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Optimization of Drying Parameters for African Giant Snail (Achatina achatina) Utilizing Response Surface Methodology

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Abstract:

The optimization of drying parameters for the African Giant Snail (Achatina achatina) is crucial for enhancing its shelf life and nutritional quality. This study employed Response Surface Methodology (RSM) to determine the optimal drying conditions, focusing on moisture content reduction. The snails were cleaned and sorted according to their weight. The collected samples were dried in triplicate using a WTCB 1718 laboratory drying oven utilizing Design of Experiment (DOE) at various temperatures of 60, 65 70, and 75°c and times of 360, 480, 540, and 600 minutes. With two variables (temperature and drying time) and one response (moisture content), a total of 20 experimental runs were produced using the Design Expert version 13 software. A statistical study was conducted using the central composite design. The results indicated that the optimum moisture content achieved was 19.20% at a drying temperature of 60°C and an air velocity of 600 mm/s. The statistical analysis revealed a model F-value of 4.24, indicating a significant relationship between the drying parameters and moisture content reduction, with a corresponding P-value of 0.05. These findings suggest that the identified parameters are effective for optimizing the drying process of the snail, providing a framework for further research and practical applications in food processing and preservation. The study underscores the potential of RSM as a valuable tool in optimizing drying techniques for various agricultural products.

Key words: temperature; africa giant snail; drying; optimization; drying time and oven

1.Introduction

The African Giant Snail (*Achatina achatina*) is a significant species in the field of malacology and has garnered attention for its potential in food security, traditional medicine, and as a source of protein in various cultures [Nwafor et al., 2020]. However, the effective preservation and processing of this mollusk are crucial for maximizing its nutritional value and extending its shelf life. Drying is one of the most common methods employed to preserve food products, as it reduces moisture content, thereby inhibiting microbial growth and enzymatic activity [Khan et al., 2019]. Optimizing the drying process for A. achatina is essential to maintain its quality attributes, including texture, flavor, and nutritional content. Traditional drying methods often lead to suboptimal results, such as nutrient loss and undesirable changes in organoleptic properties [Akinmoladun et al., 2021]. As they creep or crawl on the earth, snails are vulnerable to numerous types of pollutants and bacteria, which can cause them to sustain harm quickly. They are typically smoked and dried before being sold by table-top vendors in an effort to lessen this restriction. Despite having a high local market value, smoke-dried snails do not match international standards for earning foreign cash. Snails are abundant during the rainy season, when rural populations harvest them in huge quantities and they are inexpensive. However, because they are hard to locate during the dry season, they become scarce and costly [Egbe et al., 2021]. Therefore, employing advanced statistical techniques like Response Surface Methodology (RSM) can significantly enhance the optimization of drying parameters. RSM is a collection of mathematical and statistical techniques useful for developing, improving, and optimizing processes [Montgomery, 2017]. It allows for the evaluation of multiple variables and their interactions, providing a comprehensive understanding of the drying process. Previous studies have demonstrated the effectiveness of RSM in optimizing drying conditions for various food products, including fruits and vegetables (Kumar et al., 2020). By applying RSM to the drying of A. achatina, researchers can systematically investigate the effects of parameters such as temperature, air velocity, and drying time on the final product's quality. This approach not only enhances the efficiency of the drying process but also contributes to the sustainability of snail farming by reducing waste and improving product quality [Ogunleye et al., 2022]. Fungal and bacterial infections impact the quality, shelf life, and value of African Giant Snails (*Achatina achatina*), and drying is a crucial stage in their preservation following harvest. This

is why this study was conducted. Traditional drying methods, like the sun, can result in uneven drying, either too dry or too wet, which can lower nutritional value and marketability and result in large losses. Snail meat is important, but not much study has been done to improve drying techniques for higher quality and effectiveness. The Response Surface Methodology (RSM) was employed in this study in order to determine the coefficients of cross product terms of the variables in the model used to predict the moisture content of snail meaty in addition to the linear and quadratic terms.

2.Materials and Method

A local but general market in Ondewari town, Southern Ijaw Local Government Area, Bayelsa state, Nigeria, provided 5 kg of newly collected African Giant Snails (*Achachatina achatina*). They were given a thorough wash in fresh water, and the meat was carefully extracted from the shell using a sterile needle before being let to settle in the lab environment. The meat from African giant snails (*Achachatina achatina)* that would be used in the drying tests was measured for basic dimensions using a 0.001 cm precision veneer caliper. The meat was then stratified into groups of varying but equal thickness and length, re-stabilized, and stored in refrigerated cabinets in the Food Processing Laboratory of the Department of Agricultural and Environmental Engineering at Niger Delta University in Bayelsa State. Then, for the drying tests, identical samples were taken from the stratified batch. A WTC binder oven Model WTCB 1718 was then used to oven dry the samples in a thin-layered form to a consistent final weight at temperatures ranging from 55 – 74^0C degrees Celsius. With a precision of 0.01 g, a top digital balance of the laboratory type was used for all weight measurements. The oven method of ASAE standard was used to take the initial and all subsequent moisture content values [ASAE, 2000]. For every sample, the moisture reduction process (i.e., weight loss) was tracked at predetermined intervals (about 10 minutes) until equilibrium was reached, using the protocol outlined in the studies of Egbe & Davies [2021] on fresh water prawn, Egbe and Zibokere [2021] on fresh water crayfish and Egbe, [2023] on red pepper. Three replications of each drying test were conducted at each temperature level and the average results were noted. The final moisture content for each replicate was calculated using the weight differences before and after drying, all of which were assessed on a dry basis (Mohsenin, 1986).

2.1 The Oven Drying Method

Random parameters created by the experiment's design were used in the drying experiments. Following the procedure by Inyang and Bassey [2021], the drying experiment was carried out in an oven that had been preheated for ninety minutes in order to attain a stable condition. After pouring the African Giant Snails (Achachatina achatina) samples into an aluminum foil-covered pan to dry, they were placed in the oven tray using an oven model, the WTCB 1718. As it is indicated in Table 1, RSM controlled the oven's temperature and drying duration for every run, ensuring that the samples were removed at the conclusion of each run and taken for additional examination.

2.2. Model Development Using Response Surface Methodology (RSM)

To examine the impact of two distinct variables on the moisture content of the dried African Giant Snail (*Achachatina achatina*), the drying temperature and drying duration were changed. To achieve the best outcome, several runs of the previously specified parameters were generated using Design Expert. 13: drying duration varying from 400 minutes to 600 minutes and drying temperature ranging from 550 to 740 hours. The factor values of the independent variables pertaining to snail drying are displayed in Table 1.

Independent variables	Low level (-1)	High level (+1)
Drying Temperature ^0C	60	75
Drying Time (min)	400	600

Table 1: Independent Variable Factor Levels for Parameter Drying.

Run	Factor 1 **A: Drying Temperature** Celsius	Factor 2 **B: Drying time** Min	Response 1 **Moisture Content** %
1	60	360	
2	70	540	
3	65	480	
4	60	540	
5	65	480	
6	60	600	
7	60	480	
8	65	360	
9	70	480	
10	65	540	
11	55	540	
12	75	600	
13	55	540	
14	60	540	
15	70	480	
16	60	480	
17	65	600	
18	70	360	
19	75	480	
20	75	480	

Table 2: Central Composite Design for Various Drying Situations

2.3. Data Analysis

The experiment analysis was planned and designed using Design Expert software version 13 and the response surface methodology (RSM) technique based on central composite design (CCD) (Adum and Inyang, 2024). Noordin et al. (2004) and Ramakrishna and Susmita (2012) state that Response Surface Methodology (RSM) is one of the experimental design techniques that can overcome the drawbacks of traditional approaches taken as a whole. It also has the benefit of requiring fewer experimental trials to assess several parameters and their interactions. The drying temperature (◦C) and drying time (min) were the independent factors, while the meaty's moisture content (%) was the dependent variable. Therefore, the significance of the relationship between the dependent and independent variables was assessed using Analysis of Variance (ANOVA), which was based on the p-value and the coefficient of determination (Adeyeye et al., 2022). Thus, the model's fitness was evaluated using analysis of variance (ANOVA). In this work, 20 experiments were conducted using a one-level, two-factor central composite design. The Central Composite Design for Various Drying Conditions is displayed in Table 2. Regression analysis, response surfaces, and analyses of variance (ANOVA) were then performed using Design Expert Software (Version 13). The ideal parameter (s) for maximal dry matter was produced using the software's numerical optimization tool.

3. Results and Discussion

3.1 Model Fitting and Analysis of Variance

Table 3 presents the findings from the 20 experimental runs. The model F-value of 4.24 indicates that the model is significant, it's very low probability value (p = 0.0038) indicates significant model fit. The lack of fit value of 0.61 indicates that the lack of fit is not significant in relation to the pure error, and non-significant lack of fit is good. Table 3 demonstrated that at 60°C and 540 minutes of drying time, experimental run 6 produced the highest moisture content of 19.20%.

	Factor 1	Factor 2	Response 1
Run	**A: Temperature** Celsius	**B: Drying time** Min	**Moisture Content** %
1	60	360	10.20
2	70	540	15.56
3	65	480	10.80
4	60	540	17.57
5	65	480	13.12
6	60	600	19.20
7	60	480	17.65
8	65	360	17.24
9	70	480	10.20
10	65	540	16.23
11	55	540	15.67
12	75	600	10.46
13	55	540	11.45
14	60	540	12.78
15	70	480	13.25
16	60	480	12.54
17	65	600	14.56
18	70	360	13.24
19	75	480	12.35
20	75	480	15.67

Table 3: Results Experimental Runs

The model's significance was estimated at the 5% significance level using analysis of variance, as recommended by Lilian and Charles (2008). The drying process's statistical parameters (R^2, Adj-R^2, and projected R^2) were estimated using ANOVA. A larger F-value and a smaller p-value (prob. > F) indicate a more significant matching coefficient according to Yi *et al.*, (2010). The significance probability value or p-value of a model term is regarded as significant if it is less than 0.05. The p-value of 0.38% and the F-value of 4.24 moisture content responses demonstrated the significance of the model (i.e., the 0.38% probability that an F-value this large could be caused by noise).

Response	Moisture Content
R^2	0.8719
Adjusted R^2	0.7063
Predicted R^2	0.4284
Adequate Precision	9.4778

Table 4: Statistical Parameters from ANOVA for Response 1: Moisture Content

The model's fit quality can also be assessed using the statistical parameters listed in Table 4. A model is considered fit when the adjusted R^2 and the predicted R^2 differ by less than 0.2, the adequate precision is greater than 4 and the coefficient of determination (R^2) which quantifies the proportion of the dependent variable's variation that can be predicted from the independent variable or variables is closer to 1. In addition to taking into consideration the quantity of terms in a model adjusted R^2 indicated how well terms match a line or curve. The adjusted R^2 takes into

consideration the number of independent factors included in the prediction of the target variable. By adding new variables, we may then determine whether the model fitness has actually improved. Adding unnecessary variables to a model will result in a decrease in the adjusted R^2. The inclusion of more advantageous variables will increase the adjusted R^2 value. R^2 will always be larger than or equal to adjusted R^2. The anticipated R^2 indicated how well a regression model predicted the behavior of new observations while its ability to produce accurate predictions for new observations is diminished, it helps identify instances in which the model fits the original data. Predicted R^2 has the significant benefit of avoiding overfitting a mdel. Due to its excessive number of predictions, an overfit model begins to simulate random noise. Since it is impossible to predict random noise, the expected R^2 of an overfit model must drop. Should the expected R^2 be significantly less than the actual R-squared, there are most likely too many terms in the model. The coefficients of determination for moisture content (R^2 = 0.8719) are high and not very near to 1; the adjusted R^2 values (0.7063) for the moisture content responses do not reasonably agree with their predicted R^2 values (0.4284) because they differ by more than 0.2, which could be the result of an excessive number of terms in the model. The signal-to-noise ratio is measured with a higher level of sufficient precision than the response (9.4778). The moisture content data for moisture absorbed during the drying process perfectly matched the model's expected value according to all of these validations.

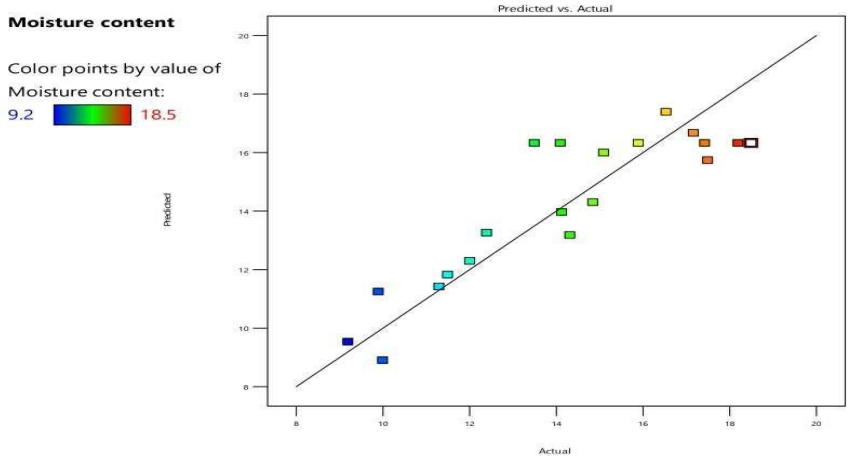

Figure 1: A Comparison of Expected and Actual Moisture Content Response Values

Figure 1 displays the difference between the experimental and projected moisture contents. The expected moisture is represented by the straight line, little departures from this line indicate that the model is substantial.

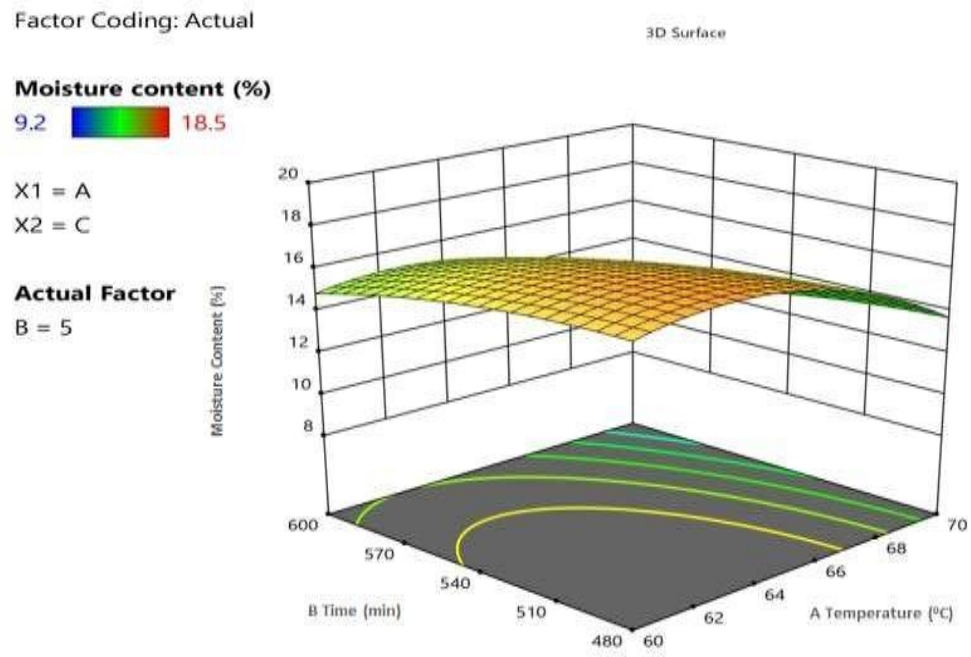

Figure 2: A 3D plot illustrating how drying time and temperature affect the moisture content response.

To analyze the relationships between the independent variables and identify the ideal levels of each variable, response surface plots were produced using the statistical models. The figures illustrate how the snail moisture content is impacted by drying temperature and drying duration. The 3D plot of the moisture content vs temperature and drying time is displayed in Figure 2. The surface plot clearly shows that the moisture content rises with increasing drying time and temperature. Temperature

and drying time have a linear relationship with moisture content similarly investigated by Adum and Inyang (2024).

3.2. Numerical Optimization

The reaction was numerically optimized to maximize the moisture content. During numerical optimization, the independent variable values were fixed within the experimental range, as indicated in Table 3. The optimal conditions were selected as the one with the highest desirability value following an evaluation of the model graphs and the solutions recommended by the numerical optimization tool. Therefore, the Design Expert V13 was used to numerically optimize the drying process's operating parameters for moisture content in order to produce the best results. Based on the optimization results, the ideal moisture content was found to be 19.20 at ideal temperature (60°C) and time (600 minutes). The goal of the optimization is to maximize the moisture content, and all operating parameters are within range. Bell pepper Odewole and Olaniyan (2016); Egbe, (2023) on periwinkle and plantain Inyang et al. (2019) have shown similar outcomes when oven-drying a variety of food items. The moisture content had the highest optimum desirability of 0.999. The features of every anticipated response are converted to a dimensionless desirability value (d) using the desirability function approach; these values fall between d = 0 and 1. When d = 1, it indicates that the result is precisely the desired value, and when d = 0, it implies that the expected value is undesirable. When the appropriate response becomes more desirable, the value of d rises (Montgomery, 2005). The ideal operating temperatures of 60°C and 600 minutes of drying time resulted in a moisture content that ranged from 10.20% to 19.20 because of the developed model's ability to convert removed moisture optimally, the optimization failed to maximize moisture content.

4.Conclusion

In order to model and optimize the moisture content in the drying process of African Giant Snails *(Achachatina achatina*), a three variable central composite design for response surface methodology was used. The snail's moisture content was greatly impacted by both time and temperature. The ideal temperature of 60°C and time of 600 minutes produced the best moisture content value of 19.20%. There was no discernible discrepancy between the mode prediction and experimental findings, according to the model's validation. The model is considered significant based on its F-value of 4.24. Additionally, model terms are significant according to the model P-values (I = 0.05). Furthermore, the lack of fit is not significant in relation to the pure error, as indicated by the lack of fit F-value of 0.6719. The results of this study suggest that additional research might be conducted using different drying techniques, such as osmotic and freeze drying; temperatures that are greater or lower than those utilized can be used. Additionally, optimization ought to be done with the Box-Behnken Design (BBD) and full factorial design (FFD), after which the ideal values of the Central Composite Design (CCD) employed in this investigation are compared.

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