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The Effects Of Temperature,Thickness And Air Velocity On The Air Drying Characteristics Of Taro (Colocassia Esculenta)

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Abstract

This study was carried out to determine the effects of temperature, sample thickness and air velocity and on the thin layer drying characteristics of Taro (Colocassia esculenta) dried using hot air in a convective cabinet dryer. A 2^3 *factorial experimental design of Temperature T (50 °C,70°C), sample thickness D (4 mm,8 mm) and Air velocity V (0.8 m/s,1.2 m/s) was run in two replicates. 25g of taro were dried for six hours and mass recorded at 2, 3, 4, 5 and 6 hours. The results of the analysis were presented in ANOVA table. The main effects, the 3 two-factor interaction effects and the three-factor interaction effect were evaluated. The percentage contribution of these effects to the total variability were determined. The effects were tested at 5% significant level. The analysis show that temperature was the single most significant factor during taro drying and accounted for 97.35, 85.1, 76.23, 73.43 and 70.99% of the total variability at 2, 3, 4, 5 and 6 hours respectively. Sample thickness had no significant effect and accounted for less than 0.5% of the total variability during the drying. The air velocity had less significance on the drying of taro and contributed 1.06, 5.2, 7.85 and 7.65% of the total variability at 2, 3, 4, 5 and 6 hours respectively. Regression models were proposed and their adequacy tested by plotting the predicted values against the residuals. They never showed any funnel shape in each case which indicated good fit for the experimental data.*

Key words: Taro, drying, temperature, thickness, air velocity.

1. Introduction

Taro (*Colocasia esculenta*) is an important staple cultivated in the South Eastern and Southwestern parts of Nigeria. It is a tropical tuber crop that is cultivated for its corms, cormels and leaves. Taro has been reported to have 70 to 80% starch with small granules [5]. Taro is rich in gums (mucilage) and up to 9.1% crude taro mucilage its starch granules, taro is highly digestible, and as such has been reported to be used for the preparation of infant foods in Hawaii and other Pacific Islands [7]. Taro has a high nutritional, industrial and health importance but it has a high post-harvest loss due to its high moisture content, estimated to be 30% during storage [2]. In order to minimize tuber-losses, they must be converted from perishable to non-perishable forms through food processing operations such as drying and milling [1]. Drying is the best and convenient method for post-harvest management because it increases shelf life by reducing the moisture content of the product. Agricultural products in the tropics are usually dried in the open sun but this method has a major drawback of food contamination by dust, insects and rodents, thus making the final product unsafe for human consumption. Drying using hot air and in thin layers therefore has a major advantage of exposing the food product to hot air consequently causing uniformity in drying and also makes the product hygienically safe for human consumption. [6] dried yam strips of 5 mm long and 10 mm thick at 60^0C to examine the effect of loading rate on the drying characteristics of yam. Her results revealed that the single layer loading dried faster than 3 layers of loading. [8] on their work on the drying of Kiwifruit samples at initial moisture content of 5.33 (d.b decimal), temperatures of 40 , 50 , 60 and 70 ^{0}C respectively and air velocity of 1.1m/s found that avoiding hardening of the sample surface accelerated the drying rate of Kiwifruit. [10] examined the dehydration characteristics of garlic slices at air temperatures of 40, 50 and 60^0C and thicknesses of 3 and 5 mm respectively at a constant air velocity of 0.8 m/s. They found that the drying characteristics of garlic slices were affected by air temperature and sample thickness. [12] on their study of the drying characteristics of Roselle, dried Roselle (60 to 61 g) from average initial moisture content of 10.285db to an average final moisture content of 0.183db. The time required for drying Roselle decreased considerably with the increment of the drying-air temperature. The drying process was continued until no significant change in Roselle's mass was observed with the increment of the drying time and the moisture content was then considered as the dynamic equilibrium moisture content. Their findings were that the effect of temperature on the drying time was very significant (p = 0.000) as the drying process was enhanced substantially with the increment of the drying temperature and that the effect of relative humidity on the drying time was not significant (p = 0.996). [11] in the drying of Roselle (variety Arab) at 35, 45, 55 and 65 ^{0}C and five relative humidities (30, 35, 40, 45, and 50%) respectively, found that drying temperature was the main factor influencing the drying kinetics of Roselle. [9] dried tomato of average initial moisture content of about 14.02kg (H_20/ kg dry matter) until no further change in their masses were observed. The drying experiments were conducted at 50, 60, and 70 ^{0}C air temperatures and a constant air flow rate of 0.8 m/s. He found that the drying time decreased considerably with increase in the air temperature. Research on the effects of the drying conditions and the crop parameters on the drying characteristics of food products are important for the determination of the optimal drying conditions of these products. This has both domestic and industrial applications. The objectives of this research were to determine the effects of drying temperature, thickness of the samples and air velocity on the drying characteristics of Taro.

2. MATERIALS AND METHOD

2.1 Materials

The cormels of Taro (*Colocasia esculenta*) were purchased from a local market in Akure in Ondo State of Nigeria and stored at ambient temperature of 22 to 25^{0}C in an open shade for a day. They were manually washed with tap water and peeled after which the cormels were cut into 4 and 8mm thick slices using a metered board and fixed knife.

2.2 Moisture Content

The moisture content of Taro cormels was determined using the Vacuum oven method, drying the samples at 70^{0}C for 24 hours (AOAC, 1990). The average moisture content (db) was obtained from 3 samples tested.

2.3 Drying

A cabinet dryer constructed at the Federal University of Technology, Akure was used for the experiment and first run idle for 30 minutes to reach thermal stability. Samples of 25g were used in all experimental runs. The samples were placed in the dryer and dried for 6 hours. The samples were removed at 2, 3, 4, 5 and 6 hours cooled in a dessicator, weighed and returned to the dryer until a constant weight was obtained.

2.4 Experimental Design

A 2^3 factorial experimental design of 3 factors at 2 levels was studied. The factors and their levels were Air temperature T (50 ^{0}C, 70 ^{0}C); sample thickness D (4mm, 8mm) and air velocity V (0.8 m/s, 1.2 m/s). The experiments were run in two replicates.

2.5 Statistical Analysis

The weights of the samples were used directly for the analysis. The main effects and interaction effects of the three factors (Temperature T, thickness D, air velocity V) were determined and analysis of variance (ANOVA) was done for 2, 3, 4, 5, and 6 hours respectively. This was tested at 5% significant level.

3. Results and Discussion

3.1 Moisture content

The average moisture content of taro was found to be 2.33 (d.b decimal).

3.2 Effects of temperature, sample thickness and air velocity

The results of the factorial analysis for 2, 3, 4, 5 and 6 hours of drying are shown as analysis of variance (ANOVA) in Tables 1 to 5. The calculated effects and the percentage contributions of the factors are shown in Tables 6-10 respectively. In Table 1 at 2 hours of drying, temperature (T) is highly significant when tested at 5% significance level, has an effect of -4.82 which accounts for 97.35% of the total variability as shown in Table 6. The sample thickness (D), air velocity (V), temperature-sample thickness interaction (TD) and sample thickness- air velocity interaction (DV) are significant but have very low effects and accounts for 0.24, 1.06, 0.24 and 0.41% of the total variability. In Table 2, after 3 hours, temperature is highly significant, the effect is -2.84 and accounts for 85.1% of the total variability as shown in Table &. The air velocity, temperature-sample thickness (TD), temperature- air velocity (TV) and sample thickness-air velocity (DV) interactions and the tree- factor (TDV) interaction are also significant. However Table 7shows that these factors have very little effects and account for 5.2, 2.45, 1.27, 3.07 and 1.77% of the total variability. In table 3, at 4 hours of drying, only temperature is significant, the effect is – 2.29 and accounts for 76.23% of the total variability as shown in Table 8.

In Table 4 at 5 hours of drying, temperature is very highly significant, the effect is -1.98 and accounts for 73.43% of the total variability as shown in Table 9. The air velocity and TD interaction effect are highly significant. The

TD and TV interactions are also significant. However, the effects are small and account for 7.65, 2.92, 3.95, 7.35 and 4.17% of the total variability respectively as shown in Table 9.

In Table 5, at 6 hours of drying, temperature is very highly significant, the effect is – 1.84 and accounts for 79.99% of the total variability. The air velocity, the TD, TV, DV and TDV interaction effects are highly significant however the effects are very small and account for 7.57, 2.80, 5.25 ,7.50 and 5.28% of the total variability respectively as shown in Table 10. The sample thickness was shown to be significant, the effect is – 0.14 and accounts for less than 1% of the total variability. The results show that the temperature effect decreased from -4.82 to – 1.84 with increase in hours of drying with a corresponding decrease in the percentage contribution from 97.35 to 70.99%. The sample thickness had no effect during the drying process and the apparent effects could be generated by noise.

Table 1**: ANOVA at 2 hours**

Source of variation	SS	DF	MS	F_{cal}	F_{tab}
Main effect					
T	92.74	1	92.74	2506.5	5.32
D	0.23	1	0.23	6.2	
V	1.051	1	1.051	28.4	
2-way interaction					
TD	0.23	1	0.23	6.2	
TV	0.141	1	0.141	3.8	
DV	0.391	1	0.391	10.6	
3-factor interaction					
TDV	0.141	1	0.141	3.8	
Error	0.296	8	0.037		
TOTAL	95.22	15			

Table 2: ANOVA at 3 hours

Source of variation	SS	DF	MS	F_{cal}	F_{tab}
main effect					
T	32.26	1	32.26	632.55	5.32
D	0.0042	1	0.0042	0.08	
V	1.97	1	1.97	38.63	
2-factor interaction					
TD	0.93	1	0.93	18.24	
TV	0.483	1	0.483	9.47	
DV	1.167	1	1.167	22.88	
3-factor interaction					
TDV	0.672	1	0.672	13.18	
Error	0.41	8	0.051		
TOTAL	37.9	15			

Table 3: ANOVA at 4 hours

Source of variation	SS	DF	MS	F_{cal}	F_{tab}
main effect					
T	21	1	21	23.7	5.32
D	0.0004	1	0.0004	0.00045	
V	2.12	1	2.12	2.39	
2-factor interaction					
TD	1.04	1	1.04	1.17	
TV	0.56	1	0.56	0.63	
DV	1.51	1	1.51	1.7	
3-factor interaction					
TDV	0.941	1	0.941	1.06	
Error	0.379	8	0.886		
TOTAL	27.55	15			

Table 4: ANOVA at 5 hours

Source of variation	SS	DF	MS	F_{cal}	F_{tab}
main effect					
T	15.72	1	15.72	1122.9	5.32
D	0.0001	1	0.0001	0.071	
V	1.638	1	1.638	117	
2-factor interaction					
TD	0.6241	1	0.6241	44.6	
TV	0.846	1	0.846	60.43	
DV	1.575	1	1.575	112.5	
3-factor interaction					
TDV	0.893	1	0.893	63	
Error	0.112	8	0.014		
TOTAL	21.408	15			

Table 5: ANOVA at 6 hours

Source of variation	SS	DF	MS	F_{cal}	F_{tab}
main effect					
T	13.51	1	13.51	2702	5.32
D	0.073	1	0.073	14.6	
V	1.44	1	1.44	288	
2-factor interaction					
TD	0.533	1	0.533	106.6	
TV	1.00	1	1.00	200	
DV	1.428	1	1.428	285.6	
3-factor interaction					
TDV	1.005	1	1.005	201	
Error	0.043	8	0.005		
TOTAL	19.031	15			

Table 6: Percentage contribution of the factors to the total variability at 2 hours of drying.

Factors	Effects	Sum of squares	%Contribution
T	- 4.82	92.7	97.35
D	0.24	0.23	0.24
V	- 0.51	1.01	1.06
TD	0.24	0.23	0.24
TV	0.19	0.14	0.15
DV	0.31	0.39	0.41
TDV	- 0.19	0.14	0.15

Table 7: Percentage contribution of the factors to the total variability 3 hours of drying.

Factors	Effects	Sum of squares	%Contribution
T	- 2.84	32.26	85.1
D	0.03	0.0042	0.011
V	- 0.7	1.97	5.2
TD	0.48	0.93	2.45
TV	0.35	0.483	1.27
DV	0.54	1.167	3.07
TDV	- 0.41	0.672	1.77

Table 8: Percentage contribution of the factors to the total variability at 4 hours of drying.

Factors	Effects	Sum of squares	Contribution
T	- 2.29	21	76.23
D	0.01	0.0004	0.002
V	- 0.73	2.12	7.85
TD	0.51	1.04	3.77
TV	0.37	0.56	2.03
DV	0.62	1.51	5.48
TDV	- 0.49	0.941	3.42

Table 9: Percentage contribution of the factors to the total variability at 5 hours of drying.

Factors	Effects	Sum of squares	%Contribution
T	- 1.98	15.72	73.43
D	- 0.01	0.0001	0.0047
V	- 0.64	1.638	7.65
TD	0.04	0.6241	2.92
TV	0.46	0.846	3.95
DV	0.63	1.575	7.35
TDV	- 0.47	0.893	4.17

Table 10: Percentage contribution of the factors to the total variability at 6 hours of drying.

Factors	Effects	Sum of squares	%Contribution
T	- 1.84	13.51	70.99
D	- 0.14	0.073	0.38
V	-0.6	1.44	7.57
TD	0.37	0.533	2.80
TV	0.5	1	5.25
DV	0.6	1.428	7.50
TDV	- 0.5	1.005	5.28

3.4 Regression models

The regression model for estimating the mass of Taro during drying for 2, 3, 4, 5 and 6 hours are shown in equations (1) to (5) respectively. Where Y is the predicted mass of the sample after drying; T is the temperature, V is the air velocity, DV is the thickness-velocity interaction, TV is the temperature-air velocity interaction and TDV is the temperature-sample thickness-air velocity interaction. The models were formulated with factors that show significant effects and contributed not less than 5% to the total variability.

$$Y = 11.99 - 2.41T \quad (1)$$

$$Y = 10.44 - 1.42T + 0.352V \quad (2)$$

$$Y = 9.8 - 1.145T \quad (3)$$

$$Y = 9.37 - 0.992T - 0.32V + 0.314DV \quad (4)$$

$$Y = 9.03 - 0.92T - 0.3V + 0.25TV + 0.286DV - 0.25TDV \quad (5)$$

3.6 Model Adequacy

The predicted values were plotted against the residuals. Figures 1-4 do not show the funnel shape in each case indicating a good fit.

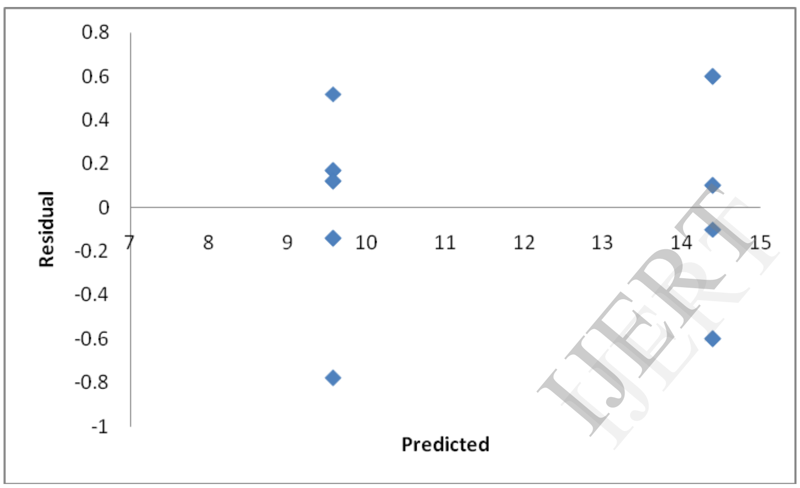

Figure 1: Adequacy of model 1

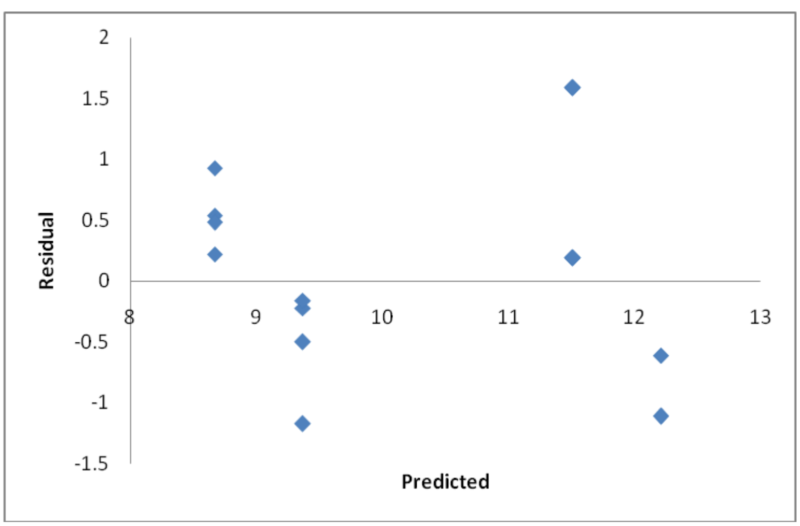

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Figure 2: Adequacy of model 2

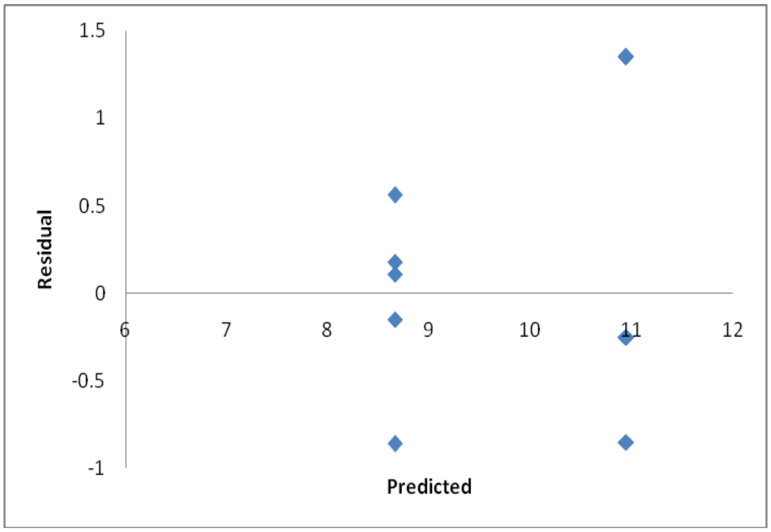

Figure 3: Adequacy of model 3

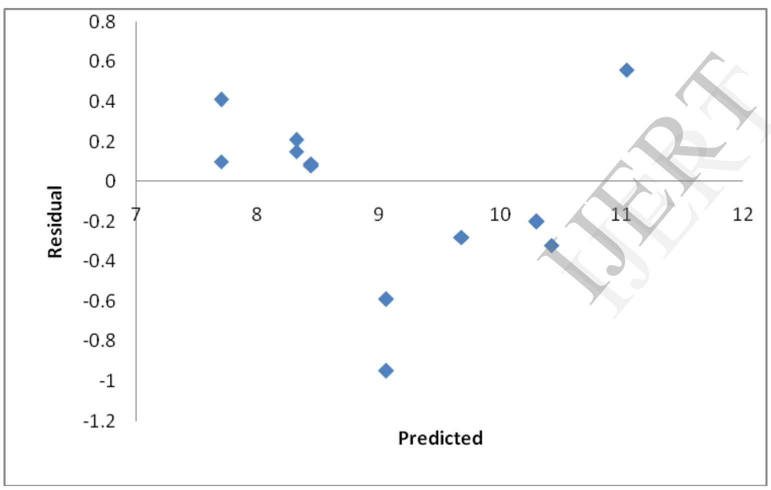

Figure 4: Adequacy of model 4

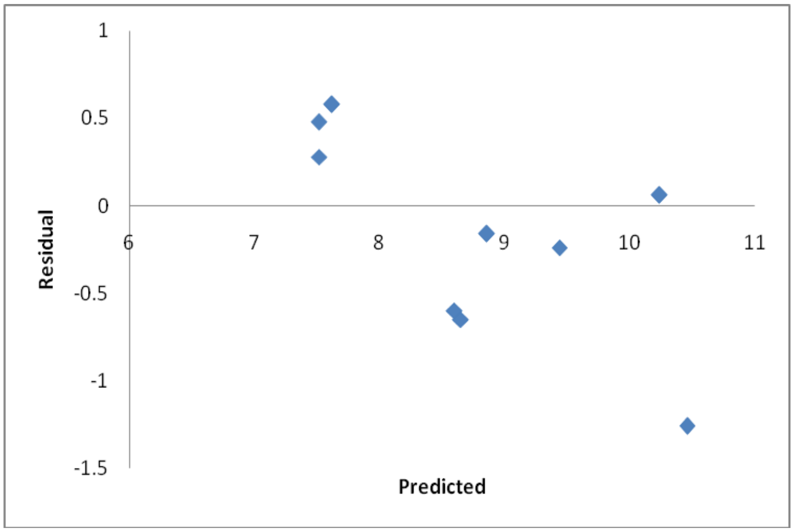

Figure 5: Adequacy of model 5

4 Conclusion

The analysis of the results shows that temperature was the main factor influencing the drying of taro. This is similar to the findings of Saeed et al;(2006) in the drying of Roselle (variety Arab) at 35, 45, 55 and 65°C and five relative humidities (30, 35, 40, 45 and 50%). Increasing the temperature from 50 to 70°C significantly increased the loss of moisture from the sample. The sample thickness had no effect on the drying of taro. The air velocity had a low effect on the drying of taro and the results show that increase in air velocity from 0.8 to 1.2 m/s increased the loss of moisture in the samples.

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