural products at the low temperature and high relative humidity period of the year. This enables products to be dried without cracking and hence minimizes the exposure of the products to fungal and bacteria infestation and wastage and suitable for bulk drying.

Dehydration is dependent on two fundamental processes; the transfer of heat into the product and subsequent removable of moisture from it, which are, heat and mass transfer processes, respectively [11]. Therefore, the objective of this work is to study the moisture removal rate of sliced yam, bitter yam, cocoyam, cassava and plantain at 60^{O}C air temperature and 2.5m/s air velocity in a multipurpose convective cabinet drying system.

The principles of drying

In the most basic terms, drying is the removal of water from products into surrounding air. Usually products are dried using hot air to remove the water. For effective drying, the air should be hot, dry and moving. These factors are inter-related and it is important that each factor is correct:

- air must be dry, so it can absorb the moisture from the products
- heating the air around the product causes it to dry more quickly
- if the air is not moving across the food, it cannot get rid of the water vapour that it has collected. A fan or air blower is needed to keep the air circulating.

The dryness of air is referred to as the humidity - the lower the humidity, the dryer the air. There are two ways of expressing humidity; the most useful is a ratio of the water vapour in air to air which is fully saturated with water. This is known as the relative humidity (RH). Air that is completely dry has a RH of 0% and air that is fully saturated with water vapour has a RH of 100%.

In summary – when product is been dried, hot dry air comes into contact with the product. The hot air absorbs water from the product and is moved away from the product. New dry air takes its place and the process continues until the product has lost all its water. In air drying, the rate of removal of water depends on the conditions of the air, the properties of the product and the design of the dryer.

Moisture can be held in varying degrees of bonding. Formerly, it was considered that water in a product came into one or other of two categories, free water or bound water. Water is held by forces whose intensity ranges from the very weak forces retaining surface moisture to very strong chemical bonds. In drying, it is expected that the water that is loosely held will be removed most easily. Thus it would be expected that drying rates would decrease as moisture content decreases, with the remaining water being bound more and more strongly as its quantity decreases.

Theory of drying

Most agricultural products, which are dried may be seen as solid, porous or coarse material in a loose bulk state (i.e. in piles or in layer).The pile is blown through by pre-heated air during drying, by means of which energy needed for evaporation is provided for the materials. Evaporating water from the surface of the material is removed by air.

Moisture is removed as a result of the difference in vapour pressure between the surface and its surroundings. There is migration of moisture to the surface under the effect of the moisture gradient forming between the inner parts of the surface. Drying process lasts until equilibrium is attained between the surface and the inner part and between the surface and the ambient.

Temperature is a decisive factor in drying. Both the concentration gradient and the diffusion coefficient increase with temperature, whereby the amount of water removed is also increase.

The main factor that controls drying rate is the rate that moisture can move from the interior of a piece of product to the surface. Therefore, the shorter the distance that moisture has to travel, the faster the drying rate. For this reason, wherever possible, products should be cut into small pieces prior to drying. Reducing the size also increase the surface area of the food in relation to the volume of the pieces, this increases the rate at which water can be evaporated from the product.

MATERIALS AND METHODS

Equipment Used

The following equipment were used for the experiment; multipurpose convective cabinet dryer (designed and fabricated by National Engineering Design Development Institute (NEDDI) Nnewi), digital weighing balance and stop watch.

The multipurpose convective cabinet dryer consists of a heating chamber, a drying chamber, an exhaust fan, digital temperature controller. The drying chamber is made of stainless steel sheet and double walled construction with insulation between inner and outer wall. The door is provided with gasket to prevent heat loss. The chamber is housed with five stainless steel trays in a rack. Air heated by electric filament is blow into the drying chamber to achieve faster drying by increasing convective heat transfer rate.

Materials

a) Five types of food samples (A, B, C, D, E) sliced into 2mm thickness

Methodology

Before starting the test, the dryer was preheated for ten (10) minutes with set temperature and velocity. The sliced samples were spread uniformly in a thin layer on the sample tray. The weight losses were recorded from weigh balance after each drying periods of fifteen minutes which continued until the weight of the samples do not change any more which signify that they have reached a constant weight and all the moisture has been removed. The weigh balance has a capacity of 5000g and readability of 0.01g. The quality of the dried product is ensured based on the criteria of colour through visualization, taste and smell.

Fig-1: Samples before drying

Fig-2: Arrangement of food samples in the dry

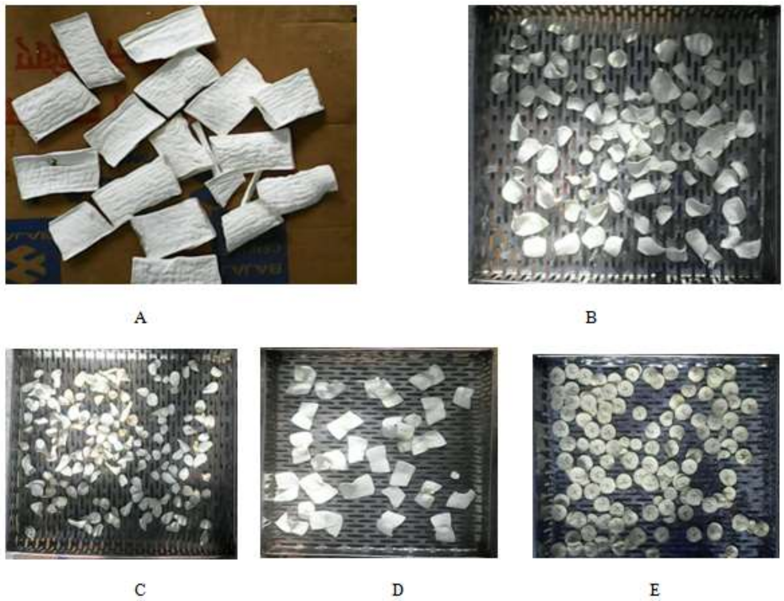

Fig-3: Samples after drying

RESULTS AND DISCUSSIONS

Table 1: Mass of samples against drying time

Time, t (min)	Mass of yam, M_y (g)	Mass of bitter yam, M_b (g)	Mass of cassava, M_c (g)	Mass of cocoyam, M_c (g)	Mass of plantain, M_p (g)
0	500.0	500.0	500.0	500.0	500.0
15	422.6	426.5	456.5	449.2	415.5
30	369.0	362.7	419.7	401.4	360.8
45	326.4	310.4	379.1	361.6	317.1
60	292.7	266.0	350.1	316.7	284.3
75	268.8	228.2	320.1	276.9	253.5
90	250.0	199.2	295.9	243.0	235.6
105	237.1	177.0	271.8	216.1	220.7
120	232.1	162.5	253.4	197.2	211.7
135	221.2	153.8	236.9	180.3	206.8
150	215.3	144.1	225.3	168.3	199.8
165	211.3	142.2	213.7	159.4	196.8
180	208.3	140.2	206.0	153.4	194.8
195	205.4	136.4	196.3	148.4	192.8
210	203.4	136.4	192.5	146.4	192.8
225	202.4	136.4	188.6	145.4	192.8
240	201.4	136.4	180.9	145.4	192.8
255	200.4	136.4	177.9	145.4	192.8
270	199.4	136.4	177.9	145.4	192.8
285	199.4	136.4	177.9	145.4	192.8
300	199.4	136.4	177.9	145.4	192.8

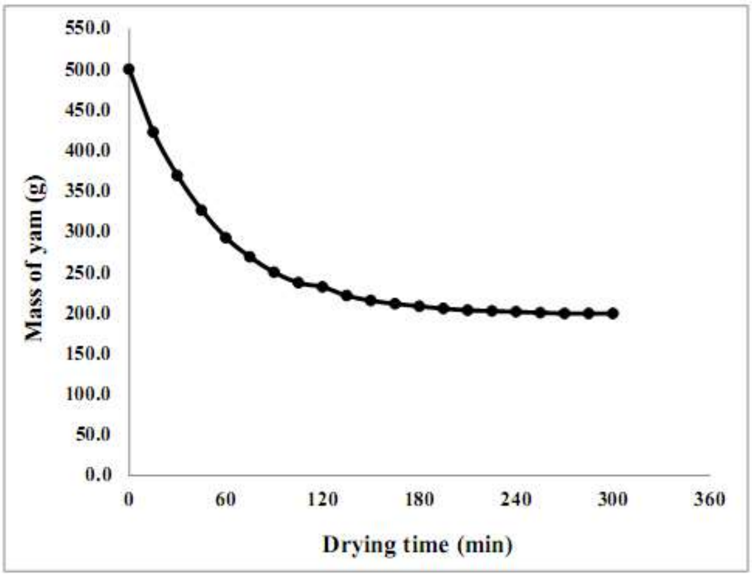

Fig-4: Variation of mass of yam against drying time

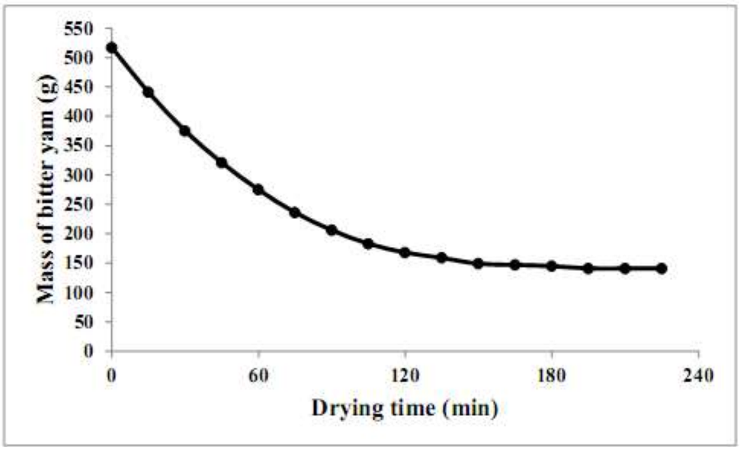

Fig-5: Variation of mass of bitter yam against drying time

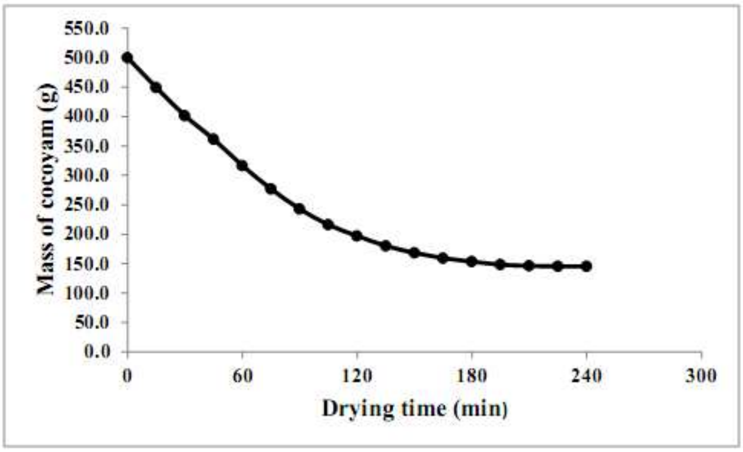

Fig-6: Variation of mass of cocoyam against drying time

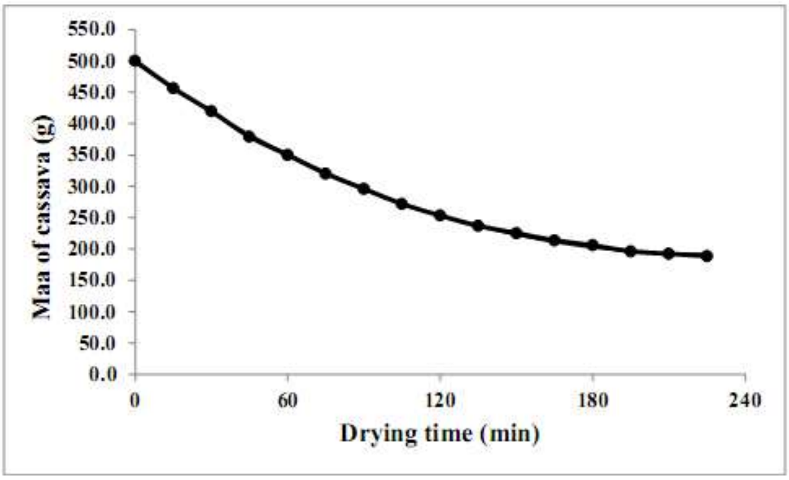

Fig-7: Variation of mass of cassava against drying time

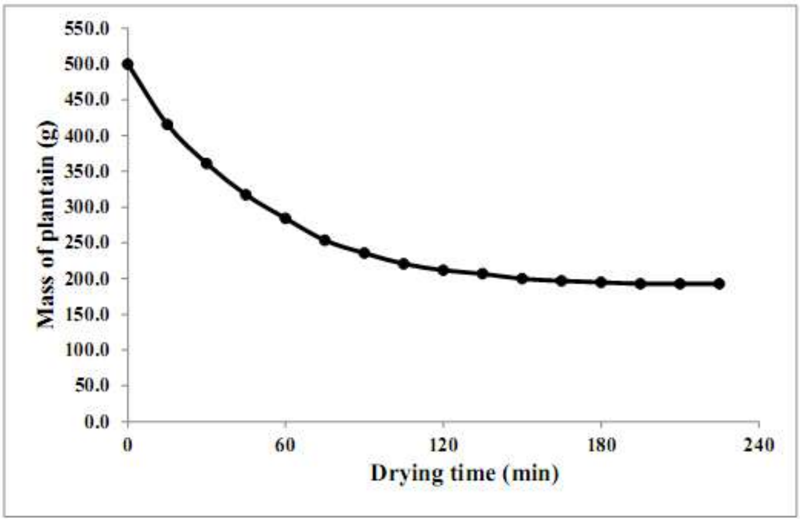

Fig-8: Variation of mass of plantain against drying time

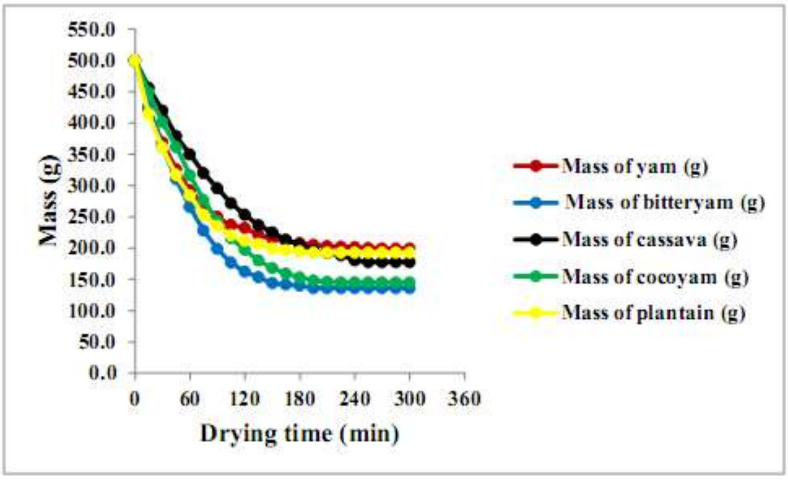

Fig-9: Variation of mass of the five samples against drying time

The variation of mass of samples with drying time is illustrated in Table 1. The mass of yam decreases progressively from 500g as the drying proceed until it became constant after 270 to 300 minutes of drying attaining the minimum value of 199.4g. The drop was rapid at the beginning of the drying as shown in figure 4. The mass of bitter yam decreases progressively from 500g as the drying proceed until it became constant after 195 to 300 minutes of drying attaining the minimum value of 136.4g. The drop was also rapid at the beginning of the drying as shown in figure 5.

The mass of cassava decreases progressively from 500g as the drying proceed until it became constant after 255 to 300 minutes of drying attaining the minimum value of 177.9g. The drop was rapid at the beginning of the drying as shown in figure 6. The mass of cocoyam decreases progressively from 500g as the drying proceed until it became constant after 225 to 300 minutes of drying attaining the minimum value of 145.4g. The drop was rapid at the beginning of the drying as shown in figure 7.

The mass of plantain decreases progressively from 500g as the drying proceed until it became constant after 195 to 300 minutes of drying attaining the minimum value of 192.8g. The drop was rapid at the beginning of the drying as shown in figure 8. The average mass of the sliced yam, bitter yam, cocoyam, cassava and plantain were reduced from about 500g to 199.4g, 136.4g, 145.5, 177.9 and 192.8g after 300min, 225min, 240min, 270 and 225min respectively. The reduction is as a result of removal of moisture from the samples which continued throughout the drying process. The moisture removal during the initial stages of drying was observed due to evaporation of free moisture from the outer surface layers and then gets reduced due to internal moisture migration from inner layers to the surface, which results in a process of uniform dehydration.

CONCLUSIONS

From the experimental results, it was observed that the drying time required to reach from initial to final moisture contents are 270 min, 195min, 225min, 255min and 195min respectively for yam, bitter yam, cocoyam, cassava and plantain. From the plot of mass against drying time, it was also observed that in general, the reductions in mass of the sliced samples occur at falling rate period. This indicates that the moisture removal from the samples is controlled by the mechanism of diffusion. An electric assisted multipurpose convective cabinet dryer that was designed and fabricated to carry out the experiment has a good drying efficiency. The dryer with insulated chamber enables to maintain consistent air temperature inside the dryer. The thin layer drying tests are conducted under controlled conditions of drying temperature and velocity.

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