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Optimization of Drying Parameters of Periwinkles (*Turritella Communis*) Using Response Surface Methodology

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Abstract

Optimization of drying parameters of periwinkles (Turritella communis) using Response Surface Methodology (RSM) to obtain high quality product, it is very vital as improper drying conditions can affect the composition of the dried Periwinkles and thereby increases the risk of it running into deterioration of the nutrient contents of the product and post-harvest loss. Periwinkles were processed by washing, sorting into required weight (1kg). Samples obtained were dried in triplicate using WTCB 1718 laboratory drying oven at different temperatures of 55, 65, and 70˚C and time of 360, 480 and 540 minutes by employing Design of Experiment (DOE). A total of 15 experimental runs were generated from Design Expert version 13 software; with two factors (temperature and drying time) and one response (moisture content). Statistical analysis based on central composite design was carried out. The significant factors were identified. The optimum conditions obtained were at a temperature of 60˚C, time of 540 minutes which resulted in final moisture content of 18.48% and R^2 value of 0.7719. From these results obtained, the use of response surface methodology in drying operation for optimizing periwinkles could be used.

***Keywords**: Periwinkle, Oven, Drying, Optimization, Temperature and Drying time*

1.0 INTRODUCTION:

Drying is the oldest and most widely used preservation technique and the most diversified unit activity in agricultural grain processing (Hashim *et al.*, 2022). Drying is an important unit operation used to elongate the stability and preserve the quality of fruits and vegetables. Preserving different products to achieve a quality state of products has been done years ago with drying process. The drying process could be done by removing the moisture content from food products using the method of evaporation, which increases the shelf-life of the products (Aghbashlo *et al.*, 2008; Inyang and Bassey, 2021). Oven drying has been one of the most successfully used methods of food drying over the years because of the hotness exhibited to the surrounding. This method's advantages are its heat and mass transfer efficiency, low cost, ability to retain the quality of food products, and high capacity for drying. For the reasons stated above, the oven-drying method is often used in research experiments (Tulek, 2011).

Fungal and bacterial diseases could spoil the fruits and vegetables after harvest to about 20 – 25% in the world. Postharvest losses may be severe because of lack of storage and transportation facilities which is common in underdeveloped countries. Thus, processing the postharvest will reduce losses. Hence, efficient and effective postharvest, technique will be needed to make the product last longer (Akter *et al*., 2022; William, 2022).

Periwinkle Snail (*Turritella communis*), is locally known as mfi in Akwa Ibom State, southern part of Nigeria. It is a seafood, usually harvested (mainly hand-picked) at the tidal shore areas of a sea estuary. It constitutes a very vital meaty ingredient in the preparation of different delicacies of people living along the coastal areas in Nigeria and perhaps, beyond. Adekanmbi Falodun (2015) reported that periwinkle meat is a good source of protein for the consuming locals. It is also known that dried periwinkle meat is nutritionally richer than the fresh ones (Adebayo and Ogunjobe, 2008; Wisdom, 2023). Adebayo and Ogunjobe (2008) reported that fresh periwinkle meat undergo rapid deterioration and decay, thus requires preservative attention almost immediately after dislodging the meat from the shell (Wisdom, 2023). The common periwinkle or winkle (*Turritella communis*) is a species of small edible whelk or sea snail, a marine gastropod mollusc that has gills and an operculum, and is classified within the family *Turritella*, the periwinkles (Vinarski, 2022). The average winkle lives three years and grows to a shell height of 20 mm, but the largest recorded winkle grew to 52 mm. They are common in the riverine areas and coastal regions of Nigeria where they are used for food (Falade, 2015). Figure 1 is group of single meaty part of the periwinkle snails while Figure 2 is auger-shaped periwinkle snails with tail nipped to dislodge the meat.

Response surface methodology (RSM) is a collection of mathematical and statistical techniques in which a response of interest is influenced by several variables in a system (Montgomery and Runger, 2015). The eventual objective of RSM is to determine the optimum operating conditions for a system or to determine a region of factor space in which the operating specifications are satisfied (Montgomery, 2018). The optimization technique basically requires sets of experimental data whereby the parameters that determine the response which are under investigation are varied within chosen range (Khuri and Mukhopadhyay, 2010). The response values form a surface placed above the plane of these variables. It is therefore convenient to produce the response surface in the plane of two or more variables such that curves are obtained by connecting the points with the same yield (Myers and Montgomery, 2020). Localization of optimal response is done by graphic analysis, which allows for a visual detection of the response and this determines the robustness of the response surfaces (Montgomery, 2018).

Experimental design method is introduced mainly to evaluate several factors simultaneously and to predict interactions between factors, hence the choice of modeling designs or Response Surfaces mainly on the Box-Behnken model. The latter is from the three large families of design of experiments with the mixing and screening designs (Makela, 2017).

The motivation of this study was because drying is a key step in preserving periwinkles (*Turritella communis*) after harvest, fungal and bacterial diseases affect their quality, shelf life, and value. However, traditional drying method for instance sun, often lead to inconsistent results, such as over-drying or under-drying, which can reduce nutritional value and marketability, causing significant losses. Despite the importance of periwinkles, little research has been done to optimize drying methods for better quality and efficiency. Response Surface Methodology (RSM) was adopted in this research so that the coefficients of cross product terms of the variables in the model used to predict the moisture content of periwinkle could be ascertained alongside the linear and quadratic terms.

Figure 1: Group of Single Meaty Part of the Periwinkle Snails

Figure 2: Auger-Shaped Periwinkle Snails with Tail Nipped to Dislodge the Meat

2.0 MATERIAL AND METHODOLOGY:

Periwinkles were purchase from Use market in Uyo Local Government Area of Akwa Ibom State, Nigeria. What-man no. 1 filter paper, sodium chloride and distilled water were purchase at Ene and Sons Chemical Company limited Uyo. The chemical (NaCl) used in this study were analytical reagent (AR) grade

2.1 Sample Preparation

One kilogram (1 kg) worth periwinkle snails was purchased from Use market in Uyo Local Government of Akwa Ibom State, Nigeria. They were properly group-washed with clean water and parboiled for about 15 minutes. This was done to weaken the bond between the meat and the shell as to ease separation of the meat from each shell in a process known as tweaking. Tweaking was done using sterilized needles after the tail part of each of the auger-shaped periwinkle snails was cut away manually with a cutlass. The group of meat so obtained was parked in plastic containers and stored in a refrigerator to stabilize in the Processing Laboratory of the Department of Chemical Engineering, University of Uyo, Akwa-Ibom State, Nigeria. The initial moisture content of the meat was determined by an oven drying method (ASAE Standard S368.41 2000) using 100g samples after being immersed in 5% NaCl solution with the oven set at a temperature range of $55^0C - 74^0C.$ All experiments were replicated thrice. Oven model (WTCB1718) was used for the drying process, and all the weight measurements of each samples were taken with a 0.01 mm precision digital scale (Max cap: 210g, Power requirements: 8-14.5V, 50/60Hz, 60V). See similar approach/method was applied by Zibokere and Egbe (2019) on red palm weevil larvae, Burubai and Bratua (2015) on acute mud-snail, and Sankat and Mujaffar (2006) on catfish.

Moisture contents were measured on dry-basis (Mohsenin, 1986). Using equation (1)

$$\%\ Moisture\ Content = \frac{W_{3-}W_1}{W_{2-}W_1}\ X\ 100 \qquad \text{Equation 1}$$

Where;
W_1 is the mass of empty crucible weight, g
W_2 is the mass of crucible plus sample before drying weight, g
W_3 is the mass of crucible plus sample after drying weight, g

2.2 Oven Drying Process

Drying experiments were conducted following random parameters generated by the design of the experiment. The drying experiment was done following the method by Inyang and Bassey (2021); this was done in the oven to reach a steady state, which was preheated for 90 minutes. The periwinkle (*Turritella communis*) samples were poured into a pan covered with aluminum foil for drying and were transferred into the oven tray with oven Model WTCB 1718. The temperature of the oven and the drying time were regulated to the specified temperature and time by RSM for each run, as shown in Table 3, at the end of each run, the samples were withdrawn and taken for further analysis.

3.0 Response Surface Methodology (RSM) Model Development

3.1 Drying Parameters for the Periwinkle

Two different parameters (drying temperature and drying time) were varied to study their effects on the moisture content of the dried periwinkle (*Turritella communis*). To obtain the optimal result, Design Expert. 13 were used to generate some runs of the aforementioned parameters: drying temperature ranging from $55^0C – 74^0C$ and drying time ranging from 360 minutes to 540 minutes. Table 1 shows the Factor levels of the independent variables of the drying of periwinkle.

Table 1: Factor Levels of the Independent Variables for the Drying of Parameters.

Independent variables	Low level (-1)	High level (+1)
A: Temperature ^0C	55	74
B: Time (min)	360	540

Table 2: Central Composite Design of Different Drying Conditions

	Factor 1	Factor 2	Response 1
Run	**A: Drying Temperature** Celsius	**B: Drying time** Min	**Moisture Content** %
1	60	480	
2	70	540	
3	65	480	
4	60	540	
5	65	480	
6	60	480	
7	60	480	
8	65	360	
9	70	480	
10	65	540	
11	55	540	
12	74	540	
13	55	540	
14	60	540	
15	70	480	

3.2 Data Analysis

Response surface methodology (RSM) technique based on central composite design (CCD) was used to plan and design the experiment analysis using Design Expert software version 13 (Adum and Inyang, 2024). According to Noordin *et al.* (2004) and Ramakrishna and Susmita, (2012), Response Surface Methodology (RSM) is one of the experimental designing methods that can surpass the limitations of conventional methods collectively and has the advantage of reducing the number of experimental trials needed to evaluate multiple parameters and their interactions.

The dependent variable was the moisture content (%) of the periwinkle and the independent variables were the drying temperature (°C) and drying time (min). Hence, Analysis of variance (ANOVA) was used to determine the significance of the relationship between the dependent and independent variables, for which the coefficient of determination (i.e R-squared and adjusted R-squared) and p-value were used to judged (Box and Draper, 2007; Adeyeye *et al.*, 2022). Thus, analysis of variance (ANOVA) was used to assess the fit of the model.

This study used a one-level two-factor central composite design, leading to 15 experiments. Table 2 shows the Central Composite Design of Different Drying Conditions Subsequently, Design Expert Software (Version 13) from Stat-Ease Inc. (Minneapolis, MN, USA) was used in analyses of variance (ANOVA), regression analysis and response surfaces. The software's numerical optimization function generated the optimal parameter (s) for maximum dry matter.

4.0 RESULTS AND DISCUSSION

4.1 Model Fitting and Analysis of Variance

The results of the 15 experimental runs are shown in Table 3. Equation 2 is the second order statistical model obtained after applying multiple regression analysis to the experimental data. The equation represents Moisture content as a function of drying temperature (A), drying time (B).

$$Moisture\ Content = +16.319 + -1.60481 * A + 1.28339 * B + -0.615 * AB + -1.66941 * A^2 + -0.971143 * B^2. \quad \text{Equation 2}$$

The results obtained after performing ANOVA are presented in Table 4. The model F-value of 4.24 implies that the model is significant. Also, the model F value of 4.24 have very low probability value (p = 0.0038) implies significant model fit. From the regression model, A, B, A2 are significant model terms. The lack of fit value of 0.61 implies that the lack of fit is not significant relative to the pure error and non-significant lack of fit is good.

Table 3: Results Experimental Runs

	Factor 1	Factor 2	Response 1
Run	**A:Temperature** Celsius	**B: Drying time** Min	**Moisture Content** %
1	60	480	11.02
2	70	540	17,43
3	65	480	12.40
4	60	540	18.48
5	65	480	14.13
6	60	480	15.10
7	60	480	16.56
8	65	360	17.50
9	70	480	9.20
10	65	540	15.90

11	55	540	14.56
12	74	540	9.95
13	55	540	10.01
14	60	540	11.50
15	70	480	12.01

Table 3 shows that experimental run 4 gave the maximum moisture content of 18.48% at temperature of 60^0C and drying time of 540 minutes.

Table 4: ANOVA for Linear Model (Response 1: Moisture Content)

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	125.23	9	14.11	4.24	0.0038	Significant
A:Temperature	34.25	1	34.25	9.40	0.0771	
B:DryingTime	13.97	1	13.97	4.29	0.0311	
AB	2.81	1	2.81	0.9038	0.9522	
A^2	40.39	1	40.39	12.60	0.019	
B^2	13.80	1	13.80	4.42	0.3258	
Residual	13.18	10	3.36	-	-	
Lack of Fit	10.94	6	2.05	0.6719	0.6063	not significant
Pure Error	21.60	4	4.60	-	-	
Cor Total	154.21	12	-	-	-	

As suggested by Lilian and Charles (2008), analysis of variance was applied for estimating the significance of the model at the 5% significance level. ANOVA was used to estimate the statistical parameters (R^2, Adj- R^2, and predicted R^2) of the drying process. Table 4 shows the ANOVA table for the moisture content response surface linear model for the drying process. According to Yi *et al.* (2010), a more significant matching coefficient is shown by a greater F-value and a smaller p-value (prob. > F). If the p-value (significance probability value) is less than 0.05, a model term is considered significant. The model is significant, as shown by the F-value of 4.24 moisture content-responses and p-value of 0.38% (that is, a 0.38% chance that an F-value this large could occur due to noise). Additionally, the moisture content-model terms (A and B) in Table 4 have p-values that are less than 0.05, indicating that they are significant model terms.

Table 5: Statistical Parameters from ANOVA for Response 1: Moisture Content

Response	Moisture Content
R^2	0.7719
Adjusted R^2	0.6063
Predicted R^2	0.3284
Adequate Precision	9.3778

The model's statistical parameters in Table 5 can also be used to evaluate the model's fit quality. When the coefficient of determination (R^2), which measures the percentage of the dependent variable's variation that can be predicted from the independent variable or variables, is closer to 1, the difference between the adjusted R^2 and the predicted R^2 is less than 0.2, and the adequate precision is higher than 4, a model is said to be fit. Adjusted R^2 not only accounts for the number of terms in a model but also shows how well terms fit a curve or line. The number of independent factors used to predict the target variable is taken into account by the adjusted R^2. We may next assess if the model's fit is indeed improved by including new variables. The adjusted R^2 will drop when unneeded variables are added to a model.

The adjusted R^2 will rise with the addition of more beneficial variables. Adjusted R^2 will never be greater than R^2 or the same as it. The expected R^2 shows how accurately a regression model forecasts how fresh observations will behave. Although it is less capable of making reliable predictions for brand-new observations, it aids in determining when the model fits the original data. Predicted R^2 has the important advantage of preventing over fitting a model. An over fit model starts to model random noise because it has too many predictions. Random noise cannot be foreseen, hence an over fit model's expected R^2 must decrease. There are almost probably too many terms in the model if the anticipated R^2 is considerably lower than the actual R-squared.

The coefficients of determination for moisture content ($R^2 = 0.7719$) as shown in Table 5 is high and not too close to 1; the adjusted R^2 values (0.6063) for the moisture content responses are not in reasonable agreement with their predicted R^2 values (0.3284), since their difference is more than 0.2 which may be due to too many terms in the model. The adequate precision that measures the signal-to-noise ratio is greater than for the response (9.3778). All of these validations showed that the moisture content data for moisture absorbed from the drying process matched the model's projected value accurately.

The empirical relationship between the moisture content responses was modeled, giving a linear equation. The independent variables given in Equation 1, A and B are coded terms used for the temperature and drying time:

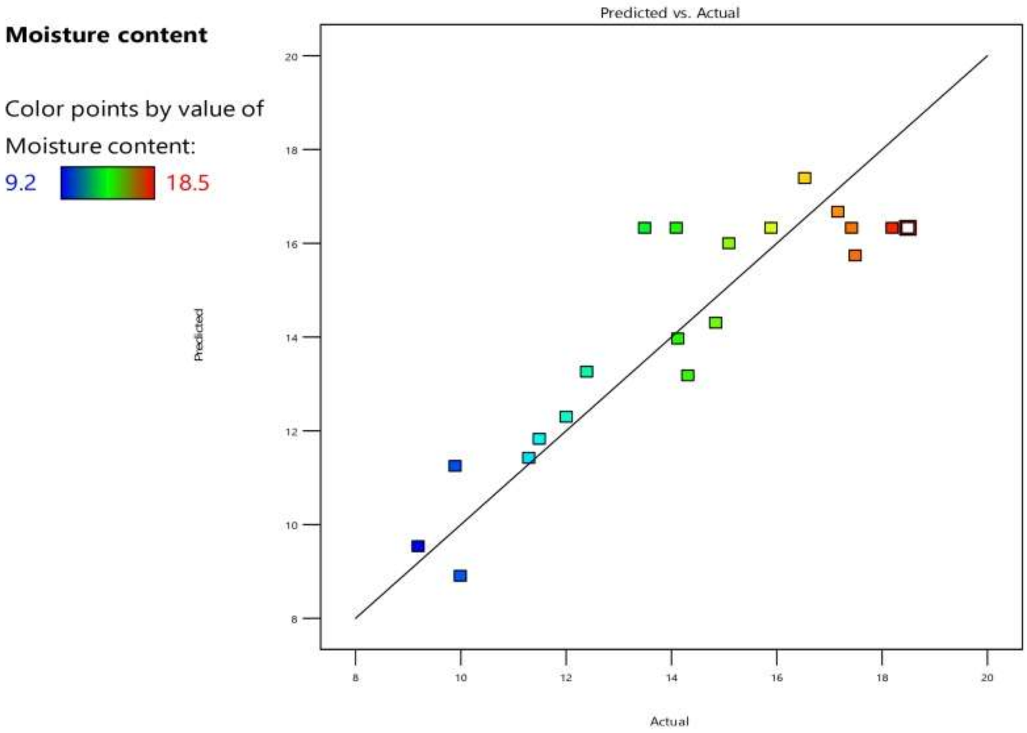

Figure 3: A Plot of Predicted Values Versus Actual Values for Moisture Content Response

Figure 3 shows the actual moisture content from the experimental versus the predicted. The straight line shows the expected moisture there are slight deviations from the expected moisture showing that the model is significant.

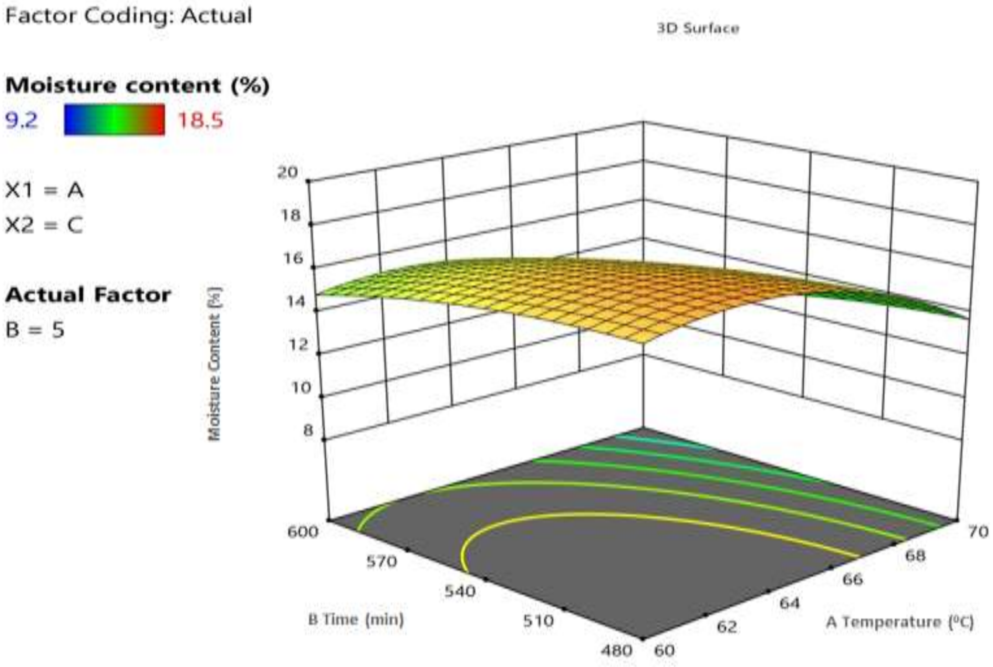

Figure 4: 3D Plot Showing the Effect of Temperature and Drying Time on Moisture Content Response.

Response surface plots were generated from the statistical models to examine the interactions between the independent variables and to determine the optimum levels of the variables. The plots show how drying temperature and drying time affect the moisture content in periwinkle. Figure 4 shows the 3D plot of moisture content in relation to the temperature and drying time. It is evident from the surface plot that moisture content increases as the drying time increases and the temperature increases. The influence of drying time and temperature on moisture content is linear. Similar to the work of Adum and Inyang (2024).

4.2. Numerical Optimization

Numerical optimization of the response was carried out to optimize the moisture content. The values of the independent variables during numerical optimization were fixed within the experimental range as shown in Table 3. After evaluating the model graphs and the solutions suggested by the numerical optimization package, the optimum conditions were chosen as the one with the highest desirability value. Hence, the operating parameters of moisture content from drying process were optimized numerically with the Design Expert V13 to obtain optimal parameters and responses. The optimization results revealed that the optimum moisture content was obtained as 18.480 at optimum conditions of temperature (60˚C and time (540 min). All the operating parameters are in range and the optimization aimed at maximizing moisture content Similar results for Oven drying of various food products has been recorded for plantain Inyang *et al*., 2019, bell pepper Odewole and Olaniyan (2016).

Table 6: Optimum responses and operating parameters values

Number	Temperature	Drying Time	Moisture Content	Desirability	
1	60.000	540.000	18.480	0.999	Selected

The highest desirability for the optimization was 0.999 for moisture content The desirability function approach transforms the properties of each predicted response to a dimensionless desirability value (d), the dimensionless desirability values range between d = 0 to 1. When d = 0, it suggests that the predicted value is unacceptable and when d = 1, it means that the value is exactly the target value. The value of d increases as the desirability of the corresponding response increases (Montgomery, 2005). The optimum operating parameters that gave moisture content from 17.97% to 18.48 are 60^{o}C and 540 minutes drying time. The optimization was not able to maximize moisture content; this can be attributed to the developed model able to convert removed moisture optimally.

5.0 CONCLUSION

The modeling and optimization of the Moisture content in Periwinkles (*Turritella communis*) drying was carried out using a three variable central composite design for response surface methodology. The second order statistical model developed was statistically significant and did not show lack of fit. The moisture content in the Periwinkles was significantly affected by temperature and time. Optimum moisture content value of 18.480 % was obtained at optimum conditions of temperature (60^{o}C) and time (540 min).Validation of the model indicated no significant difference between experimental observations and mode prediction. The Model F-value of 4.24 implies that the model is significant. Also, the model P-values (I = 0.05) indicates that model terms are significant. Also, lack of fit F-value of 0.6719 shows that the lack of fit is not significant relative to the pure error.

Based on the findings in this work**,** further research could explore with other drying methods such as freeze drying and osmotic drying; lower temperatures or higher than what were used can be employed. Also, optimization should be carried out using the Box-Behnken Design (BBD), full factorial design (FFD), thereafter comparison is made with the optimum values of Central Composite Design (CCD) used in this study.

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