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Effect of drying of pseudostem from banana variety, *Musa balbisiana* Colla on its nutritional composition

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ABSTRACT

Banana pseudostems are nutrient-dense plant biomasses that are majorly wasted or burnt, leading to disruption of the environment as well as the economy. In an attempt to prevent this, the present study was designed to assess the effect of drying Musa balbisiana Colla pseudostems on its nutritional composition. The process of drying was optimized using central composite design (CCD) technique of response surface methodology (RSM). Taking oven temperature and time as input variables and moisture content as a response, a set of 19 experiments was designed and carried out. The results obtained showed that oven temperature and time had a significant ($p < 0.05$) influence on drying of the banana pseudostems. By using the optimum oven temperature (56°C) and time (1186 minutes) led to a moisture content of a value as low as 4.03%. The dried pseudostems revealed an appreciable amount of dietary fiber, insoluble dietary fiber in particular and minerals like potassium, calcium, phosphorus, and iron. Banana pseudostems are one the majorly wasted biomasses which generate environmental as well as economical loss along with the loss of the nutrient therein. The optimized drying of banana pseudostem could serve as a method of its preservation and utilization in food applications without altering the nutritional composition.

Keywords: *Banana pseudostem, Musa balbisiana Colla, Oven drying, Optimization, Nutritional composition, Dietary fibre, Minerals, Nutraceutical*

Introduction

Banana (*Musa*) is a tropical herbaceous plant and an important commodity cultivated in over thirty countries across the world. It is one of the majorly consumed staples after rice, wheat and corn. The yield of bananas is highly prolific and attains a superior rank globally. The production of bananas was reported to be 121 million tons in 2021, contributing to around 16% of the production of the total fruit (1, 2). India stands second in the production of banana contributing about 23% to its total world production. *M. acuminata* and *M. balbisiana* are two wild species of banana that are cultivated largely in India (3).

Bananas are monocarpic plants and hence they flower once their lifetime. After each harvest, the stem dies and develops into a pseudostem. The pseudostem continues to grow in height as the leaves emerge one after the other and reaches its maximum height when the inflorescence emerges at the top of the plant. After harvesting the fruits, the bare pseudostem is cut and usually left on the plantation as a residual biomass. Due to their prolific harvest action, a large amount of biomass is generated which results in biodiversity problems like soil toxicity, air pollution, raised carbon points, and food safety problems (4, 5).

Several research findings have elucidated the health benefits of banana pseudostem.

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In ancient medicinal practices, including Ayurveda, banana pseudostem was used as a traditional medicine for gastrointestinal problems such as bloating, gastritis, constipation, and colitis (6). It is rich in nutrients such as minerals like sodium, potassium, chromium, magnesium, zinc, copper, iron and phosphorus, dietary fiber, and antioxidant (7). Studies have reported that dietary fiber present in banana pseudostem (50-70%) has the potential to impart a plethora of health benefits in terms of physiology and metabolism. One of its major functions is improving gut function by regulating the gut microbial biomass (8). Other benefits include body weight management, improvement of satiety, regulation of glucose and insulin response, and cholesterol management. Certain studies have also proven that banana pseudostem has antioxidative properties and its long-term consumption has preventive action against cancer, particularly colorectal cancer. The action of banana pseudostem in chronic diseases such as cardiovascular diseases, obesity, coronary heart disease, diabetes mellitus, kidney stones, and colorectal cancer have been extrapolated in many animal and human model studies (9). Banana pseudostem can also be appropriately utilized in agricultural sectors such as soil management and animal husbandry. Its high potassium content makes it suitable to be used as soil fertilizer to enhance the organic content. It can also be incorporated into fodder for ensuring proper animal nutrition (10).

In most cases, the enormous generation of banana pseudostem gets wasted over time, which are mostly burnt or decomposed and this contributes to the generation of a huge amount of bio-waste leading to environmental issues and economic loss. The wastage of banana pseudostem is a loss of the nutrient value therein.

The center core of the banana pseudostem has a high moisture content of about 90 per cent and hence cannot be kept for a long period of time. Moreover, the surface of the banana pseudostem is easily subjected to browning after harvest, which has a major effect on its sensory attributes and economic value (11).

To overcome this wastage, there is a need to develop a sustainable as well as cost-effective preservation technique which will help conserve the banana pseudostem and enable its utilization in the food and biomedical industry. Banana pseudostems have a very high moisture content of 94% which makes its highly perishable and susceptible to microbial contamination. Drying or dehydration would be the most feasible method for its preservation as it involves the removal of moisture without alteration in its nutritional values (12).

The most commonly used drying method is conventional open sun drying. Sun drying is an uncontrolled process and often deteriorates the product as a result of direct sun exposure and contamination. Other drying techniques such as oven drying, tray drying, fluidized bed drying, spray drying, flash drying, rotary drying, belt drying, vacuum drying and freeze drying which are better alternatives as they minimizes contamination and improve the quality of the product considerably (13). Studies have reported oven drying to be the most suitable form of drying of banana pseudostem as it results in maximum moisture reduction with minimum loss in nutrients. A well-designed oven drying technique can be used as an effective and sustainable method for the preservation of banana pseudostem and prevent its wastage on a large scale. The process of oven drying is controlled by parameters such as temperature and time, both of which influence the extent to which moisture is reduced. To obtain the desired result, it is essential to optimize the drying parameters for every particular food material (14). A statistically optimized drying model would ensure its feasibility and viability. Response surface methodology (RSM) is a statistical and mathematical technique used for the optimization of processes by estimating the relationship between independent variables and responses observed. It is used extensively in food and agricultural research for process and formulation optimization (15).

Although several efforts have been made in order to preserve and utilize banana pseudostems across the world, no scientific documentation has been done on the wild varieties of banana grown in the north-eastern regions of India. For the present study, *M. balbisiana* Colla, a native banana variety from the state of Assam was chosen. It is one of the widely grown and consumed banana varieties in the state. Although, its pseudostem forms a part of the Assamese cuisine, a major portion of it gets wasted all throughout the year. The present study is an attempt to develop an optimized model for oven drying of *M. balbisiana* Colla pseudostem by the use of the response surface methodology (RSM) to enable its use in various food and pharmaceutical preparations.

Objectives

1. To determine the optimum drying parameters viz., oven temperature and time for drying of *M. balbisiana* Colla pseudostem.

2. To analyse the nutritional composition of dried *M. balbisiana* Colla pseudostem

2. Materials and Methods

2.1 Source and preparation of sample

Musa ballbisiana Colla pseudostems were collected from the campus of Assam Agricultural University, Jorhat, Assam. The pseudostems were washed and cut transversally into thin slices of 4 mm thickness using a slicer. The sliced portions were treated with 4 % (w/v) citric acid solution for 10 minutes to prevent browning.

2.2 Drying of banana pseudostem

Drying of the sliced banana pseudostems was carried out in a forced air laboratory oven at the Department of Food Science and Nutrition, College of Community Science, Assam Agricultural University, Jorhat, Assam, India.

2.3 Optimization of drying parameters

Optimization of drying parameters was done using response surface methodology (RSM). Two independent variables viz., oven temperature and time; and one response (dependent variable) i.e. moisture content were taken into consideration. Using 40-60°C and 900-1260 min as the ranges of oven temperature and time respectively, a set of 19 experimental runs are generated according to central composite design (CCD), which is a 2^2 factorial experimental design with four axial points and five central points. The coding of test variables was done using the following equation.

$$\frac{(X_i - \bar{X}_i)}{\Delta X_i = X_i} \qquad .....(1)$$

(i= 1,2,3,……..k)

Table 1 represents the levels of variables (oven temperature and time) in the 19 experimental runs along with the responses (moisture content) obtained against each variable.

Response surface methodology (RSM) was applied to the experimental data using statistical package, Design Expert version 7.0. The following second order polynomial model (Eq. 2) was fitted to each of the response variable (Y) with the two independent variables (x) which is given below:

$$Y_k = b_{ko} + \sum_{i=1}^{2} b_{ki} X_i + \sum_{i=1}^{2} b_{ii} X_i^2 + \sum_{i \neq j=1}^{2} b_{kij} X_i X_i$$

(k = 0,1,2,3…..) ……(2)

Regression analysis and analysis of variance (ANOVA) were conducted on fitted models represented by equation (2) and the statistical significance of the model terms was determined. The adequacy of the models were determined by model analysis, lack of-fit test R^2 (coefficient of determination) and coefficient of variance.

Response surfaces and contour plots were generated with the help of a commercial statistical package, Design Expert – version 7.0. The numerical optimization technique of the Design-Expert software was used for the simultaneous optimization of the multiple responses. The desired goals for each variable and response were chosen. All the independent variables were kept within range while the response moisture content was minimized.

For each of the 19 experimental runs carried out, 150 g of sliced banana pseudostem were weighed and placed in each compartment of the dryer.

2.4 Determination of moisture content

To determine the moisture content, 1 g of the dried sample was placed on an aluminium pan in the moisture analyzer that was operated at 105° C for 10 min, after which the moisture content of the sample was displayed on the screen of the analyser (16).

2.5 Determination of the nutritional composition of dried banana pseudostem

2.5.1 Proximate analysis

Proximate analysis of the dried banana pseudostem was carried out to determine the crude fat, crude protein, carbohydrate, crude fiber and ash content to check the effects of the operating variables (oven temperature and time) on the nutritional composition of the dried banana pseudostem samples. Ash content is determined by incineration of the sample 3 hours at 600°C (16). Crude protein is estimated by Kjeldahl method by estimating the nitrogen content. The basis of this method was the conversion of nitrogenous compounds in the analyzed substance to ammonium sulphate through digestion of the sample with concentrated sulphuric acid in the presence of selenium (16). Crude fat is estimated by Soxhlet method using petroleum ether extraction, followed by evaporation to constant weight. The weight of the residue after incineration was expressed as percent (16). Crude fiber was estimated according to Hennerberg, Stohmann and Rauterberg method. This involves acid and subsequent alkali treatment which leads to oxidative hydrolytic degradation of the native cellulose and considerable degradation of lignin. The residue obtained after final filtration is weighed, incinerated, cooled and weighed again. The loss in weight gives the crude fiber content (17).

2.5.2 Determination of minerals

For analysis of mineral content, 0.5 g of the ash obtained is digested with triple acid mixture (1:2:4) HCl-HNO_3-H_2SO_4 to dryness. The residue is dissolved in 2N HNO_3, the insoluble portion is filtered out with Whatman-42 filter paper; the filtrate is made up to 50 ml and preserved for analysis of the metals. The concentration of Potassium (K), Iron (Fe), Calcium (Ca) and Phosphorus (P) was measured by Atomic Absorption Spectrophotometer. Standard solutions of each mineral with concentrations 0.1 μg/mL, 0.2 μg/mL, 0.3 μg/mL, 0.4 μg/mL, and 0.5 μg/mL were used to obtain the calibration curve. The absorbance of all standard solutions and samples was measured by atomic absorption spectrometer using respective minerals hollow cathode lamp at a respective wavelength for Potassium (768 nm), Iron (248.30 nm), Calcium (422.70 nm), and Phosphorus (213.60 nm) using air acetylene flame. Finally, the concentration of test solution was calculated from the calibration curve (18).

2.5.3 Determination of dietary fiber and its constituents

Dietary fiber content was estimated by enzymatic-gravimetric method. The samples were taken for sequential enzymatic digestion by heat-stable α -amylase, protease and amyloglycosidase to remove starch and protein. For determining insoluble dietary fiber (IDF), enzyme digestase is mixed with samples, filtered and the residue was washed with warm water and then dried and weighed. For soluble dietary fiber (SDF), combined filtrate and washes were precipitated with alcohol, which was then filtered, dried and weighed. The sum of IDF and SDF is the total dietary fiber (TDF) (19).

Neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin were estimated by method described by Van Soest and Wine and modified McQueen and Nicholson (20, 21). Hemicellulose and cellulose content were estimated according to the formula: [Hemicellulose = NDF– ADF]; and [Cellulose =ADF– lignin], respectively.

Total pectin was estimated according to the method described by Ranganna, 1979 (22).

3. Results

3.1. Optimization of drying parameters for drying of banana pseudostem

A total of 19 experiments with various combinations of oven temperature (°C) and time (min) were conducted according to the experimental plan and responses were taken. The levels of variables and responses are given in Table 1.

The second-order polynomial response surface model (Equation. 2) was fitted to each of the response variables (Y) and coefficients were estimated. The calculated correlations of moisture content in the banana pseudostem slices were found to be the functions of oven temperature (°C) and time (min).

The regression equation between the variables and response is as follows:

Regression analysis and ANOVA were conducted on the fitted model to examine the statistical significance of model terms. The estimated regression coefficients of the quadratic polynomial models for the response variables, along with the corresponding R^2 and coefficient of variation (CV) values are given in Tables 2. ANOVA showed that the model was significant for the response.

The fit statistics did not result in a significant F-value for response (moisture content) indicating that the model is sufficiently adequate to predict the responses. The R^2 value is high indicating the high proportion of variability explained by data and the model is adequate.

As a general rule, the coefficient of variation (CV) should not be greater than 10%. In this study, the coefficients of variation is less than 10% for the response (moisture content), indicating better precision and reliability of the experimental runs carried out.

The 3D response surface plots described by the regression models are shown in Figure 1 to illustrate the effects of independent variables (oven temperature and time) and their interaction on the moisture content of the banana pseudostem.

The numerical optimization was carried out using the developed models and the optimum conditions were: Temperature: 56°C and drying time: 1186 min. The predicted moisture content was 4.1%. The validation of optimized conditions was done by conducting the drying experiment at oven temperature: 56°C and time: 1186 min and good agreement was found between actual and predicted values as the obtained moisture

content was 4.03% $R1 = 4.92 - 0.77a - 0.3630B - 0.0250aB + 0.2354a^2 + 0.0547B^2$ ...(3)

3.2 Nutritional composition of the dried banana pseudostem

The proximate, mineral, and dietary fiber composition of the dried banana pseudostem (dry matter basis) is given in Table 3. The proximate analysis shows that the percentage of crude protein in dried banana pseudostem was 2.70 ± 0.00, crude fat was 1.11 ± 0.00, crude fiber was 24.33 ± 0.9, ash was 15.97 ± 2.07 and total carbohydrate was 51.86 ± 2.07. Mineral analysis in dried banana pseudostem shows that the content of iron was 3.31 ± 0.05 mg, calcium was 1264 ± 10.02 mg and phosphorus was 113.57 ± 1.69 mg. The percentage of TDF was 66.09 ± 3.60, IDF was 62.88 ± 3.12 and SDF was 3.21 ± 0.10.

4. Discussion

It is evident from equation (3) that both oven temperature and time had highly significant effect ($p < 0.01$) on the moisture content of the banana pseudostem, while the interaction between oven temperature and time did not have any significant effect on the moisture content. The moisture content tends to decrease with higher temperatures and longer drying time. The process of drying facilitates water evaporation from the surface of the food which influences its moisture content. With increasing these two parameters, contractile stresses occur in the cell wall structure of the food since the amount of heat given to food material increases. Therefore, the porosity of the dried samples increases leading to a decrease in the water or moisture content. Similar experiments on the optimization of oven drying parameters have shown that temperature and time play a significant role in the drying of food materials. Several research conducted banana pseudostems also report a drying temperature of 50-60°C and time of 20-22 h to result in a good reduction of moisture content as obtained in the optimized model in the present study (14).

The nutritional composition obtained in the present study reveals good nutritional composition in the banana pseudostem after drying. A similar proximate composition of 1.11% crude fat, 2.70% crude protein, 6.75% ash, 24.33% crude fiber and 81.60% total carbohydrate was observed in dried (60°C) banana pseudostem was reported by Ho *et al*., 2018 (23). Similar values for moisture (6.2%), crude fat (1.8%) and crude protein (3.6%) in banana pseudostem flour was also reported by Sangroula, 2018 (24). The ash value in the present study is as compared to 6.75% as reported by Ho *et al*., 2018 (23). This change can be attributed to factors such as varietal difference, degree of maturation of the pseudostem and different drying techniques used. In some studies, lower values of crude fiber content was observed when the banana pseudostem was dried at a higher temperature (70 ºC and above) as a result of disruption in the cellular matrix (25). The mineral content obtained in the present study is per several studies which have documented the abundance of minerals in banana pseudostems, in particular potassium (680.00– 1,078.20 mg/100g), calcium (318.00–1,335.33 mg/100 g) and phosphorus (137.82 mg/100 g) (26, 27, 28, 23, 29). The iron content obtained in the present study is in the similar range (3.31 mg/100 g of dry sample) as reported by Happi Emaga *et al*., 2007 (30). Similar levels of dietary fiber composition were reported in the order of insoluble (64.49%), soluble (2.58%) and total dietary fibers (67.07%) in native banana pseudostem flour by Aziz *et al*., 2011 (31). Lakshman *et al*., 2015 (13) also reported that banana pseudostem central core is rich dietary fiber (72%).

5. Conclusion

In the present study it is observed that oven temperature and time are important parameters affecting the process of drying of banana pseudostem. The outcome of the optimized model developed in this study indicated a low residual moisture content of 4.03% using the optimum values of 56°C and drying time: 1186 min, respectively was estimated by the use of Design Expert Version 7.0.0. This optimized model can be extensively used to prevent microbial contamination and help in increasing the shelf life of the banana pseudostem. The results obtained from this study also revealed that banana pseudostems contain appreciable amounts of crude fiber, insoluble dietary fiber, total carbohydrates and minerals such as potassium, calcium, phosphorus and iron, which make it to serve as a good source of these nutrients, even after drying. These findings indicate that banana pseudostem has the potential to be used as a plant source of functional properties in food and pharmaceutical industries. These banana waste residues can be transformed into upscale products to contribute to good health and well-being. The exploitation of the banana pseudostem will also be significantly beneficial for the environment as well as the economy.

FUTURE SCOPE

The wastage of banana pseudostems generates immense environmental as well as economical loss, along with the loss of the nutrient therein. The optimized drying of the banana pseudostem could enable its preservation and utilization in food application without altering its nutritional composition. Incorporation of the dried banana pseudostem could enable development of nutrient dense food products, particularly high in dietary fibre and minerals. Further, in-vitro and in-vivo digestibility studies could extrapolate its potential as a dietary fibre supplement for the management of digestive disorders like constipation and diverticulosis.

CONFLICT OF INTEREST

The authors declare no conflict of interest relevant to the study.

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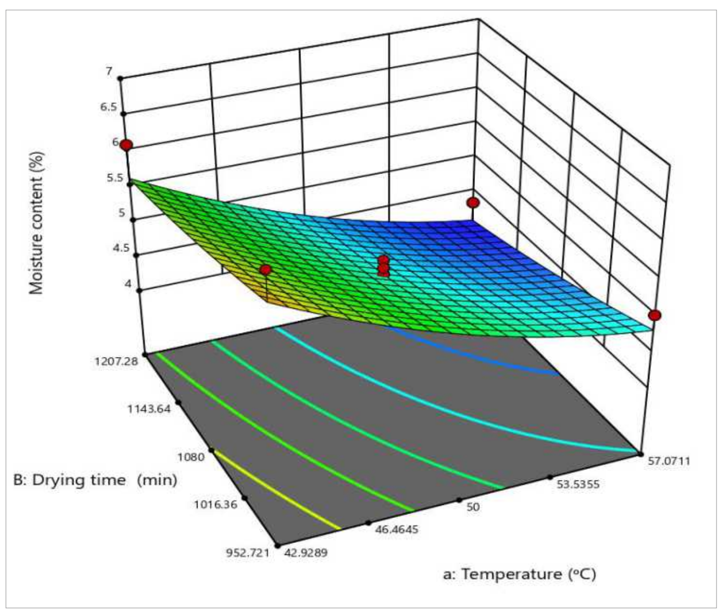

Figure 1. Response surface of moisture content in banana pseudostem after drying

Table 1. Experimental runs obtained by RSM and the corresponding responses

Experiment no.	Independent variables		Response
	Temperature (°C)	**Drying time (min)**	**Moisture content (%)**
1	42.929	1207.279	6.11
2	42.929	952.721	6.72
3	50	1080	5.12
4	50	1080	4.85
5	50	1080	4.91
6	50	900	5.25
7	50	1260	4.13
8	57.071	952.721	5.03
9	57.071	1207.279	4.32
10	50	1080	4.85
11	50	1080	5.01
12	50	1080	4.92
13	60	1080	4.24
14	60	1080	4.15
15	50	1080	4.88
16	50	1080	4.90
17	50	1080	4.82
18	40	1080	6.22
19	40	1080	6.27

Table 2. ANOVA of the polynomial model and estimated coefficients for response

Source	DF	Error DF	F-value	p-value	
Whole plot	3	3.98	12.09	0.0181	Significant
a-a	1	4.00	33.53	0.0044	
a^2	1	3.96	2.73	0.1743	
B^2	1	3.97	0.1071	0.7599	
Sub-plot	2	8.95	67.22	< 0.0001	Significant
B-B	1	8.95	134.13	< 0.0001	
aB	1	8.95	0.3181	0.5866	
Fit statistics					
R^2	0.9865				
Adjusted R^2	0.9780				
C.V.%	6.54				
Mean	5.09				
Std.Dev.	0.3330				

Table 3. Nutritional composition of dried banana pseudostem

Parameters	Composition per 100g
Moisture (%)	4.03 ± 0.60
Crude protein (%)	2.56 ± 0.89
Crude fat (%)	0.9 ± 0.05
Crude fiber (%)	25.11 ± 0.9
Ash (%)	15.97 ± 2.07
Total carbohydrate (%)	51.86 ± 1.20
Potassium (mg)	720 ± 0.30
Iron (mg)	4.09 ± 0.05
Calcium (mg)	1264.00 ± 10.02
Phosphorus (mg)	113.57 ± 1.69
Total dietary fiber (%)	66.09 ± 3.60
Insoluble dietary fiber (%)	62.88 ± 3.12
Soluble dietary fiber (%)	3.21 ± 0.10

Values are expressed as the mean ± Standard deviation (n = 3)

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