PERFORMANCE EVALUATION OF A MULTI-LAYER SOLAR TENT DRYER USING SHEA NUT

Oyewole, S. N.[1*], Olaoye, J. O.[2], Ibrahim, S. A.[3], Ayanda, I. S.[3], Ogunbiyi, A. O.[1] and Akinyera, O. A.[1]

[1.]Postharvest Engineering Research Department, Nigerian Stored Products Research Institute, Km 3, Asa-Dam Road, P.M.B. 1489, Ilorin, Nigeria.
[2.]Agricultural and Biosystems Engineering Department, University of Ilorin, P.M.B. 1515, Ilorin, Nigeria.
[3.]Perishable Crops Research Department, Nigerian Stored Products Research Institute, Km 3, Asa-Dam Road, P.M.B. 1489, Ilorin, Nigeria.

Corresponding author's email: snoyeengr@gmail.com, +2348030434718*

ABSTRACT

Solar dryers are developed to improve food safety and efficiency of solar drying at minimal cost. The application of any new design of solar dryer to crop drying requires adequate performance evaluation to guarantee food hygiene and cost effectiveness of the application. A newly developed multi-layer solar tent dryer by Nigerian Stored Products Research Institute was evaluated using shea nut. The evaluation was aimed at bringing out the effect of different layers on quality of shea nut and kernel as well as drying parameters. The parameters considered for the evaluation were; drying rate, cracking efficiency, percentage kernel breakage, moisture content, proximate compositions, microbial loads and sensory assessment. The obtained data were subjected to statistical analysis using SPSS 20.0 version. New Duncan's Multiple Range Test was adopted to separate the means ($P < 0.05$). The results showed that the drying operation took 19 days to reduce the moisture content of boiled nut dried in the solar tent dryer from 72.1 ± 0.2 %db to 12.90 ± 1.60, 15.26 ± 2.36 and 15.76 ± 1.12 %db on layer 1 (top trays), layer 2 (middle trays) and layer 3 (bottom trays) respectively, while the control sample (sun drying) was reduced to 13.80 ± 1.50 %db. The average temperature recorded on layers 1, 2 and 3 were 47.0 ± 6.4, 38.4 ± 5.6 and 32.6 ± 2.6 °C respectively, while the control had 30.5 ± 2.1 °C. The highest drying rate of 0.90 kg/day was recorded for nut dried on layer 1 while layers 2 and 3, and control recorded 0.76, 0.73 and 0.74 kg/day respectively. The cracking efficiencies of nuts dried on layers 1 to 3 were 98.9, 99.0, 97.9% respectively, while control was 94.7%. Percentage kernel breakage of 5.68, 2.72, 2.28 and 1.73% were recorded in samples dried on layers 1 to 3 and control respectively. The proximate compositions of the dried shea kernel were not negatively impacted by the drying operation. The layer 3 recorded the highest microbial loads and was significantly different from others ($P < 0.05$). Therefore, the solar tent dryer could be used for drying of shea nut and kernel without quality loss in the product, but the loading should be limited to two layers for efficient quality maintenance.

KEYWORDS: Cracking efficiency, drying rate, kernel breakage, sensory evaluation, shea kernel

1. INTRODUCTION

Preservation of agricultural produce to prevent deterioration and food quality and quantity losses has necessitated development of series of produce dryers in different capacities. The principle of drying is the same globally but the mode of operation of dryers differs from one design to another. One of the factors in which their mode of operation could be based is source of energy, and some are more cost effective than the others. Notable among the cost-effective

categories are the solar dryers (Visavale, 2012). Solar drying is an improved technique of drying agricultural products using solar energy to reduce drying time and improve end-product quality. It has capacity to address most of the identified challenges associated with sun drying of agricultural products (Olokor and Omojowo, 2009; Assefa *et al.,* 2013; Oyewole *et al.,* 2016; Olaoye *et al.* 2020). Its operation principle is based on concentration of received radiation of solar energy in an enclosed structure causing temperature increase and reduction in humidity to create a favourable atmosphere for moisture removal from product to the ambient (Assefa *et al.,* 2013).
Solar dryers can be used to preserve a wide range of agricultural produce from quality loss as well as prevent economic loss that could arise due to produce deterioration (Assefa *et al.*, 2013; Oyewole *et al.,* 2016; Akomolafe *et al.*, 2021). Several designs of solar dryers are available with varying principles of operation (Olokor and Omojowo, 2009; Babarinsa *et al.*, 2011; Oyewole *et al.*, 2016; Ade *et al*, 2018, Oyewole *et al.*, 2022). Basically, solar drying systems could be classified as high and low temperature solar dryers. Further classification could be based on the following criteria; mode of air movement, air flow direction, dryer arrangement, solar contribution and type of target crop (Dhumne *et al.*, 2015). Other classifications made by other researchers were based on methods of transferring heat, handling characteristics, physical properties of the wet material and mode of utilization (Sharma *et al*., 2009; Belessiotis *et al*., 2011). Whichever classification it is, its functionality in terms of quality preservation and enhancement as well as cost effectiveness are very vital to guarantee its application to agricultural products dehydration.

A multi-layer solar tent dryer developed by Nigerian Stored Products Research Institute (NSPRI) has been used to dry different agricultural products, shea nut inclusive (Ade *et al.,* 2018; Oyewole *et al.,* 2019; Ogunsua *et al.*, 2020). Shea is one of the wildly grown fatty agricultural products with wide range of applications. The tree usually bears fruit that contains nut. In the nut is the kernel where the oil is naturally embedded. The utilization of the oil popularly referred to as shea butter is found in many industrial sectors which cover pharmaceutical, cosmetics, food and soap industries (Michael and Kofi, 2001; Moore, 2008; Atehnkeng *et al.,* 2013). Most importantly, it is a good source of foreign exchange earnings to government based on past export record where Nigeria was reported to account for 50% out of the 600,000 tonnes traded volume (Salawu and Ayanda, 2014). The awareness has prompted the producing countries mostly from Africa, including Nigeria, to see the handling of the product as a business rather than hobby. Processing of shea fruit to kernel ahead of butter extraction requires some postharvest activities, which drying is very critical. The producers in Nigeria usually sun-dry the product and this is associated with a lot of challenges because the harvesting period of the product usually coincides with period of the rainy season characterized with cloudy weather condition that is not favourable for sun-drying (Oyewole *et al.*, 2019).

Having a solar dryer that can successfully handle the drying of shea nut and kernel will not only improve product quality but will safe processors from the rigor of packing in and out whenever it is about to rain. The NSPRI multi-layer solar tent dryer has been found appropriate for drying of agricultural produce (Ogunsua *et al.,* 2020; Akomolafe *et al.*, 2021), but little attention has been paid to the effect of the different layers positioned at different altitudes in the drying chamber on drying parameters and quality indices of the product. Therefore, this study was aimed at establishing the effect of the multi-layer arrangement in the dryer on drying rate and quality parameters of shea nut and kernel.

2. MATERIALS AND METHODS

2.1 Collection of Materials

Vitellaria paradoxa species of shea that is common in Nigeria was used for the evaluation study. The collected freshly fallen shea fruit was procured from fruit pickers in Adeleji community, in Asa Local Government Area of Kwara State in Nigeria (Latitude: 8.6188°N, Longitude: 4.3821°E).

2.2 Description of the Solar Dryer

The solar dryer was made of dwarf block wall, wooden frame and UV screened greenhouse film. The dryer has a total effective drying area of 8.48 m^2 and a dimension of 3.2 x 4.0 x 3.1 m with the longer side facing the East-West direction for maximum solar radiation reception. The wall base was constructed of block of 0.8 m height (dwarf wall) while the upper part of the wall and the roof were covered with UV screened greenhouse film. The floor of the dryer which serves as the heat collector was constructed of concrete, adequately insulated to prevent heat sink to the ground and painted with food grade black paint to enhance heat absorption. The solar dryer is naturally ventilated through six (6) adjustable inlet vents and one (1) pneumatic aspirator positioned on the roof of the dryer for moisture removal (Figure 1). The drying rack has three layers made of wood with 18 trays constructed of 25 mm square pipe and galvanized mesh. It has an access door provided at one end of the structure.

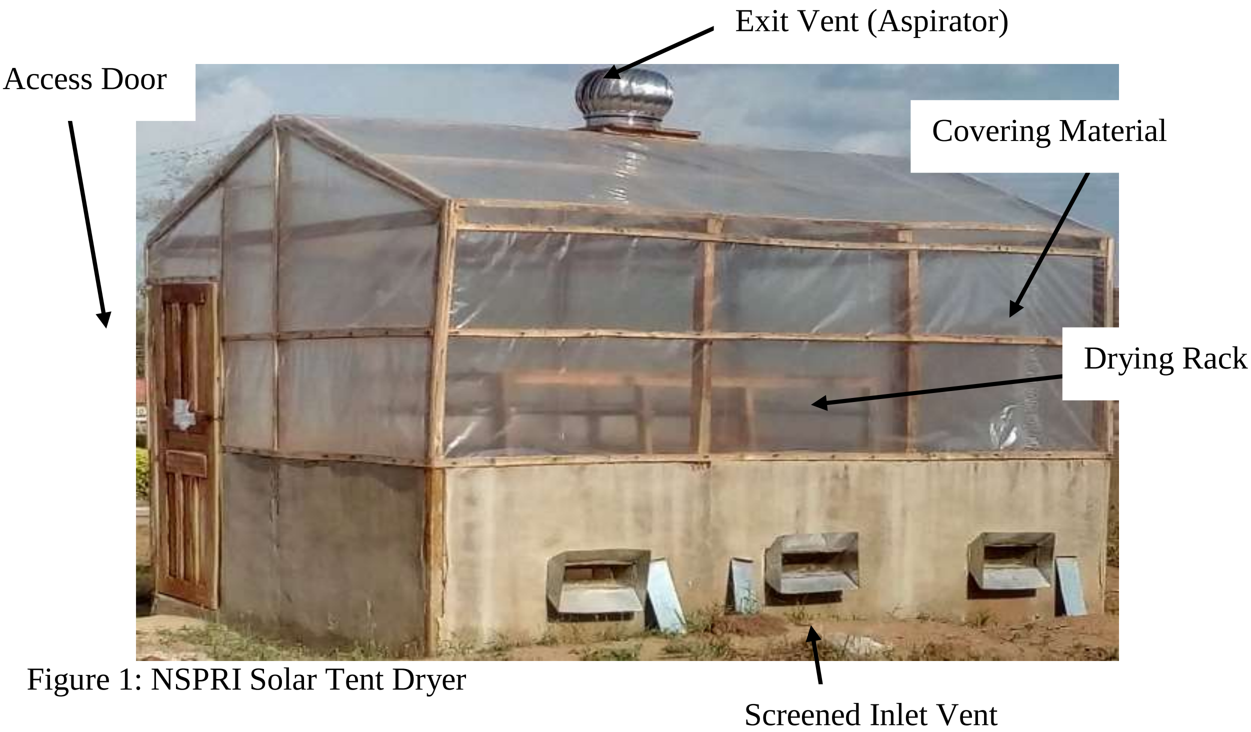

Figure 1: NSPRI Solar Tent Dryer

2.3 Processing of Fruit into Nut

The shea fruit was processed in the premises of Nigerian Stored Products Research Institute (NSPRI). The processing involved the following postharvest operations; de-pulping, washing, boiling, nut drying, decorticating, cleaning, kernel drying, sorting and packaging (Figure 2). The traditional technique of processing fruit into kernel cum procedures reported by Olaoye and Babatunde (2001); Olaoye (2012) and Atehnkeng *et al.* (2013) were modified and adopted (Figure 2). The fruits were de-pulped manually. The remnant of pulp on the nuts was thoroughly washed with potable water. Boiling period of 120 minutes was adopted in line with the findings of Womeni *et al.* (2006) and Nde Bup *et al.* (2012). The boiled nuts were left in water to cool till the next day before the water was drained off.

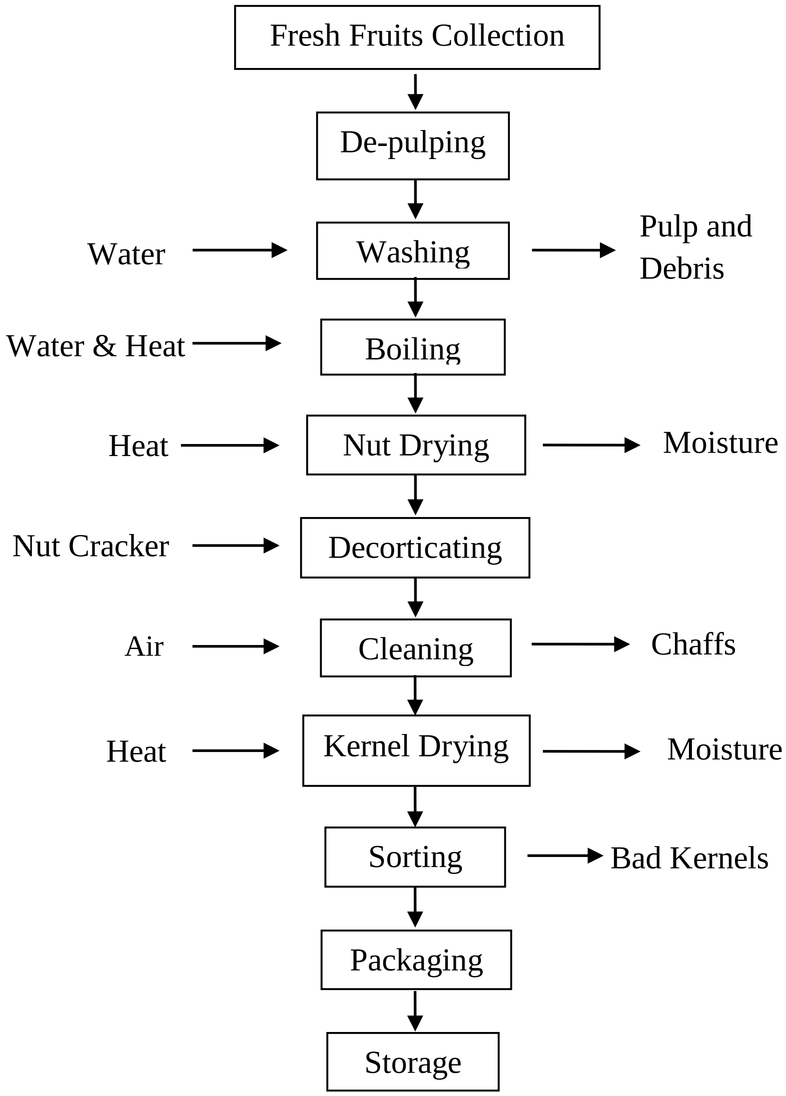

Figure 2: Flow Chart for Processing of Shea Fruit to Kernel
Source: Olaoye and Babatunde (2001); Atehnkeng *et al.* (2013); Olaoye (1995)

2.4 Nut and Kernel Drying

Ten kilogrammes of boiled shea nut was loaded into each tray in the dryer (Figure 3a) while 3 trays loaded with same quantity of nut were placed on a raised concrete platform as control under the sun (Figure 3b). The solar radiation and air velocity were monitored using solar power meter DT-1307 (Resolution – 1 W/m^2; max. – 1999 w/m^2; accuracy - ±10 W/m^2) and testo 410-1 air velocity meter (Resolution – 0.1 m/s; accuracy - ±1 m/s) respectively. The moisture loss in the process of drying was monitored and recorded daily (8am) using electronic weighing balance (Camry ACS-30-JE11; accuracy - ±10 g). The values obtained were used to determine the drying rates (Equation 1) and plot the drying curves.

$$DR = \frac{Mo - Mt}{dt} \qquad (1)$$

where; DR is the drying rate (kg/day), M_o is the initial weight of the sample (kg), M_t is the weight of the dried sample at time t (kg), t is the drying time (day).

Figure 3a: Samples of Shea Nut being Dried on Different Layers in the Dryer

Figure 3b: Control Samples of Shea Nut on Raised Concrete Platform

2.5 Nut Cracking and Cleaning

The nuts were cracked manually. Twenty (20) kg of dried shea nut was packaged in 25 kg size polypropylene bag. Fifty (50) strokes of 2 kg wooden plank were applied to the packaged nut. Thereafter, the kernel was separated from the shell through manual winnowing. Percentage kernel breakage and cracking efficiency were determined for each of the samples based on drying layer in the dryer using Equations 2 and 3 respectively.

$$\%K_b = \frac{W_b}{W_t} \qquad (2)$$

where; $\%K_b$ is the percentage kernel breakage (%), W_b is the weight of broken kernel (kg), W_t is the total weight of kernel (kg).

$$CE = \frac{W_c}{W_t} \quad (3)$$

where; *CE* is the cracking efficiency (%), W_c is the weight of cracked nut (kg), W_t is the total weight of nut before cracking (kg).

2.6 Proximate and Microbial Quality Assessment

Moisture content of the shea nut was determined before and after boiling using standards of Association of Official Analytical Chemists (AOAC) (2005). Samples of the dried shea kernel were subjected to proximate analysis. The quality parameters (total ash, crude protein, crude fibre, crude fat and carbohydrate) were determined in accordance with the methods of the Association of Official Analytical Chemists (AOAC, 2005). The samples were also subjected to microbial analysis. The manual of Food Quality Control of the Food and Agriculture Organization was used for the microbial analysis (FAO, 1997).

2.7 Physical Quality Assessment

Samples of shea kernel collected after cracking and cleaning were subjected to sensory analysis to assess the effect of different drying layers on sensory quality of the kernel. The parameters considered were appearance, presence of physical mould and aroma. The analysis template used by Oyewole *et al.* (2013) and Olayemi *et al.* (2017) was modified for the assessment. The template was based on a 9-point hedonic scale, and it gave the panelists opportunity to choose from a range of like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much and dislike extremely; and they were allocated 9, 8, 7, 6, 5, 4, 3, 2 and 1 marks respectively. Thirty (30) panelists were considered and each of them was given an assessment sheet per sample. After the tests, the results were extracted and analysed.

2.8 Statistical Analysis

The data collected were subjected to statistical analysis using SPSS 20.0 version. New Duncan's Multiple Range Test (NDMRT) was run to separate the means.

3. RESULTS AND DISCUSSION

3.1 Drying of Shea Nut

The initial moisture contents of the shea nut (uncracked) determined before and after boiling were found to be 61.2 ± 0.3 and 72.1 ± 0.2%(db) respectively. Moisture contents of cracked raw nut and boiled nut were 91.9 ± 0.8 and 123.6 ± 0.4%(db) respectively. The variation in moisture contents of the cracked and uncracked nuts is an indication that the amounts of water present in the kernel in raw state and after boiling were higher than that of the shell covering it. The operation took 19 days to reduce the moisture of boiled nut (72.1 ± 0.2%db) dried in the solar tent dryer on layer 1 (top trays), layer 2 (middle trays) and layer 3 (bottom trays) to 12.90 ± 1.60, 15.26 ± 2.36 and 15.76 ± 1.12%db respectively, while the control sample was reduced to 13.80 ± 1.50%db. The average daily solar radiation received in the solar dryer and ambient were 509.31 ± 145.62 and 637.09 ± 184.82 W/m^2 respectively. The average daily air movement in the solar dryer was 0.95 ± 0.32 m/s, while 2.14 ± 0.66 m/s was recorded in the ambient. The average temperature recorded on layers 1, 2 and 3 were 47.0 ± 6.4, 38.4 ± 5.6 and 32.6 ± 2.6 °C respectively, while the control had 30.5 ± 2.1 °C.

The drying curves of the nut dried on the three layers of the dryer and control are shown in Figure 4. The highest drying rate of 0.90 kg/day was recorded for nut dried on layer 1, while layers 2 and 3, and control recorded 0.76, 0.73 and 0.74 kg/day respectively. This finding is similar to what was reported by Akomolafe *et al.* (2021) while evaluating a multi-layer solar dryer using cassava mash; however in their report, the product on layer 2 recorded the least drying rate. The initial high drying rates experienced by the nut under the four conditions was as a result of large amount of free water present in the nut that resulted from the boiling process (Oyewole and Olaoye, 2013; Ogunsua *et al.*, 2020). The drying rates kept on decreasing until the fourth day when a rise that led to another set of reduction in drying rates was recorded. The increase in drying rate experienced on the fourth day was due to the temperature increase of about 25% recorded that day compared to available temperature on the third day. The reduction continued till the eighth day of drying with another gentle rise in the drying rates due to another significant temperature increase. Throughout the remaining days (9th – 19th day) of drying, the rates were very low and relatively the same for all the three layers and the control. Falling rate period was experienced throughout the drying experiment, and this has been reported as usual characteristics of agricultural product during drying (Ajala *et al*., 2012; Dairo *et al.*, 2015; Argo *et al.*, 2018; Ogunsua *et al.*, 2020; Akomolafe *et al.*, 2021).

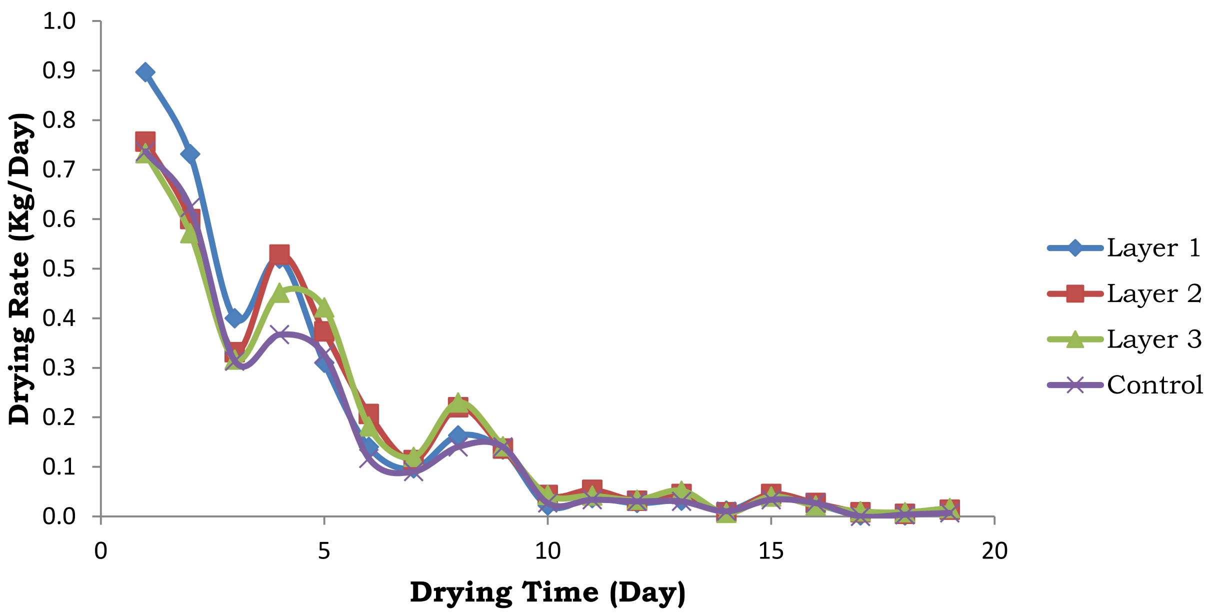

Figure 4: Drying Curves for the Shea Nut Dried on Different Layers of the Evaluated Solar Tent Dryer

3.2 Cracking Efficiency and Percentage Kernel Breakage

The cracking efficiencies for nuts dried on layers 1 to 3 and control were 98.9, 99.0, 97.9 and 94.7% respectively. These values show that irrespective of the drying layer in the solar dryer, the efficiency was higher than what was obtained in the control sample. The high cracking efficiencies of nut dried on the 3 layers of the dryer may be attributed to higher drying temperature range (32.6 – 47.0 °C) attained compared to what was obtained under control condition (30.5 °C) (Ade *et al*., 2018; Oyewole *et al*., 2019). Percentage kernel breakage of 5.68, 2.72, 2.28 and 1.73% were recorded in samples dried on layers 1 to 3 and control respectively (Figure 5). Layer 1 was significantly different from other layers in % kernel breakage ($P < 0.05$). The lowest percentage kernel breakage experienced in the control sample could not be solely attributed to moisture content of nut at the point of cracking because moisture content of samples dried on layers 2 and 3 were higher than that of control. The higher breakages recorded in the dryer may be due to the conditions in the drying chamber with respect to temperature they were subjected to during drying unlike the control that was placed in the ambient.

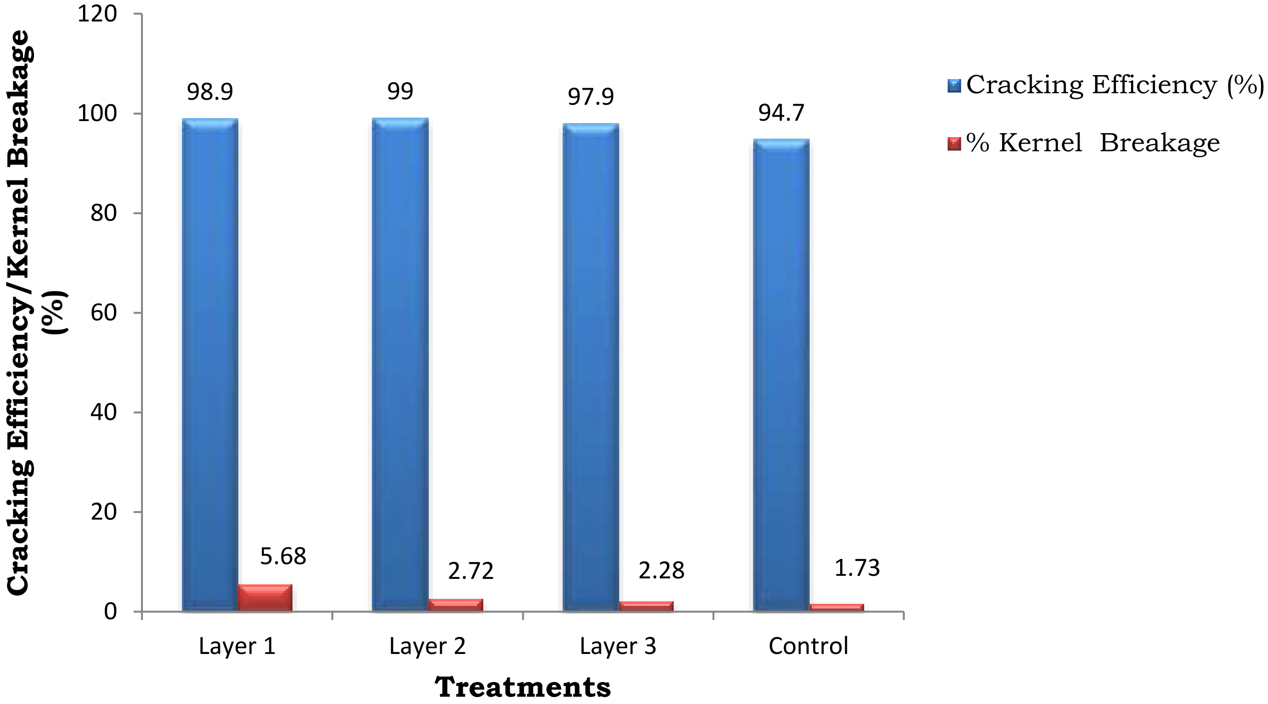

Figure 5: Cracking Efficiency and Percentage Kernel Breakage

3.3 Drying of Shea Kernel

It took 8 days to dry the shea kernel to a safe moisture level from initial moisture contents of 12.90 ± 1.60, 15.26 ± 2.36, 15.76 ± 1.12 and 13.80 ± 1.50%db to 5.55 ± 0.19, 6.04 ± 0.43, 7.11 ± 0.30 and 7.23 ± 0.08%db for layers 1 to 3 and control respectively. The average temperature recorded on layers 1, 2 and 3 were 45.3 ± 5.6, 39.2 ± 4.1 and 36.7 ± 3.9 °C respectively, while the control had 31.0 ± 2.8 °C. The drying rates of the three layers and control were characterized with rise and fall. The highest drying rate recorded during the drying was 0.0325 kg/day and was recorded in sample on layer 1 in the dryer. The control could not achieve any significant moisture loss for the first two days of the operation partly due to cloudy weather. After the third day, the drying rate of layers 1 and 2 dropped to 0 kg/day because there was no sufficient solar energy to remove moisture from the kernel due to the moisture loss experienced during the first three days of drying. Despite availability of low solar energy, layer 3 and control were able to release moisture to the ambient because the available energy (37.1 and 32.1 °C respectively) had potential to reduce moisture from their respective high moisture contents. On the sixth day, there was no drying in all the layers and the control because the weather was cloudy. There was improvement in available solar energy on the seventh and eighth day and this led to appreciable drying rate in all conditions under consideration. The drying curves also exhibited the falling rate period associated with agricultural produce (Ajala *et al*., 2012, Dairo *et al.*, 2015; Argo *et al.*, 2018; Akomolafe *et al.*, 2021).

3.4 Proximate and Microbial Qualities Evaluation

The results of the mean separation analysis conducted on the proximate compositions of the dried shea kernel on the three different layers and control showed that the mean values of ash, fat, crude fibre and carbohydrate in the four samples were not significantly different at P < 0.05 (Table 1). However, samples dried on layer 3 was significantly lower in crude protein content than samples on layer 2, while samples dried on layer 1 and control were not significantly different from the other two samples. The ash content of the shea kernel ranged from 2.26 to 2.71% and this is relatively close to 1.3 and 3.2% reported by earlier study carried out on shea kernel by Chukwu and Adgidzi (2008). Raimi *et al.* (2014) reported ash content of 4.18%, which is slightly higher than value recorded in this study and those reported by Chukwu and Adgidzi (2008). The difference could be attributed to variation in mineral compositions of soil and other environmental parameters of the locations where the nuts were collected (Maranz and Wiesman, 2003).

A crude fibre content of 12.47 – 15.07% was recorded in the study and this is in line with the report of Raimi *et al.* (2014) (12.68%). This composition indicates that the shea kernel is a good source of crude fibre, therefore reveals its potential as roughage that could be added to livestock feed after extraction of fat to aid digestion in animals (Alinnor and Oze, 2011). The crude fat of the shea kernel ranged between 48.13 and 48.88%. The crude fat (49.16%) reported by Raimi *et al.* (2014) was in the range of values recorded in this study. However, a slightly higher value that ranged from 52.63 to 55.68% was reported by Aculey *et al.* (2012) in a study conducted on effect of parboiling and drying methods on fat content of shea kernel.

The recorded protein content in this study ranged from 6.96 to 8.66%. Ugese *et al.* (2010) reported 6.3 to 8.9% protein content for kernel samples collected from 8 different locations across Sudan Savannah, Southern and Northern Guinea Savannah of Nigeria. Protein contents of 9.30% and 7 – 9% reported by Umali and Nikiema (2002) and Raimi *et al.* (2014) respectively are in the range recorded in this study. Carbohydrate content of 20.96 – 21.49% was recorded across the three layers and the control, which was very close to the value (21.84%) reported by Raimi *et al.* (2014). These compositions are evidences that the drying process did not in any way negatively impact the proximate composition of the dried shea kernel.

Table 1: Result of New Duncan's Multiple Range Test Analysis of Proximate Compositions of the Dried Shea Kernel

Treatments	**Ash (%)**	**Crude Fibre (%)**	**Crude Protein (%)**	**Crude Fat (%)**	**Carbohydrate (%)**
Layer 1	2.71 ± 0.06^{a}	15.07 ± 1.04^{a}	7.18 ± 0.61^{ab}	48.13 ± 0.96^{a}	20.98 ± 0.22^{a}
Layer 2	2.39 ± 0.02^{a}	12.47 ± 0.80^{a}	8.66 ± 0.09^{a}	48.76 ± 0.32^{a}	21.39 ± 0.01^{a}
Layer 3	2.45 ± 0.20^{a}	13.86 ± 0.54^{a}	6.96 ± 0.36^{b}	48.88 ± 0.76^{a}	21.47 ± 0.47^{a}
Control	2.26 ± 0.21^{a}	13.80 ± 0.49^{a}	7.31 ± 0.25^{ab}	48.67 ± 0.60^{a}	20.96 ± 0.54^{a}

Note: Mean ± S.E. within a column with different letters differ significantly at P<0.05 (New Duncan's Multiple Range Test)

In the microbial load evaluation, four parameters were considered namely; bacteria, fungi, total and faecal coliforms (Table 2). The results showed that it was only the bacteria loads of sample on layer 3 that was significantly different from others. The fungi counts of samples on layers 1 and 2 were not significantly different, and layer 3 and control samples were significantly the same. Analysis of coliform counts indicated that total count in sample on layer 1 was significantly different from that of layer 2 but layer 3 and control samples were not significantly different from both of them. Faecal coliform in samples dried on layer 1 was not significantly different from that of control. Also, layers 2 and 3 samples were significantly the same but different from samples on layer 1 and control. The inability of the nut on layer 3 to release moisture at the early period of the drying may be responsible for the high level of bacteria and fungi recorded in sample dried on the layer.

Table 2: Result of New Duncan's Multiple Range Test Analysis of the Microbial Loads in the Dried Shea Kernel

Treatments	Bacteria Loads (Cfu/g)	Fungi Counts (Cfu/g)	Total Coliform Counts (Cfu/g)	Faecal Coliform Counts (Cfu/g)
Layer 1	$2.9 \times 10^3 \pm 4.5 \times 10^{2\,b}$	$4.0 \times 10^3 \pm 2.6 \times 10^{2\,b}$	$7.7 \times 10^1 \pm 4.0 \times 10^{1\,b}$	$1.0 \times 10^1 \pm 0.6 \times 10^{1\,b}$
Layer 2	$3.6 \times 10^3 \pm 1.1 \times 10^{3\,b}$	$4.8 \times 10^3 \pm 6.2 \times 10^{2\,b}$	$3.8 \times 10^2 \pm 1.2 \times 10^{2\,a}$	$1.4 \times 10^2 \pm 1.2 \times 10^{1\,a}$
Layer 3	$2.0 \times 10^4 \pm 4.8 \times 10^{3\,a}$	$2.0 \times 10^4 \pm 6.5 \times 10^{3\,a}$	$2.9 \times 10^2 \pm 1.7 \times 10^{1\,ab}$	$1.5 \times 10^2 \pm 3.0 \times 10^{1\,a}$
Control	$4.5 \times 10^3 \pm 6.8 \times 10^{2\,b}$	$2.0 \times 10^4 \pm 2.2 \times 10^{3\,a}$	$1.7 \times 10^2 \pm 5.4 \times 10^{1\,ab}$	$3.7 \times 10^1 \pm 3.7 \times 10^{1\,b}$

Note: Mean ± S.E. within a column with different letters differ significantly at P<0.05 (New Duncan's Multiple Range Test)

3.5 Moisture Contents of Dried Shea Nut and Kernel

The New Duncan's Multiple Range Test carried out on the moisture contents of samples collected from different layers showed that there was no significant difference in the mean values of moisture content of shea nut. However, the analysis revealed that moisture contents of shea kernel dried on layers 1 and 2 were not significantly different ($P < 0.05$). Likewise, the means of moisture content of kernel sample dried on layer 3 and that of control were statistically the same but different from the layers 1 and 2 samples (Table 3). This justifies the drying rates recorded by the treatment. Akomolafe *et al.* (2021) also reported similar finding in evaluation of solar dryer using cassava mash.

Table 3: Result of New Duncan's Multiple Range Test Analysis of the Final Moisture Content of the Dried Shea Nut and Kernel

Treatments	Moisture Content of Nut (%)	Moisture Content of Kernel (%)
Layer 1	13.10 ± 0.79^a	5.55 ± 0.11^b
Layer 2	15.05 ± 1.17^a	6.04 ± 0.14^b
Layer 3	15.82 ± 0.45^a	7.11 ± 0.07^a
Control	13.80 ± 0.98^a	6.81 ± 0.42^a

Note: Mean ± S.E. within a column with different letters differ significantly at P<0.05 (New Duncan's Multiple Range Test)

3.6 Sensory Evaluation of Shea Kernel

The statistical analysis of the means of the parameters evaluated for sensory showed that there was no significant difference in the mean of shea kernel dried on layer 1 and control but different from layers 2 and 3 for appearance and presence of physical mould parameters. Also, layers 2 and 3 samples were statistically different from one another ($P < 0.05$). The result of the aroma showed that samples of kernel dried on layer 1 was statistically different from that of layer 3, while layer 2 and control samples were not different from layers 1 and 3 (Table 4). Figure 6 shows the general acceptability of the sensory evaluation with samples on layer 1 and control having the best results. The least general acceptability of the sensory quality was recorded in layer 3.

Table 4: Result of New Duncan's Multiple Range Test Analysis of the Sensory Parameters of the Dried Shea Kernel

Treatments	Appearance	Presence of Physical Mould	Aroma
Layer 1	7.80 ± 0.00[a]	7.70 ± 0.00[a]	7.70 ± 0.00[a]
Layer 2	6.90 ± 0.30[b]	6.60 ± 0.10[b]	7.10 ± 0.00[ab]
Layer 3	6.10 ± 0.20[c]	5.60 ± 0.00[c]	6.70 ± 0.40[b]
Control	8.10 ± 0.10[a]	7.60 ± 0.10[a]	7.40 ± 0.10[ab]

Note: Mean ± S.E. within a column with different letters differ significantly at $P<0.05$ (New Duncan's Multiple Range Test)

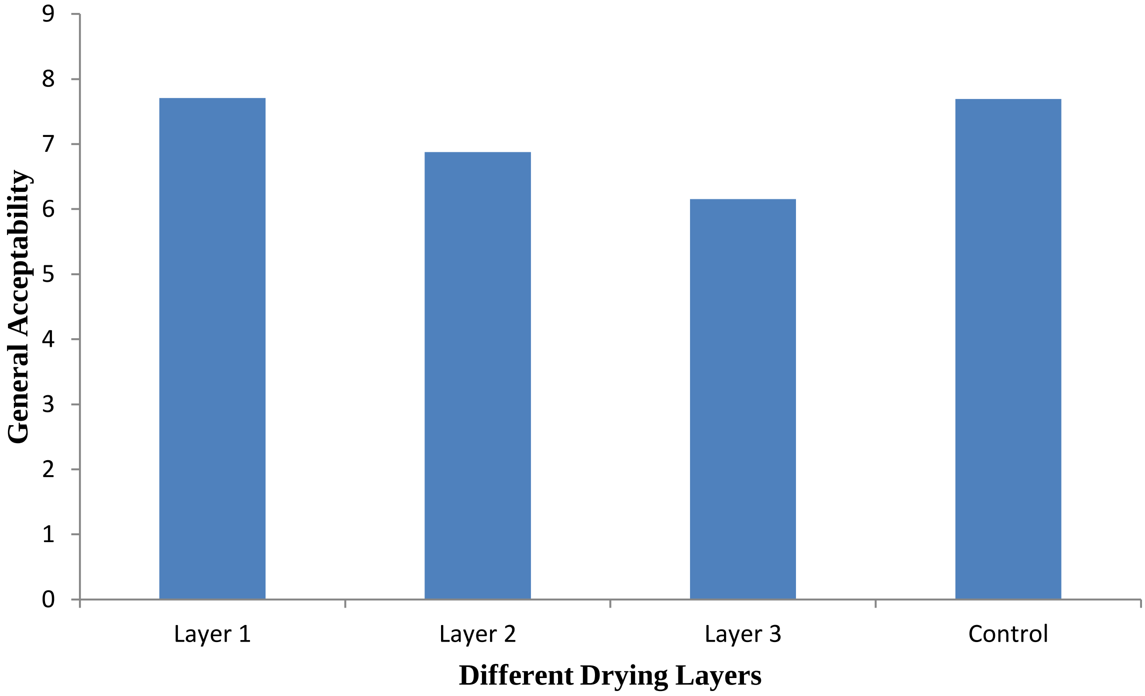

Figure 6: General Acceptability of the Sensory Evaluation of the Dried Shea Kernel

4. CONCLUSION

The result obtained from the solar tent dryer showed that it could be used for drying of shea nut and kernel without loss of quality parameters. However, the evaluation of the drying output with respect to layers of the dryer indicated that the loading of the dryer should be limited to two layers to avoid quality deterioration. The use of this dryer will go a long way in solving the challenges being faced by shea nut processors when drying the product which usually occur during the season characterized with low solar radiation as a result of cloudy sky.

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