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Investigating the Effects of Different Drying Methods on the Drying Kinetics and Proximate Composition of Zobo Calyces

Olosunde William Adebisi[1*], William Edidiong Bassey[1], Olosunde Oluwapelumi Oluwabusayo[2]
Amanyunose Aderonke Abiodun[2]

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ABSTRACT

Hibiscus sabdarrifa are cultivated and consumed as tea, whereas other hibiscus varieties are planted for the fibers they produce. Hibiscus sabdariffa known as roselle, is one of the underexploited food crops with nutritional and food industry processing potential. Thus, this study was undertaken to determine the effects of different drying methods (sun, solar and oven drying) and drying kinetics on the proximate composition of dried calyx (Proximate and Mineral composition) using AOAC Standard. The data obtained from this study was statistically analyzed using Tukey HSD (Tukey Honest Significant Difference). The values of the model constant and other Statistical parameters for moisture ratio were obtained. The two-term exponential model had the highest R^2 and the lowest x^2 and RMSE value. The model constants, the R^2, x^2 and RMSE for each model were obtained. The page model had the highest R^2 and lowest x^2 and RMSE and was selected as the best fit model for describing the drying kinetics zobo calyces in an oven dryer while Logarithmic model and Wang and Sing Model was selected for modeling of zobo calyces in sun and solar dryer respectively. The experimental and predicted moisture ratio values are very close to the each other given the R^2 value and the straight-line graph when the predicted moisture ratio is plotted against the experimental moisture ratio. Sample dried with oven dryer gave the highest carotenoid and vitamin C content compared to other drying methods. Therefore, oven dryer is recommended for drying of zobo calyces as compared to sun and solar dryer.

INTRODUCTION

Roselle, Hibiscus sabdariffa L. is a plant that is indigenous to the tropics. Different authors have reported a wide range of names depending on their areas of research and country. Roselle is known as Isapa pupa in the South Western part of Nigeria and Zobo in Northern, South-East and South-South part of Nigria (Nwachukwu, 2007; Nwafor, 2012). Zobo is produced from the dried calyces of Hibiscus sabdariffa. H. sabdariffa which belongs to Malvaceae family and is an annual erect bushy branched herb found in tropical and semi-tropical regions of the world (Nwachukwu, 2007). Hibiscus sabdariffa belongs to the super order Malvacea and it is believed to originate from East Africa (llondu and lloh, 2007).

Hibiscus sabdariffa are cultivated and consumed as vegetable and tea, whereas other hibiscus varieties are planted for the fibres they produce (FAO, 1990). It is called different names like Roselle and Sorrel in English and it is locally called zobo and Isapa in Nigeria (Adebayo and Samuel, 2000).

Figure 1: Roselle Plant

Figure 2: Roselle Calyces

Hibiscus sabdariffa known as roselle one of the underexploited food crops with nutritional and food industry processing potential. The flowers are axillaries or in terminal racemes, the petals are white with reddish center at the base of the stamina column (Umeh *et al*., 2015; Zumes *et al*. 2014). The more economically important is var. altissima, which is cultivated for its jute-like fiber in India, East Indies, Nigeria and South America, whereas var. sabdariffa is another distinct type of Roselle and is also widely exploited for its calyces and fiber. Roselle plants are suitable for tropical climates with well-distributed rain-fall of 15002000 mm/year, from sea-level to about 600 m in attitude. It can grow up to 5-7 feet in height, with lobed leaves sometimes used for greens

[1] Department of Agricultural and Food Engineering, Faculty of Engineering, University of Uyo, Uyo, P. M. B. 1017, Akwa Ibom State, Nigeria
[2] Department of Food Science and Technology, Osun State Polytechnic, Iree, Nigeria
[*] Corresponding author's email: williamolosunde@uniuyo.edu.ng

(Kumar and Saga (2014). The narrow leaves and stems are reddish green in color and the calyces are reported to numerous essential, economic and health benefits (Yousefi *et al*., 2013; Onwunde *et al*. 2017). Therefore, the objective of this study was to determine the effects of different drying methods on the drying kinetics and proximate composition of zobo calyces.

METHODS

Sample Collection and Preparation

The samples for experimental analysis were obtained from NRF Tetfund zobo project farm at the Department of Agricultural and Food Engineering, Faculty of Engineering, University of Uyo, Akwa Ibom State, Nigeria. The zobo calyces were thoroughly cleaned and sorted to remove debris and stones. Samples were stored in a Zip-locked bag to avoid any form of contamination and moisture absorption. The experiments were carried out at the Food Engineering Laboratory, University of Uyo, Nigeria.

Proximate Composition Determination

The proximate composition of the samples was determined using the standard methods of analysis of the Association of Official Chemists (AOAC), 2010. Crude protein, crude lipid, carbohydrate, Moisture content, and ash contents in the samples were analyzed. The same procedures were carried out in all the samples.

Determination of Moisture Content

Ten grams (10g) of the sample was placed in an oven at 105 0C for 2hours, and constant weighing was done at 30 mins interval until a constant weight was reached. The moisture content was calculated using Equation 1.

Moisture Content= $(W_1 - W_2)/W_1 \times 100$ (1)

where; W_1 = initial weight of the ground sample, W_2= weight of dried sample.

Determination of Crude Protein

Five grams (5g) of the sample was weighed and placed in a Kjeldahl flask. Ten grams (10g) of Sodium Sulphate ($Na2SO4$), 1.5g of Copper Sulphate ($CuSO4$) and 10ml of concentrated sulphuric acid ($H2SO4$) was added to the sample in the flask. The flask was placed tilted to an angle in the digester, boiled and allowed to stand until the solution is bluish. The solution was allowed to cool while gradually, 90ml of distilled water was added to the digested sample and the volume was made- up to 100ml using 100ml volumetric flask. 20 ml of the digested solution and 20ml of 40% sodium hydroxide solution was added 250ml flat bottom flask. The flask was quickly connected to the distillation unit and the distillate was collected under 10ml saturated boric acid in a 250ml conical flask. At the end of the distillation, the distillate was titrated with 0.1M hydrochloric acid (HCL) using drops of mixed indicator until the solution changed from blue to reddish brown. This procedure will be repeated for all sample in triplets. The crude protein content was then calculated equation using Equations 2 and 3 (AOAC, 2010).

% nitrogen content=(0.14 × titre value (sample))/(weight of the sample) (2)

% protein= % Nitrogen × 6.2 (3)

Determination of Crude Fibre

Five (5grams) of sample was defatted in 200ml of N-hexane for 2 hours in a 250ml conical flask; after this 200ml of 5M sulphuric acid was added to the flask and the mixture was boiled under reflux for 30minutes, the hot solution was quickly filtered under suction. The insoluble matter was washed several times with hot distill water until it was acid free. It was quantitatively transferred into the flask and 200ml of 5M NaOH solution was added, the mixture was boiled under reflux for 30minutes and filtered under suction. The residue was washed with boiling water until it was base free, dried to constant weight in an oven at 1000C, cooled in a desiccator and weighed (A). The weight sample as incinerated in a muffle furnace at 5500C for 2 hours, cooled and in a desiccator and reweighed (B) (AOAC, 2010).

The crude fiber was calculated using the Equation 4.

Percentage crude fiber= $(W_1 - W_2)/W_1 \times 100$ (4)

where; W_1 = Weight of crucible + Fiber + ash,

W_2 = Weight of crucible + ash, W_0 = Weight of food sample.

Determination of Ash Content

The Fat content was carried out following the standard method by Association of Official Analytical Chemist (AOAC, 2010). Five (5g) grams of the sample was weighed into the previously cleaned, dried crucible of known mass. The crucible with the content was weighed and mass recorded. The crucible with content was placed into a muffle furnace at 550oC for 3 hours until the sample turned white and free from carbon. At the end of incineration, the ash substance was withdrawn and cooled in a crucible and reweighed. The mass of the residual incinerate was used to calculate the percentage ash content using Equation 5.

Percentage Ash Content= (weight of sample - weight of ash)/(weight of sample) × 100 (5)

RESULTS

Result for the Drying Kinetics of Zobo Calyces

The percentage moisture content of zobo calyces in open sun, solar drier and oven is shown in Figure 3. Oven drying gave the shortest drying time compared to other methods. This shows that the oven drier dries faster (with an average drying time of 150 min to reach a constant moisture mass) than other method. This could be due to the high temperature of the oven and the confinement which does not allow heat to escape. The sun drying had the longest drying time. The drying shows a falling rate period for solar, sun and oven. Similar results have been observed in the drying of different fruits and vegetables: kiwifruit, carrot pomace, pineapple, mango, guava and papaya, hazelnut, and apple pomace. At the initial stage, moisture evaporation proceeds rapidly in an exponential manner and then slowly decreased with increase in drying time until the latter stages of drying when moisture evaporation became non-existent. The moisture content was observed to reduce as the time of drying increased which is probably due to the reduction in available water for evaporation as drying progresses.

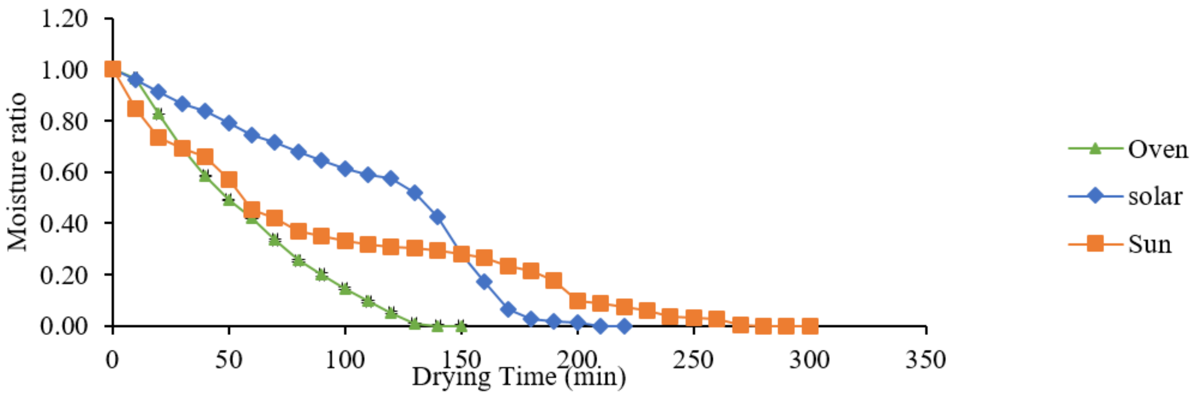

Figure 3: Moisture Ratio with Respect to Time for Drying

Modelling of the Drying Kinetics of Zobo Calyces

The experimental moisture ratio was calculated from experimental data and five thin layer drying models was used to evaluate the best model that describe the drying kinetics of zobo calyces. The values of the model constant and other Statistical parameters for moisture ratio are presented in Table 1. For open sun drying, enhanced sun drying and solar drying, the two-term exponential model had the highest R^2 and the lowest x^2 and RMSE value, hence, it is used to describe the drying kinetics. The model constants, the R^2, x^2 and RMSE for each model is shown in Table 1.

Table 1: Parameters and Regression Coefficient of Drying Models Applied to the Drying Kinetics of Zobo

Drying Method	Model	Constant	x^2	R^2	RMSE
Oven	1	k= 0.16	0.0062	0.953	0.0759
	2	k= 0.002 n= 1.505	0.0006	0.995	0.0235
	3	a= 1.396 c= -0.34 k= 0.010	0.0007	0.995	0.0251
	4	a= -13.162 b= 14.216 k_0 = 0.006 k_1= 0.006	0.0006	0.995	0.0239
	5	a= -0.012 b= 3.192×10^{-5}	0.0007	0.995	0.0262
Sun	1	k= 0.011	0.00245	0.969	0.0485
	2	k= 0.016 n= 0.912	0.0021	0.972	0.0463
	3	a= 0.098 c= -0.065 k= 0.008	0.0019	0.975	0.0429
	4	a= 0.307 b= 0.642 k_0= 0.010 k_1= 0.010	0.0022	0.972	0.0459
	5	a = -0.008 b =1.479×10^{-5}	0.005	0.927	0.0728

Solar	1	k= 0.008	0.0228	0.822	0.1474
	2	k= 1.86× 10^{-5} n= 2.232	0.0071	0.946	0.0821
	3	a= -99.44 c= 100.495 k= 5.051× 10^{-5}	0.0051	0.960	0.070
	4	a= 0.571 b= 0.571 k_0= 0.009 k_1= 0.009	0.0194	0.849	0.1362
	5	a = -0.003 b = -7.409× 10^{-5}	0.0041	0.969	0.0625

1 = Exponential model, 2 = Page model, 3 = Logarithmic model, 4 = Two term model, 5 = Wang and Singh model

The Page model had the highest R^2 and lowest x^2 and RMSE and was selected as the best fit model for describing the drying kinetics zobo calyces in an oven dryer while Logarithmic model and Wang and Sing Model was selected for modeling of zobo calyces in sun and solar dryer respectively. Figures 4 and 5 indicates that the experimental and predicted moisture ratio values are very close to the each other given the R^2 value and the straight-line graph when the predicted moisture ratio is plotted against the experimental moisture ratio. The accuracy of the selection of the Page model for oven, Logarithmic for sun dryer and Wang and Singh model for solar drying was confirmed by the relationship between the experimental moisture ratios versus predicted moisture ratio.

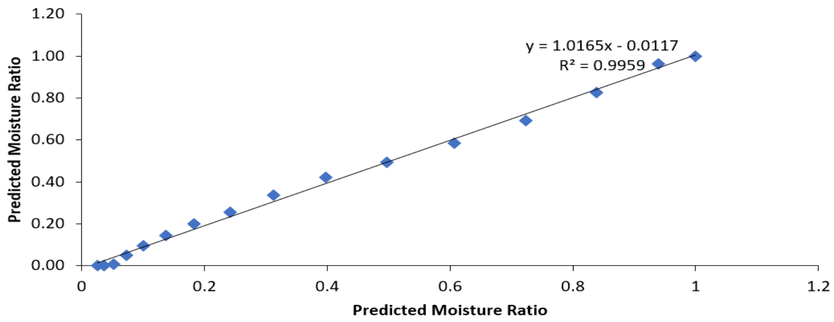

Figure 4: Experimental Moisture ratio versus Predicted Moisture Ratio for Oven Drying

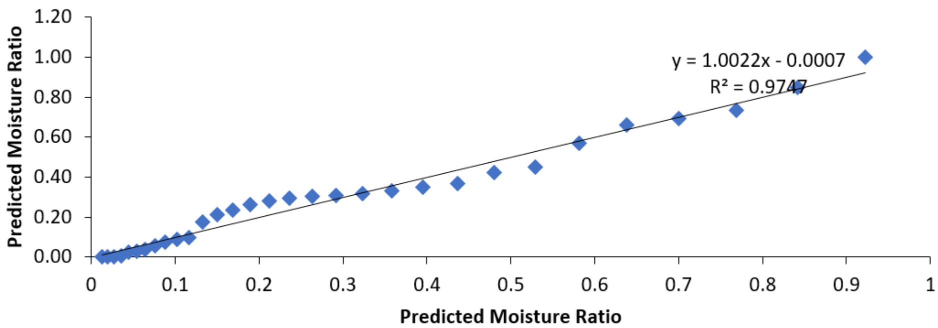

Figure 5: Experimental Moisture ratio versus Predicted Moisture Ratio for Sun Drying

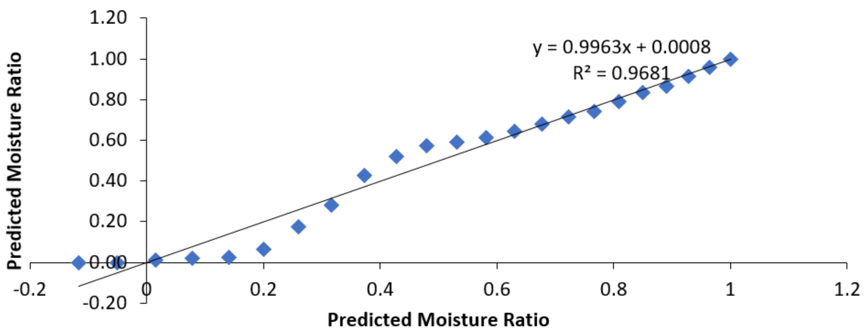

Figure 6: Experimental Moisture ratio versus Predicted Moisture Ratio for Solar Drying

Vitamin C and Carotenoid Content of Fresh and Dried Zobo Calyces

The vitamin C content of fresh zobo calyces was recorded as 22.05% (Table 4.3). For the dried samples, oven dried had the highest vitamin C content compared to other methods while the least content was seen in the sun-dried samples. The carotenoid content of fresh zobo calyces was recorded as 21.59%. Oven dried also gave the highest amount of carotenoid content while sun dried sample gave the least amount for the dried samples. There was significant difference between the carotenoid content for all drying method and the fresh sample.

Table 2: Proximate Composition of Fresh and Dried Zobo Calyces

Samples	Moisture (%)	Fibre(%)	Fat (%)	Ash (%)	Protein (%)	CHO (%)
Fresh	85.62 ± 0.02^{d}	5.82 ± 0.02^{d}	6.73 ± 0.02^{d}	5.41 ± 0.02^{d}	7.14 ± 0.02^{d}	64.81 ± 0.02^{d}
Oven	81.41 ± 0.02^{a}	3.28 ± 0.02^{c}	4.66 ± 0.02^{c}	3.53 ± 0.02^{c}	5.83 ± 0.02^{c}	63.87 ± 0.02^{c}
Solar	83.53 ± 0.02^{b}	2.76 ± 0.02^{b}	2.97 ± 0.02^{b}	2.82 ± 0.02^{b}	5.18 ± 0.02^{b}	63.74 ± 0.02^{b}
Sun	83.88 ± 0.02^{c}	2.04 ± 0.02^{a}	2.36 ± 0.02^{a}	2.38 ± 0.02^{a}	5.06 ± 0.02^{a}	63.16 ± 0.02^{a}

Values are represented as mean ± standard deviation of triplicate (3) replicate. Mean in the same column bearing different superscript differed significantly (p<0.05). CHO = Carbohydrate

Table 3: Vitamin C and Carotenoid content of Fresh and Dried Zobo Calyces

Samples	Vitamin C	Carotenoid
Fresh	22.05 ± 0.02^{d}	21.59 ± 0.02^{d}
Sun	19.30 ± 0.02^{a}	18.75 ± 0.02^{a}
Oven	21.66 ± 0.02^{c}	20.82 ± 0.02^{c}
Solar	20.84 ± 0.02^{b}	19.91 ± 0.02^{b}

Values are represented as mean ± standard deviation of triplicate (3) replicate. Mean in the same column bearing different superscript differed significantly (p<0.05)

CONCLUSION

The result obtained in this study showed that, drying methods had significant effects on the nutritional content of the zoo calyces (protein, ash, fat, crude fiber and carbohydrate). Oven dryer was observed to produce relatively better product in terms of nutrient composition compared to sun and solar dryer. Drying was also faster with the use of the oven drier as the product took lesser time to dry. It was also observed that the oven-dried method of zobo calyces had higher proximate compositional values when compared with other drying methods employed in this experiment. The Page model, Logarithmic model and Wang and Singh model best describe the drying characteristics of zobo calyces for oven, sun and solar drier respectively. Sample dried with solar drier gave the highest carotenoid and vitamin C content compared to other drying methods.

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