Research Article
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Performance evaluation of cassava drying technologies: a case study from Uganda

Abstract

Dried cassava chips have varied applications by end users that include breweries, confectionaries, starch and flour for food. In Uganda, over 80% of Cassava farmers dry their products by open sun drying and direct passive solar dryers. However, these two drying practices produce varying quality of dried products which may not be good all for the various end users. The quality of dried products depends on factors like cassava chip size, drying technology, temperature, air flow and relative humidity. The objective of this study was to assess the performance of cassava sun drying on a raised platform and drying in a direct passive solar dryer. The two drying technologies were assessed basing on drying rate and product quality of cassava using a randomized complete block design experiment. The measurements considered for drying rate and quality assessment were drying time, moisture content, pH, peak viscosity, starch content and microbial contamination in terms of Total plate count (TPC), Total coliforms (TC) and Yeast and moulds (YM). Results showed that samples dried on the raised platform had higher drying rates than those dried in solar dryer. Additionally, Cassava samples dried on the raised platform showed superior quality in terms of microbial contamination compared to samples dried in the solar dryer.

Keywords: Cassava drying, solar dryer, raised drying platform, bananas, production

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Introduction

Cassava is one of the major crops produced in Uganda, together with plantain, maize, sweet potatoes, and sugar cane.[1] It is the second most important staple crop in Uganda after bananas, with production being dominated by smallholders.[2] According to UBOS (2017),[3] the Eastern region reported the highest production of cassava followed by the northern region, Western region and Central region. The crop is grown for food and income and is traded in different forms as cassava flour (50%), dried cassava chips (45%) and raw cassava (5%) and about 200,000 MT of cassava flour are consumed per annum in Uganda, with most of it being traded in traditional informal markets and negligible quantities featuring in supermarkets,[2] the major challenges at processing level being high cost of processing, poor quality and erratic supply of cassava. The quality of dried cassava chips depends on factors like Cassava chip size, drying technology, final moisture content, microbial contamination, colour and drying time. Drying is a unit operation aimed at removing nearly all water present in a food stuff.[4] The commonly used methods of drying cassava in Uganda include use of solar dryers both active and passive, open sun drying on bare ground, raised platforms, road sides, roof tops, and tarpaulins. However, the current practices for cassava drying, mainly sun drying though economical,[5] have many disadvantages such as spoilt products due to rain, wind, dust, insect infestation, animal attack and fungi. Thus in Uganda, the crop has 19% postharvest losses with 60% aflatoxin prevalence.[6]

Materials and methods

Materials

The materials and equipment used for the investigation are the raised drying platform and direct passive solar dryer used for all the drying experiments, freshly harvested cassava tubers of the NASE 14 variety obtained from the farmer's field. All other experiments were carried out in the laboratories of the school Food Technology, Nutrition and Bio-Engineering, Makerere University.

Methods

Sample preparation: Fresh roots were harvested, peeled, washed using portable water and then sliced using hand knives. Four cassava chip sizes as illustrated in Figure 1 were studied; size 1 was 9 cm arch length obtained after first slicing of an average tuber which was found to be 6 cm diameter, size 2 was a whole tuber of 3 cm thick diameter, size 3 was 5 cm arch length obtained after second slicing and size 4 was 2 cm arch length obtained after third slicing of the average tuber.

Experimental set up: Four cassava chip sizes of NASE 14 variety, which is mostly grown in Uganda, were monitored for drying using open sun drying on a raised platform and direct passive solar dryer. A Randomised Complete Block Design experiment was set up at the farmer's field and the four cassava chip sizes were subsequently subjected to the two-mentioned drying technologies in 3 replicates. The chip sizes were randomly distributed among units of 0.75m^2 on the drying beds and uniformly spread. Two experimental runs were conducted for each treatment.

For both drying technologies; before, and after drying; moisture content and microbial load that included Total plate count (TPC), Total coliforms (TC), Yeast and Moulds (YM) were measured. After drying, pH, peak viscosity, pasting temperature, and starch content of flour produced from the two drying technologies were measured. Temperature and humidity were also measured since they have an effect on the drying rate and quality of the products. During drying, moisture content was monitored every day by weight loss method according to Kemp et al., (2001)[7] using WH–B10 Electronic scale and Equation 1. Standard air oven method according to Harrigan et al., (1976)[8] was also used to measure the initial moisture content, moisture content at day 4 and final moisture content.

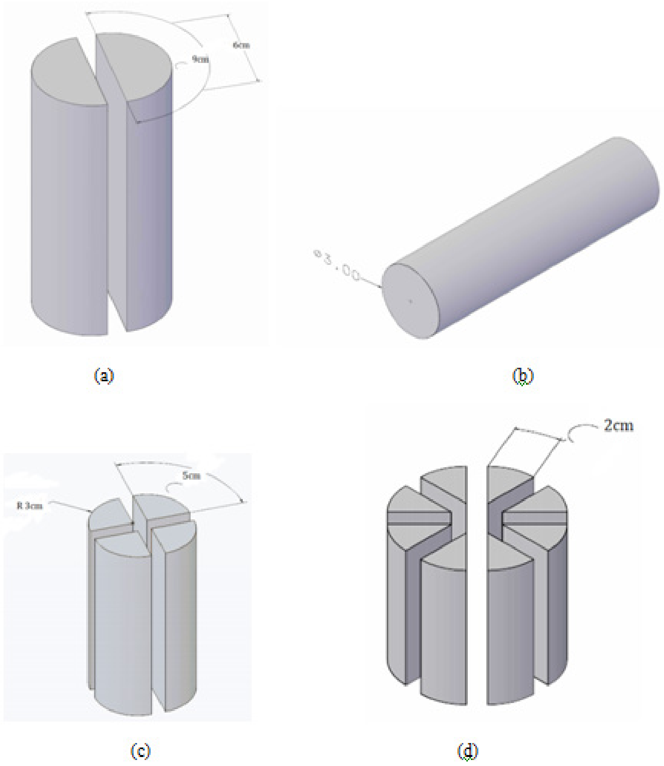

Figure 1 Illustration of cassava chip sizes: (a) size 1 of 9cm arc length (b) size 2 of 3cm diameter (c) size 3 of 5cm arc length (d) size 4 of 2cm arc length.

$$\text{Final Moisture } \% = \text{Initial weight} \times \frac{\text{initial \% moisture - 100}}{\text{100 * final weight}}$$

……….Equation 1

Drying rates for all the four cassava chip sizes dried using both drying technologies were also determined by computing and recording the slopes of moisture contents per day.[7] Curves were plotted from this data to show the relationship among the cassava chip sizes.

Analysis of chemical and functional properties of cassava chips: pH was determined using a pH meter (Jenway 3330, UK). Starch content was determined using Equation 2 as per Åman et al., (1994).[9]

$$\% starch\left(dry\, matter\right) = \frac{\left(glucose\right) \times 25.15 \times 0.9 \times 25}{Sample\, weight\left(mg, DM\right)}$$

………Equation 2

Pasting properties of cassava flours upon heating and subsequent cooling were determined by RVA general pasting method (STD1) using a Rapid Visco-Analyzer (RVA). Total running time of 13 min was used and the viscosity values recorded as the temperature increases from 50ºC to 95ºC before cooling to 50ºC again. Rotation speed was set to 960 rpm for the first 10 sec and to 160 rpm until the end.[10]

Determination of microbial load: Microbial content was determined following procedures described by Harrigan and McCance, (1976).[8] Plate count technique was used to enumerate total viable microorganisms (Total plate Count, TPC) whereby a known amount of the product is mixed with a culture medium in a petri dish, incubated, and the numbers of developed colonies counted and the viable count of the microorganisms (per gram) calculated. Yeasts and moulds (YM) were enumerated using Potato Dextrose Agar (PDA) and Total Coliforms (TC) were determined using Violet Red Bile Agar (VRBA).

Statistical analysis

Data was recorded and subjected to analysis of variance (ANOVA) for test of significance of experimental factors and interaction. The analysis of variance for each factor was done using MATLAB R2016b. A significance level or probability ($p<0.05$) was used for all analysis. Relationships for drying rates between the dryer and raised platform were determined using graph analysis.

Results and discussion

Initial measurements

Table 1 shows results of TPC, TC, and YM for fresh cassava chips. The low values of TPC and TC could be attributed to less microbial contamination of the fresh cassava samples which could only have occurred due to exposure during material handling practices of peeling, washing and slicing. The figure of 0cfu/g for yeast and moulds implies that there was no mould growth in the fresh cassava samples.

Table 1 Microbial load results for fresh cassava samples

TPC (cfu/g)	1690
TC (cfu/g)	477.5
YM (cfu/g)	0

The initial average moisture content of freshly harvested tubers was 61.4% wet basis. This is similar to values of 60.7% wet basis[11] and 63% wet basis[12] reported in other studies. The discrepancy could be attributed to the difference in variety used, difference in locality, maturity of the root and seasonality of harvesting period.[13]

Cassava drying rate

Figure 2 is moisture vs. time graph for 5 cm arc length cassava chips. The effect of humidity on drying can be shown by this Figure. When humidity is high, the drying rate is low and the drying rate increases with reduction in humidity. This is clearly observed on day 4 by the steep fall of the drying curves when humidity reduced.

Figure 3 shows that drying rates were highest during the initial stages for both the raised drying platform and solar dryer. This could be attributed to the fact that during the initial stage of drying the water lost from the cassava chips is largely the water on the surface of the chips. Once that water has been evaporated, the rate of evaporation of water from the chips begins to decrease since water must move through the material to the surface in order for drying to continue.[11] However, it is also observed that drying rate was low when moisture content was above 50% and this was on day 1. This can be explained by the short drying duration on day 1 since sample preparation (harvesting, peeling, washing and slicing) was first done and the samples were laid on drying beds at around 2 pm and dried up to 5 pm.

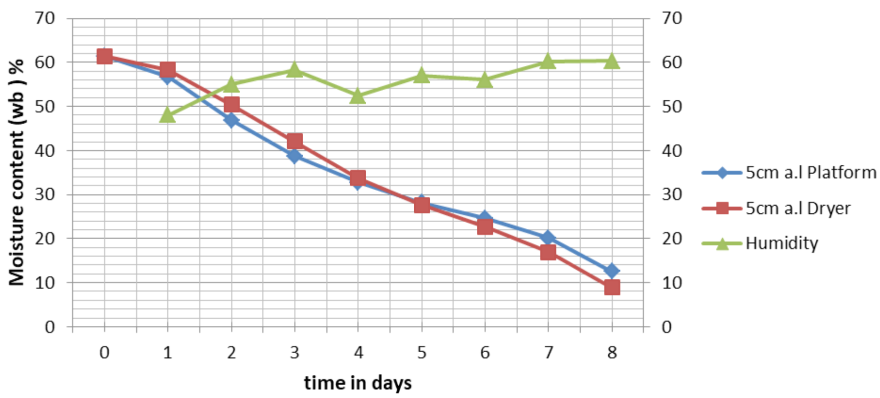

Figure 2 Moisture content vs time drying curves for solar dryer and raised platform.

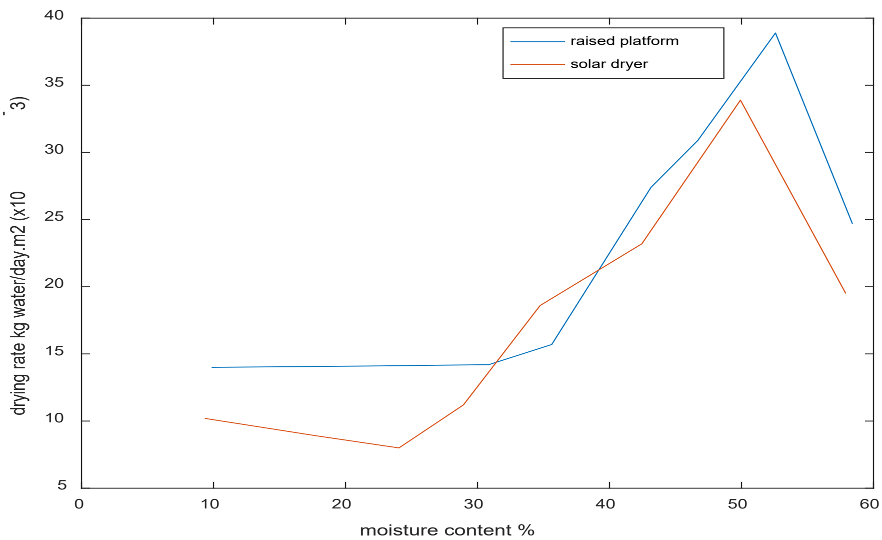

Figure 3 Drying rate vs moisture content curves for chip size of 9 cm arc length.

It is also observed from Figure 3, that samples dried on the raised platform had higher drying rates than those dried in the solar dryer. The higher drying rates on the raised platform could be attributed to sufficient airflow due to openness of the platform unlike the solar dryer. Quality of dried cassava chips Table 2 shows that the final moisture content in the dryer ranged between 8.9% for chip size of 2 cm arc length and 10.6% for chip size of 9 cm arc length, and ranged between 9.7% for chip size of 2 cm arc length and 11.9% for chip size of 9 cm arc length on the raised platform. These values are within the acceptable ranges according to UNBS, 2012,[14] Perez & Diamante, 2006, Shittu, et al., 2006,[15] CAVA, 2010. It is also observed from Table 2 that for both drying technologies, chip size of 9 cm arc length had the highest final moisture content while chip size of 2 cm arc length had the lowest final moisture content. This may be attributed to the surface area to volume ration of the two cassava chip sizes, since chip size of 2 cm arc length was the smallest with the largest exposed surface area that facilitates drying and chip size of 9 cm arc length was the biggest with the smallest surface area. Statistical analyses for moisture content showed significant difference among the four chip sizes for both the dryer and raised platform ($p<0.05$).

Table 2 Results of quality attributes for dryer and raised platform

Quality attribute	Dryer				Raised Platform			
	9cm arc length	3 cm diameter	5 cm arc length	2 cm arc length	9cm arc length	3 cm diameter	5 cm arc length	2 cm arc length
pH	5.8[a]	6.4[b]	5.7[c]	5.6[d]	5.7[e]	5.2[f]	5.7[g]	6.1[h]
MC %	10.6	10.1	9.9	8.9	11.9	11.4	10.7	9.7
TC cfu/g	8.17E+05[a]	1.17E+06[a]	4.68E+05[a]	5.95E+05[a]	8.73E+03[b]	1.05E+04[b]	4.87E+05[b]	1.61E+03[b]
TPC cfu/g	7.06E+06[a]	2.17E+07[a]	1.03E+07[a]	9.01E+06[a]	2.58E+05[b]	2.58E+05[b]	2.58E+05[b]	2.58E+05[b]
YM cfu/g	1.03E+03[a]	1.45E+04[a]	1.47E+04[a]	1.74E+04[a]	2.23E+03[a]	2.18E+03[b]	2.17E+02[c]	8.33E+01[d]
Starch %	87.5[a]	82.1[a]	83.3[a]	85.8[a]	77.1[b]	86.4[b]	84.3[b]	83.4[b]
Final viscosity cP	2874	3102	3146	2717	2051	2051	2595	2637
Pasting temp °C	67.3[a]	60.9[a]	56.8[a]	55.9[a]	66.0[b]	65.6[b]	62.1[b]	67.8[b]

*Values having the same superscript within a drying technology are not significantly different and those with different superscripts are significantly different at a significance level of ($p< 0.05$)

pH ranged between 5.6 and 6.4 which is acceptable according to the UNBS (2012)[14] quality requirements. According to Eriksson, et al., 2014,[16] flour with a pH 4 or less will have a characteristic sour aroma and taste, which is not desirable in food products. In addition, analysis of pH results in both the dryer and raised platform reported a significant difference ($p<0.05$) in pH among the four sizes. Chip size of 3cm diameter and 2cm arc length had high pH values. The increase in pH might be due to the consumption of lactic acid in a chemical reaction during drying. Lactic acid can be transformed during drying to either lactate or the lactic form may disappear.[17]

From Figure 4, it is observed that samples dried on the raised platform had less Total coliforms than those dried in the solar dryer. This suggests cassava drying on raised platform as a safer drying technology compared to drying in solar dryer. The rise in Total coliforms for chip size of 5cm arc length on the raised platform could be attributed to coliform proliferation.

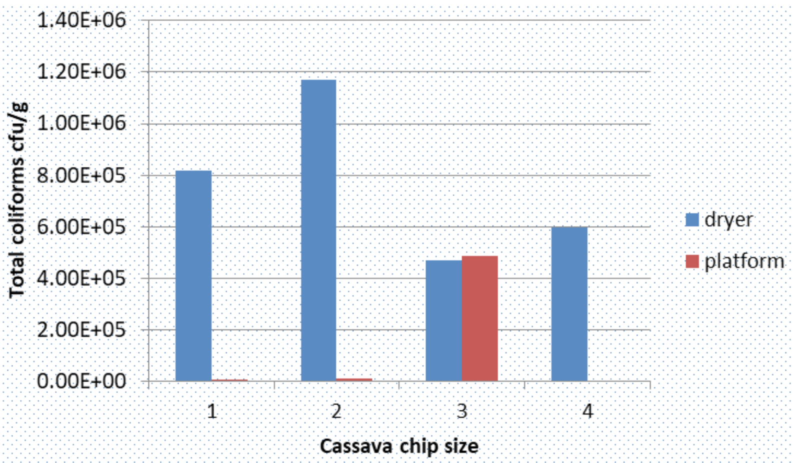

Figure 4 Effect of chip size on Total Coliforms.

It is noted that values of yeast and mould count for samples dried by both drying technologies were within the East African Standards (EAS) acceptable range of x10^4 maximum. However, it is observed from Figure 5, that samples dried on the raised platform had less yeast and moulds than those dried in the solar dryer suggesting cassava dried on raised platform to be safer for human consumption and probably having a longer shelf life than cassava dried in solar dryer. High yeast and moulds counts in solar dryer is attributed to the solid surface of its drying bed that could not allow the bottom surfaces of cassava chip samples to dry unlike the raised drying platform with a meshed drying bed that allows circulation of air to all surfaces of the samples. Cassava chip sizes demonstrated no significant effect on yeast and moulds counts for dryer unlike for the raised drying platform with chip sizes of 9cm arc length and 3cm diameter having the highest number of counts. This may be attributed to the slow drying rate of bigger chip sizes that favours mould growth.

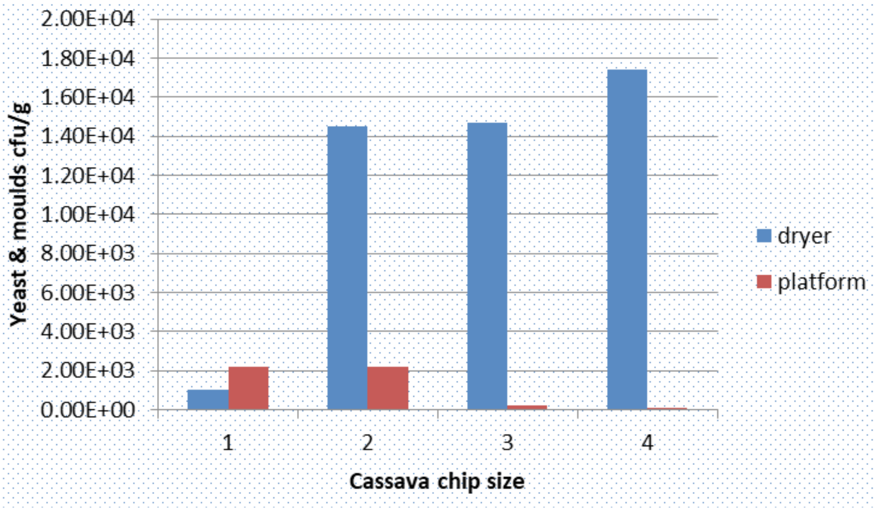

Figure 5 Effect of chip size on yeast & moulds.

From Figure 6, it is observed that samples dried on the raised platform had less Total Plate Count than those dried in the solar dryer. Total Plate Count being the total number of viable microbes in a food product, the low values for the raised platform imply that samples dried on it were less contaminated than those dried in the solar dryer. ANOVA test of Total Plate Count and Total Coliforms for both the dryer and raised platform showed no statistically significant difference of the effect of chip sizes ($p>0.05$).This implies that other factors other than cassava chip size affected Total Plate Count and Total Coliforms. Such factors could be hygiene and sanitary practices observed during the drying process.

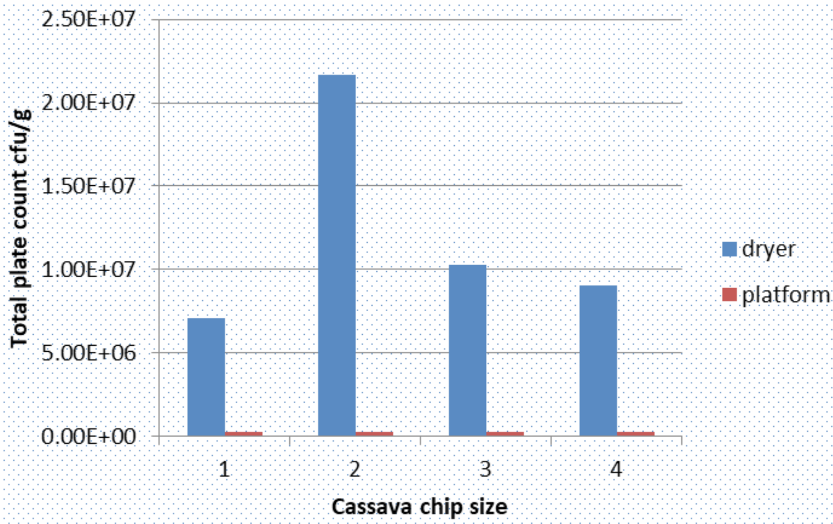

Figure 6 Effect of chip size on Total Plate Count.

One-way ANOVA test of starch content for both the dryer and raised platform showed no statistically significant difference of the effect of chip sizes ($p>0.05$). The final viscosity, a parameter commonly used to determine a sample's ability to form a gel after cooking and cooling ranged from 2717 cP to 3146 cP for dryer and 2051 cP to 2637 cP for raised platform. These findings are in agreement to those of a previous study by Shittu et al., (2016).[15] For both drying technologies, there was no significant difference in pasting temperature among the four cassava chip sizes ($p>0.05$). Flours from the two cassava drying technologies showed similar pasting temperature of between 55.9-67.8ºC. According to Eriksson et al.,2014,[16] values within this range reveal lower gelatinization temperature which translates into shorter cooking time and lower paste stability of cassava flour. These findings are also similar to those of an earlier study by Apea-Bah et al., (2011).

Conclusion

Cassava dried on the raised platform showed superior quality in terms of microbial contamination compared to that from the solar dryer. The raised platform being open allowed free movement of air around all surfaces of the cassava chips thus allowing uniform drying and less mould growth. Inadequate performance of the dryer was attributed to the moist bottom surfaces of the cassava that provided suitable environment for mould growth. While cassava chip size 2 cm arc length dries in the shortest time of 4 days under both drying technologies, it is associated to large drying area occupation, injuries and much time consumption during slicing. Therefore, cassava chip size of 5cm arc length is recommended since its drying time was not significantly longer than that for 2cm arc length, occupies less drying area and can easily be achieved by slicing using hand knives.

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None.

Conflicts of interest

The authors declare that there was no conflict of interest.

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