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Optimization of Convective Hot Air Drying of Plantain Slices Using Response Surface Methodology

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Abstract:
In this study, the combined effect of volumetric air flow rate, relative humidity, temperature and time were evaluated in the drying of plantain. Response surface methodology (RSM), using central composite design (CCD), as a tool, was used to develop, validate and optimize statistical models in order to establish the individual and interactive impact of the drying parameters on the corresponding responses (moisture, carbohydrate and protein content and total plate count). Carbohydrate and protein contents were maximised while the moisture content and the total plate count were minimised.
By applying the desirability function (obtained as 0.970), the optimum values of 0.1 m^3/s, 72.12%, 72.45^{0}Cand 344.58 minutes (for air flow rate, relative humidity, temperature and time respectively) were obtained – with corresponding predicted (experimental ± standard deviation) responses of carbohydrate, 81.50% (80.74% ± 0.3); protein 4.23% (4.61% ± 0.4), moisture content 0.75 (1.2 ± 0.56) and total plate count, 0.99cfu (1.4 ± 0).

Keywords: *drying plantain, interactive impact, statistical models*

1. Introduction

Plantain, *musa paradisiaci* is a tree crop. It is a staple carbohydrate food commonly grown in the tropical regions of the world. It is attractive to farmers for agronomic management (Mgbede *et* al, 2014). Plantain contains carbohydrate, protein, dietary fibre, vitamins (A, B, C, E and K) and minerals, with an average production estimated at 2.11 million metric tonnes (Adeniji, 2006). As a well-acclaimed diuretic, it is extremely effective against kidney and bladder problems (Adeboye *et al*, 2014).

In Nigeria, the peak period of harvest is between September to February and there is always glut and wastage at this time as the produce cannot be stored for a long time (Adeboye *et al*, 2014). Physiological deterioration which results during storage caused by natural reaction can lead to significant loss of nutritional values. It can also arise from actions of biological or microbiological agents (insects, rodents, animals, bacteria, mould, virus and yeast (Adegbehingbe, 2014).

In most developing countries, dehydration of agricultural products such as pepper, yam, plantain, okra, cassava, and others using the sun (natural drying) is a very common practice. Here the materials are spread on the floors such as the rock surfaces, soil (clay) grounds, cemented pavements, raise mesh tray, and other devices. This method is time consuming and it could take four to six days for the product to get dried. Product quality suffers because of prolonged drying which makes the product susceptible to contamination. Losses are also incurred due to repeated handling and direct consumption by animals.

Drying is a process of reducing the moisture content of products with the aim of controlling the conditions that favour the reactions which lead to the deterioration of the products. The removal of moisture arrests the growth and the reproduction of microorganism that would cause decay and minimizes many of the moisture-mediated deterioration reactions. This can be done by simultaneous heat and mass transfer and is a classical method of food preservation that provides longer shelf life, reduce weight and volume (Malaisamy, and Sabanayagam, 2014).

Drying has been found to require the mastering of three fundamental parameters viz:

The added thermal energy which heats the product, sets the moisture in it to migrate towards its surface, before turning into water vapour. The capacity of the surrounding to absorb the water vapour given off by the products this depends on the percentage of moisture already present in the air before it enters the dryer and on the air temperature (Ajax, and Fakayode, 2011).

The air velocity going over the product surface must be high (up to a certain limit) especially at the beginning of the drying process in order to take the moisture away very rapidly (Vega, *et al*, 2007).

Drying has to occur fast enough to prevent the growth of moulds on the products but it must not be too fast. Otherwise, a crust could then form on the surface which would prevent the complete drying of the products. In like manner, too high a temperature, for drying, can cause the products to develop hard exterior or get burnt. Therefore, in order to dry a product properly, the characteristics of the fresh product has to be taken into account (for instance, fatty fish/meat is not to be dried in the same way as leafy vegetables), as well as those properties expected of the final product such as texture, colour, and specific taste (Bolaji, *et al*, 2008).

Effective drying process ensures minimal change in product quality after drying. Every step involved in the preservation process, like selecting the product, dressing it, pre-treatment, also contribute to the final quality of the dried product.

There are three phases in drying process. Malaisamy and sabamay again (2014) stated that the first phase is short and it is the phase during which the drying velocities increases and corresponds to the rise in temperature of the products until it reaches and settles in equilibrium state. This is the time when the product receives as much heat as possible from the hot air which is used to vaporize the water molecule from the product.

The second phase works as the constant drying velocity period. It corresponds to the evaporation of the free water on the product, which permanently remains on the moisture coming from inside of the products settles over the surface.

The third phase is the slowing down phase and it corresponds to evaporation of bond water during the drying process.

1.1. Drying Techniques and Equipment

Within the food processing industry, the diversity of products has introduced numerous drying methods to remove moisture from the wide variety of systems. The process adopt many forms and uses many different types of dryer, with each having been evolved to suit a given operation /product.

Drying process and equipment may be categorized according to several criteria, including the nature of material, the method of heat supply and the method of operation. The selection of the particular dryer or a drying process for a specific operation is a complex problem, for which many factors have been taken into account. However, ultimately, the overall selection and design of a drying system for a particular material is dictated by the desire to achieve a favourable combination of the product quality and process economics. In general, with respect to the rate, total drying time and dryer performance is dependent on some factors.

However, despite the many commercially available drying techniques, at present most dehydrated fruits and vegetables are still produced by the method of hot air drying. This is regarded as the simplest and most economical among various processes.

2. Materials and Methods

2.1. Equipment Description

The dryer is made up of three sections, the energy source (electricity), blower and the drying cabinet sections. The energy source is located behind the dryer while the blower is located in the middle of the drying chamber and has a power rating from 1.02 Watts. The blower helps in circulating heat for effective and efficient heat flow rate within the drying chamber (Ajayeoba, *et al.*,2014).

The dryer used for this experiment was fabricated with using stainless steel and a layer of 2mm thick fiber glass was used as insulator to control heat loss by conduction. The drying chamber had slots for each drying tray (Naval, *et al.,* 2015) which are perforated for effective airflow within the chamber (Dimitrios, *et al*., 2012).

2.2. Samples Collection

The fresh plantain samples were purchased from local suppliers at Idi-oro, Lagos, South-West Nigeria. The selected samples were sorted, cleaned with brushes and weighed. The samples were kept in for some hours to achieve equilibrium temperature with the environment before usage. This is because; the sample temperature could be higher than the temperature of the environment. This practice gives better result.

2.3. Drying Procedure

The experiments were carried out using fresh unripe plantain with average moisture content of 62.04% ± 0.002. The materials were cleaned with soft brushes to remove any form of dirty, no pre-treatment was done. The materials were cut into 2mm ± 0.004 thick. The initial weight for the slices was 20.00g ± 0.002 and three runs were used for each experimental investigation.

The dryer was cleaned and heated up to the required temperature before the trays were put in the dryer. The temperature level in the dryer was set at 40^0C, 50^0C, 60^0C, and 70^0C and was regulated by temperature controllers for each of the above temperature. The functionality and operation of the dryer was tested at air velocity and relative humidity of $3m^3$/s and 60% respectively.

The drying process was monitored every 30 minutes until a constant weight (of 3.10g ± 0.001) was obtained. The hot air velocity and relative humidity were varied at 0.49 m^3/s, 1.89 m^3/s, 2.49 m^3/s , 3.58 m^3/s , and 3.88 m^3/s, and 60%, 65%, 70%, 75%, and 80% respectively. The drying process continues, as the change in weight is constantly monitored at 30 minutes interval until a constant weight is obtained in any of the experiment. The reading (experiment) is terminated when an equilibrium weight was achieved.

2.4. Design of Drying Experiment Using Central Composite Design (CCD)

For ease of analysis, the Central composite design was used. This eliminates the physical iteration involved in the optimization of the process. This design also helps to build a quadratic model for the response variables, that is, it can efficiently predict the effect of interactions between input variables on the response variable.

In this study, a four factor, five levels Central Composite Designs (CCD) in RSM of Design-Expert 6.0.4 (Stat Ease, USA) software was used in this study to generate the regression models and examine the interactive effects of process variables on the process as well as optimum conditions for drying of plantain. For the plantain samples, the generated runs of the CCD investigated in this study consisted of 30 experimental runs. The design variables were the air flow velocity (X_1), the relative humidity (X_2), the temperature (X_3) and the drying time (X_4). The coded values with their corresponding real experimental values are depicted in Tables1-4. The responses of interest in this work were moisture content, carbohydrate, protein and Total plate count. Each experimental run was carried out in triplicate and the average value was taken as response.

2.5. Statistical Analysis

Significance of an input variable on the response was basically determined by the p and F-values from the analysis of variance (ANOVA) at a confidence level of 95% (minimum). Low p-values and high F-values implied a significance of the input variable on the response variable.

2.6. Regression Model for Plantain Drying Process

The behaviour of the response surface was investigated for each of the response variables (Y_i). The experimental data were fitted to a second order polynomial model and the regression coefficients were obtained. The generalized second order polynomial model proposed for predicting the response variables is given as:

$$Y_i = \beta_0 + \beta_A A + \beta_B B + \beta_C C + \beta_D D + \beta_{AA} A^2 + \beta_{BB} B^2 + \beta_{CC} C^2 + \beta_{DD} D^2 + \beta_{AB} AB + \beta_{AC} AC + \beta_{AD} AD + \beta_{BC} BC + \beta_{BD} BD + \beta_{CD} CD \quad (3)$$

Where,

β_0; $\beta_{A,B,C,D}$; $\beta_{AA,BB,CC,DD}$; $\beta_{AB,AC,BC,BD}$ are the constants, linear, quadratic and cross product regression coefficients respectively

A, B, C, D = the coded independent variables of the air velocity, relative humidity, temperature and time.

The second order polynomial equation fitted between the responses represent moisture content (Y_M), protein (Y_P), carbohydrate (Y_C) and total plate count (Y_T) and the input variable of volumetric air velocity (X_1), relative humidity (X_2), temperature (X_3) and drying time (X_4). Eqns. (1), (2), (3) and (4) are regression models for plantain drying process. The regression model generated shows the influence of each factor and combined factors on the performance of plantain drying process. The regression models obtained for the process are:

$$Y_M = +1095.345+6.4102X_1 -22.0794X_2 -5.6890X_3 -0.9079X_4-2.6622 X_1^2 +0.1036X_2^2 +3.13883E\text{-}003X_3^2 +1.71971E\text{-}004X_4^2 +0.17540X_1X_2-0.13605X_1X_3 -5.14580E\text{-}003X_1 X_4 +0.07318X_2X_3 +0.011206X_2X_4 -5.00484E\text{-}004X_3 X_4 \quad (1)$$

$$Y_P = -1.01144 +0.43074X_1 -0.03913X_2 +0.06957X_3+0.01445X_4 -0.036956X_1^2 -6.41927E\text{-}005X_2^2 -8.69564E\text{-}004X_3^2 -1.53623E\text{-}005X_4^2-1.32161E\text{-}003X_1X_2+1.25326E\text{-}003X_1X_3-6.95771E\text{-}004X_1X_4+1.05013E\text{-}003X_2X_3 -7.69194E\text{-}006X_2X_4 -2.12553E\text{-}005X_3X_4 \quad (2)$$

$$Y_C = -507.02198+17.19854X_1 +1.20779X_2 +10.50206X_3 +1.19017X_4 +0.43010X_1^2 +2.85417E\text{-}003X_2^2 -0.046299X_3^2 -6.24678E\text{-}004X_4^2 -0.17187X_1X_2 -0.051188X_1X_3-0.012090X_1X_4 -0.014763X_2X_3 -1.47083E\text{-}003X_2X_4-0.010155X_3X_4 \quad (3)$$

$$Y_T = +46657.50000 -344.45833X_1 -60.21667X_2 -896.5958X_3 -96.25093X_4-14.04167X_1^2 +0.15833X_2^2+4.47458X_3^2+0.058282X_4^2+3.70000X_1X_2+0.48750X_1X_3 +0.25694X_1X_4 +0.3850X_2X_3 +7.77778E\text{-}003X_2X_4 +0.89625X_3X_4 \quad (4)$$

2.7. Proximate Analysis of Samples

In order to determine the effectiveness of the drying process and/or the dryer, the samples were subjected to proximate analysis to compare the nutritive quality of the dried products. The proximate analysis conducted on the samples include moisture content, ash content, protein, crude fibre, fats and total carbohydrates contents, as well as the microbiological analysis (Total plate count, TPC).

i. Moisture content determination: 5g of the sample was weighed into pre-weighed aluminium drying dishes and the samples were dried to constant weight in an oven at 105^0C for 24 hours (AOAC, 2014). The moisture content was determined as follows:

$$moisture\ content = \frac{M_1 - M_2}{M_1 - M_0} \quad (5)$$

where M_0 = weight of Aluminium dish

M_1 = weight of fresh sample and dish

M_2 = weight of dried sample and dish

ii. Protein determination: Kjedahl nitrogen method was used where 1g of the sample was introduced to the digestion flask and 5 selenium tablets of Kjedahl catalyst was added to the sample. 20ml of concentrated acid was added to each sample and fixed to the digester for 8 hours until a clear solution was obtained. The cooled digest was transferred into 100ml volumetric flask and made up to marl with distilled water. The distillation apparatus set is raised for 10mins by boiling 20ml of 4% Boric acid

was pipetted into a conical flask, then 5 drops of methyl red added to each flask as indicator. The sample was then diluted with 75ml distilled water. 10ml of the digest to be alkaline with 20ml of NaOH (20%) and distilled. The steam exit of the distilment is closed and the change of colour of the Boric acid solution to green was timed. The mixture was distilled to 15mins and the filtrated titrated against 0.1N HCl (AOAC, 2014).
Then the percentage total Nitrogen was calculated as follows:

$$\% \text{ Total Nitorgen} = \frac{\text{Titre X Normality X 0.014 X 100}}{\text{Sample weight}} \quad (6)$$

Where;
N = Normality of acid = 0,1N
Conversion factor = 6.25
% Protein = % Total Nitrogen X Conversion factor

iii. Carbohydrate determination: This was obtained by subtracting from 100, the sum of the percentage of moisture content, ash, fibre, protein, fats and the remainder is percent carbohydrate
iv. Microbiological analysis: this was carried out on the samples to determine whether the products are free from pathogenic microorganisms and hence, safe for consumption. The analysis carried out total plate count, coliform, fungi and E. coli. The method of Harrigan and Mc Lance (2004) was used where 1 gram of each sample was weighed and dispensed into 9ml of sterile water. Serial tenfold dilution was carried out and from appropriate dilution, 1ml was carefully taken and introduced into a sterile plate and cooled. Molten agar was the poured on it by the pour plate method using nutrient agar for the enumeration of the total anaerobic bacteria. The plate was then incubated at 37^0C between 24 – 48 hours.

2.8. Optimization Procedure

Numerical optimization was performed by design expert software. Multiple responses were optimized simultaneously through the use of a desirability function that combines all the responses into one measurement (Even and Kaymax-Ertekin, 2007). The desirability function is given as:

$$D(x) = (d_1 \, X \, d_2 \, X \, d_3 X \, d_4 \ldots\ldots X \ldots\ldots X \, d_n)^{1/n} \quad (8)$$

Where d_1, d_2, …..d_n = responses
n = total number of responses under investigation.
Numerical optimization method finds operating conditions (a combination of independent variables) that maximizes the desirability function, ranging from zero (which is least desirable) outside the limits to one (most desirable) at the goal (most favourable response value). The desired goal for each independent variable and responses were set to maximize carbohydrate and protein contents while minimizing the moisture content and the total plate count. Different weights were assigned to each to adjust the shape of the desirability function for optimization of the multiple responses.

2.9. Model Verification

For verification of the models obtained, experiments were conducted under the optimum conditions obtained. The responses of the experimental and predicted values were compared in order to check the validity of the models. The standard error between the experimental value and predicted value is then defined as:

$$\sigma = \sqrt{\frac{\Sigma(z_i - z_j)^2}{N}} \quad (9)$$

Where
σ = standard error
z_i = predicted value
z_j = experimental value
N = number of replications

3. Results and Discussion

For all experiments, a final moisture content of 9.916 ± 0.002 was achieved. This corresponded with a constant weight of 3.10g. Experimental results showed that temperature and air velocity are inversely related to drying time, that is, the higher these variables, the shorter the drying time. This correspond to findings of Ajav and Fakayode (2011) who investigated the optimum drying temperature for okra, pepper and plantain using an electric dryer at different temperatures and also, work of Ehiem *et al*., (2009) who investigated the effect of air flowrate by incorporating a blower. The result showed significant reduction in drying time with increase in air flow rate from $18m^3/s$ to $19.5m^3/s$.
Muhiden and Hensen (2012) and Tunde-Akintunde and Adeladu (2010) suggests that mechanical pre-treatment (making small holes on the skin) of chili pepper could reduce the drying time at the different temperatures by about 48% at 60^0C when compared to the untreated method.
On the other hand, relative humidity varied directly with drying time, that is, higher relative humidity gave longer drying time and vice versa.
Results obtained from this work were much better than those obtained when the traditional drying method of open air drying is used. The lowest temperature used in the experiment was 40^0C and the drying time was 900mins (15 hrs) as against 3 days minimum for open air drying of plantain at an average temperature of 35^0C and relative humidity of 60%.

The critical output parameters being studied could not be carried out while drying. Data were therefore, obtained after drying. Experimental results showed that temperature had effect on all outputs, as higher temperatures progressively decreased all the output variables. It was also observed that variables of relative humidity and air flow velocity that gave short drying time similarly dropped values of the output variables. These changes were quite significant in outputs to be minimised (moisture content and total plate count) while it was relatively insignificant in the outputs to be maximised (protein and carbohydrate content). The details of the ANOVA response are discussed below:

3.1. Moisture Content Response

ANOVA for plantain drying regression model of moisture content response is shown in Table 1. P values showed that individual factors of temperature and drying time were highly significant for moisture response. The quadratic terms for relative humidity and time in equation 4 are also statistically significant as indicated in Table 1. However, interaction between the parameters of relative humidity and temperature is highly significant (confidence level = 99%) in Table 1. Moreover, the interaction between other parameters like operating time and relative humidity was also significant with confidential level > 97%. Apart from the interaction, effect of individual parameters like air flow rate, temperature and drying time are significant with good confidence level as indicated in the Table 1.

3.2. Protein Content Response

ANOVA for plantain drying regression model of protein content response is shown in Table 2. P values obtained also showed that individual factors of temperature and drying time were highly significant for protein response. It was observed that effects of temperature and drying time were highly significant with p values $\leq$0.005. The quadratic terms for drying time in equation 2 are also statistically significant as indicated in Table 2. Apart from the interaction, effect of individual parameters like air flow rate, temperature and drying time are significant with good confidence level as indicated in the Table 2.

The result of second-order response surface model for plantain drying with the input variable of volumetric air flow rate (X_1), relative humidity (X_2), temperature (X_3) and drying time (X_4) and protein as response in Eqn. (5) in form of ANOVA is shown in Table 2. The significance of each parameter was also determined by F-values and P-values. The parameters for the main effects such as air flow velocity, relative humidity, temperature and time are significant in Table 2. Quadratic terms for only drying time for protein response is significant. Interactive effect of the process variables such as relative humidity and temperature, and air flow velocity and time were not significant for plantain drying with protein content as response. Low probability values ($P < 0.0001$) with the corresponding high F-values in the Table 2 demonstrates high influence of the factors on protein content of dried plantain.

3.3. Carbohydrate Content Response

ANOVA for plantain drying regression model of carbohydrate content response is shown in Table 3. It was observed that individual factors of temperature and drying time for moisture response were highly significant, having p values $\leq$0.005. The quadratic terms for relative humidity and time in equation (3) are also statistically significant as indicated in Table 3. Moreover, the interaction between other parameters like operating time and temperature was also significant with confidential level > 97%.

The result of second-order response surface model for plantain drying with the input variable of volumetric air flow rate (X_1), relative humidity (X_2), temperature (X_3) and drying time (X_4) and protein as response in equation 3 in form of ANOVA is shown in Table 3.

3.4. Total Plate Count Response

ANOVA for plantain drying regression model of total plate count response is shown in Table 4. It was observed that individual factors of temperature and drying time for moisture response were highly significant with p values $\leq$0.005. The quadratic terms for temperature and time in equation (4) are also statistically significant as indicated in Table 4. Also, the interaction between parameters like operating time and temperature was also significant with confidential level > 97%.

3.5. Optimization and Experimental Validation

The result of the numerical optimization shows that at a desirability of 0.97, the optimum value of responses are 5.3%, 4.41%, 81.5% and 34.9 x 10^{-2} for moisture content, protein content, carbohydrate content and total plate count respectively.

The optimum point for all process variables are: 3.95 m^3/sec, 71.01%, 76 ^{0}C and 271.8 m^3/sec for air flow rate, relative humidity, temperature and time respectively.

The experimental response values were found to be in agreement with the predicted values. This is similar to results obtained by Siewkian and Chung (2012).

4. Conclusion

Response surface methodology was effectively used to describe the effect of drying conditions in the retention of carbohydrate and protein and also, the decline of moisture content, total plate count. Results obtained showed that the most significant drying conditions for plantain are: temperature and drying time while the least significant are air velocity and relative humidity.

The results obtained from experiments based on the optimal drying conditions were very close in value. This shows that the statistical models efficiently describe the drying process of plantain when subjected to the parameters under investigation and using the fabricated cabinet dryer.

4.1. Disclosure of Conflict of Interest

In this work, there are no conflicts of interest in all participating authors.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	3080.167	14	220.0119	24.80506	<0.0001	Significant
X_1	54.94875	1	54.94875	6.19515	0.0250	
X_2	24.47343	1	24.47343	2.759237	0.1174	
X_3	854.2485	1	854.2485	96.31153	<0.0001	
X_4	978.3489	1	978.3489	110.3031	<0.0001	
X_1^2	194.4032	1	194.4032	21.91782	0.0003	
X_2^2	184.2413	1	184.2413	20.77213	0.0004	
X_3^2	2.70234	1	2.70234	0.304673	0.5891	
X_4^2	53.22094	1	53.22094	6.00035	0.0271	
X_1X_2	12.30602	1	12.30602	1.387432	0.2572	
X_1X_3	29.61465	1	29.61465	3.338879	0.0876	
X_1X_4	3.431713	1	3.431713	0.386906	0.5433	
X_2X_3	214.2479	1	214.2479	24.1552	0.0002	
X_2X_4	406.8733	1	406.8733	45.87259	<0.0001	
X_3X_4	3.246279	1	3.246279	0.365999	0.5542	
Residual	133.0446	15	8.869639			
Lack of Fit	103.9471	10	10.39471	1.78619	0.2710	not significant
Pure Error	29.09745	5	5.819489			
Cor Total	3213.212	29				

Table 1: ANOVA results for Plantain Drying Regression Model of %Moisture Response

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	5.62414	14	0.401724	48.25572	<0.0001	Significant
X_1	0.14505	1	0.14505	17.42364	0.0008	
X_2	0.061978	1	0.061978	7.444869	0.0155	
X_3	3.024575	1	3.024575	363.3164	<0.0001	
X_4	1.695112	1	1.695112	203.6194	<0.0001	
X_1^2	0.037461	1	0.037461	4.499898	0.0510	
X_2^2	7.06E-05	1	7.06E-05	0.008485	0.9278	
X_3^2	0.207399	1	0.207399	24.91304	0.0002	
X_4^2	0.424704	1	0.424704	51.01603	<0.0001	
X_1X_2	0.000699	1	0.000699	0.083925	0.7760	
X_1X_3	0.002513	1	0.002513	0.30187	0.5908	
X_1X_4	0.062739	1	0.062739	7.536294	0.0150	
X_2X_3	0.044111	1	0.044111	5.298671	0.0361	
X_2X_4	0.000192	1	0.000192	0.023027	0.8814	
X_3X_4	0.005855	1	0.005855	0.703332	0.4148	
Residual	0.124874	15	0.008325			
Lack of Fit	0.10579	10	0.010579	2.771797	0.1360	not significant
Pure Error	0.019083	5	0.003817			
Cor Total	5.749014	29				

Table 2: ANOVA results for Plantain Drying Regression Model of %Protein Response

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	8010.985	14	572.2132	23.50143	<0.0001	Significant
X_1	7.315104	1	7.315104	0.300439	0.5917	
X_2	0.222337	1	0.222337	0.009132	0.9251	
X_3	2740.703	1	2740.703	112.5637	<0.0001	
X_4	2634.463	1	2634.463	108.2003	<0.0001	
X_1^2	5.074	1	5.074	0.208395	0.6546	
X_2^2	0.13965	1	0.13965	0.005736	0.9406	
X_3^2	587.9571	1	587.9571	24.14805	0.0002	
X_4^2	702.2413	1	702.2413	28.84183	<0.0001	
X_1X_2	11.81641	1	11.81641	0.485313	0.4967	
X_1X_3	4.192256	1	4.192256	0.172181	0.6841	
X_1X_4	18.94426	1	18.94426	0.778062	0.3917	
X_2X_3	8.717256	1	8.717256	0.358027	0.5585	
X_2X_4	7.009256	1	7.009256	0.287878	0.5995	
X_3X_4	1336.451	1	1336.451	54.88952	<0.0001	
Residual	365.2202	15	24.34801			
Lack of Fit	241.1943	10	24.11943	0.972354	0.5488	not significant
Pure Error	124.0259	5	24.80519			
Cor Total	8376.206	29				

Table 3: ANOVA results for Plantain Drying Regression Model of %Carbohydrate Response

Table 3 shows ANOVA for Plantain Drying Regression Model of Carbohydrate as Response. For individual factor, temperature and time show high level of significance, with p value <0.0001 while air flow rate and relative humidity were not significant. This implies that only temperature and time have influence on carbohydrate content during plantain drying process. Furthermore, it was noticed that quadratic terms of temperature and time were significant based on p and F values. The interaction between temperature and time only influenced carbohydrate content of plantain during drying process as indicated from the values of p and F in Table 3.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	59944845	14	4281775	361.8241	<0.0001	Significant
X_1	44376	1	44376	3.749919	0.0719	
X_2	17821.5	1	17821.5	1.505976	0.2387	
X_3	19324971	1	19324971	1633.024	<0.0001	
X_4	19228180	1	19228180	1624.845	<0.0001	
X_1^2	5408.048	1	5408.048	0.456998	0.5093	
X_2^2	429.7619	1	429.7619	0.036316	0.8514	
X_3^2	5491720	1	5491720	464.0685	<0.0001	
X_4^2	6112805	1	6112805	516.5523	<0.0001	
X_1X_2	5476	1	5476	0.46274	0.5067	
X_1X_3	380.25	1	380.25	0.032132	0.8601	
X_1X_4	8556.25	1	8556.25	0.723031	0.4085	
X_2X_3	5929	1	5929	0.50102	0.4899	
X_2X_4	196	1	196	0.016563	0.8993	
X_3X_4	10410302	1	10410302	879.705	<0.0001	
Residual	177507.8	15	11833.86			
Lack of Fit	127240.5	10	12724.05	1.265638	0.4199	not significant
Pure Error	50267.33	5	10053.47			
Cor Total	60122353	29				

Table 4: ANOVA for Plantain Drying Regression Model of TPC Response

Table 4 shows analysis of variance for plantain drying regression model with respect to Total Plate Count (TPC) as response. It was observed based on p and F value that operating temperature and time variables affect TPC of plantain during drying process. Moreover, it was noticed that only quadratic terms of operating temperature and time were significant according to their p and F values. Also, only the interaction between temperature and time influenced TPC of plantain during drying process as indicated in Table 4.

Responses	Initial Values	Predicted Values	Experimental ± Sd	Standard Error
Moisture, %	62.04 ± 0.04	0.75	1.20 ± 0.56	0.4
Protein, %	3.80 ± 0.04	4.23	4.61 ± 0.40	0.44
Carbohydrate, %	25.90 ± 0.14	81.50	80.70 ± 0.30	0.76
Total plate count, cfu	1.4 ± 0.02	0.99	0.004	-

Table 5: Results for model validation

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