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OPTIMIZING PROXIMATE COMPOSITION OF DRIED TURMERIC RHIZOME IN A TRAY DRYER USING RESPONSE SURFACE TECHNIQUE

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Abstract: This study aims at optimizing the proximate compositions of turmeric (*Curcuma longa*) rhizome drying in a tray dryer. Fresh turmeric rhizome was oven dried at various temperature intervals. A three factor Box–Behken design was used to analyze the effect of variables, drying temperature: (40–65°C), air velocity (1.5–3m/s), and drying time: (30–240 minutes) on the responses (moisture, fats and oil, protein, fibre content, carbohydrate. At optimum conditions of 60.14°C, 3 hours and 2.0m/s for air temperature, time and air velocity respectively, the values of the moisture content, ash, fat, crude fibre, crude protein, drying matter, nitrogen, carbohydrate were found to be 8.82373%, 91.9391%, 4.62878%, 4.60806%, 7.90919%, 10.6833%, 78.8798% respectively. This study carefully demonstrated that the factors had no significant effect on the proximate composition of dried turmeric but the shelf life was enhanced.
Keywords: turmeric, drying, proximate composition, optimization

1. INTRODUCTION

Turmeric (Curcuma longa) a member of the *Zingiberaceae* family, is one of the common spices used in Asian cuisine. It grows primarily in tropical and sub–tropical regions including India, Bengal, China, Taiwan, Sri Lanka, Jeva, Peru, Australia and Thailand [1]. It is classified into herbaceous and perennial plants, with a height approximately 120 to 150cm in favorable atmospheric conditions. The rhizomes mature in the ground, their coloration are yellowish brown with the inside orange, and when it is dried, can be grounded to a powder and used for various purposes [2] the turmeric rhizomes mature around the central tuberous structure known as primary rhizome or known as head, from which forms the secondary rhizomes thinner than the head [3].

Turmeric has been reported to have a role in preventing human diseases such as cancer (as antioxidants and anti–carcinogenic) and cardiovascular diseases [4]. These medicinal properties have been credited mainly to the curcuminoids which are abundant in turmeric rhizome [5]. Nowadays, animals and human trials suggest that curcuminoids have no toxicity even at high doses; therefore, turmeric is a safe ingredient in medicines and cosmetics [6]. Commercially, turmeric can be sold either fresh or as dried powder, however, dried turmeric powder is more often sold all around the world but the price varies depending on many factors including quality—i.e. moisture content, appearance (color), and phenolic contents [7]. Therefore, it is necessary to use appropriate postharvest technology in order to prolong its shelf life. One of the primary drying method is oven drying, Oven drying is a method that accumulates the advantages of rapid energy transfer from microwave drying and fast mass transfer at low temperatures from vacuum heating [8]. This drying method decreases drying time and uses a lower temperature; thus it will increase the qualities of dry food products including color, texture and nutrients such as proteins, carbohydrates, lipids, antioxidants and vitamins [4, 9].

Drying is among the most popular methods used for the purpose preserving flesh vegetables, which can be consumed directly or used as ingredients for preparation of soups, stews, pizzas and many others.

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Thus, drying is considered as an important technique in the processing of agricultural produce. The drying process removes moisture from food material to a certain point where pathogenic spoilage is avoided and so increases the shelf life, reduces the bulk volume, transportation and storage costs of food materials [10] suggested that in the selection of drying conditions for vegetables. Hence, it is essential to select optimal drying conditions to enhance the nutritional qualities of turmeric [11]. Drying at various temperature, time, air velocity and thickness have different effects on the nutritional parameters of the turmeric, hence, the need to optimize the drying method in order to preserve the turmeric as well as retain its nutritional parameters. Available literature reported on the nutritional and proximate composition of tomato drying conditions [12,13] and Xanthaso *masagittifolian* tubers [14], none has reported on proximate compositions of dried turmeric (*curcuma longa*) rhizome. This paper therefore seeks to investigate the effect of drying parameters on proximate composition (moisture, fats and oil, protein, fibre content, carbohydrate) of turmeric rhizome.

2. MATERIALS AND METHOD

— Samples collection and Methods of Analysis

The fresh turmeric rhizome samples were obtained from National Root Crops Research Institute Umudike, Abia State, South–East of Nigeria. The samples were sorted, cleaned with brushes, cut into desired thickness and weighed. They were oven dried at different temperatures set manually through the oven regulator. Vernier calipers was used for measuring the axial dimensions as well as the thickness of the turmeric samples. Multi thermometer which is a squared thermometer was used in measuring the exhaust temperature released into the environment by the oven while Hygrometer was used in measuring the relative humidity of the environment as well as the ambient temperature of the drying environment. Sample pan was used to put the sample respectively before placing them inside the oven. Weighing balance was used to weigh the samples before and after drying in order to know the weight while Crucible was used in putting the samples in order to determine the moisture contents. Muffle furnace was used to heat the sample to the temperature of 600^{0}C while Desiccator was used to cool and preserve samples to avoid deterioration. Filter papers were used to wrap moisture free samples and an Anemometer was used to measure the air velocity.

— Experimental procedure

The sliced turmeric was dried in a laboratory oven dryer. The air velocity below the meshed sample tray was set with an anemometer (accuracy of 0.01m/s) by adjusting the flow meter. The maximum temperature recordable in this drying system is 100±0.5C. The drying compartment was of diameter 40cm with two meshed sample trays. The sliced samples (27.1g) was put in the pan and placed on the sample tray inside the oven depending on the experimental design. After the set time, each sample was taken out of the drying chamber and weighed with an electronic balance (accuracy 20.3g). On completion of drying, the samples were wrapped with nylon and placed in the desiccator for proper storage. The samples were conveyed to proximate analysis laboratory to determine the proximate composition (carbohydrate, protein, fibre, fat and moisture) of each dried sample.

— Determination of moisture Content

Moisture was determined by oven drying method; 1.5g of well mixed samples was accurately weighed in clean, dried crucible (W_1). The W_1 crucible was allowed in an oven at 100–105^{0}C for 6 – 12hours until a constant weight was obtained. Then the crucible was placed in the desiccator for 30minutes to cool. After cooling it was weighed again (W_2). The percent moisture was calculated by the following formula

$$\% \text{ moisture} = \frac{w_1 - w_2}{w_1} \times \frac{100}{1}$$

where: W_1 = initial weight of crucible + sample 1, W_2 = final weight of crucible + sample
Note: moisture free samples were used for further analysis

— Crude protein determination

Protein in the sample was determined by Kjeldahl method. The samples were digested by heating with concentrated sulphuric acid (H_2SO_4) in the presence of K_2SO_4.$CuSO_4$ digestion mixture. The mixture was then made alkaline. Ammonium Sulphate thus formed, released ammonia which was collected in 2% boric acid solution and titrated against standard HCl. Total protein was calculated by multiplying the amount of nitrogen with appropriate factor (6.60) and the amount of protein was calculated.

≡ **Reagents**

» 0.1N HCl (standard)
» Concentrated sulphuric acid
» Sodium hydroxide solution 40% w/w
» Digestion mixture: Potassium Sulphate (K_2SO_4) and copper Sulphate ($CUSO_4$)
» Boric acid: Dissolved 40g of boric acid in sufficient distilled water and made the volume up to 100ml
» Indicator: methyl red

≡ **Procedure**

Protein in the sample was determined by Kjeldahl method. 0.5 – 1.0g of dried samples was taken in digestion flask. Add 10 – 15ml of concentrated H_2SO_4 and 8g of digestion mixture i.e. K_2SO_4.$CuSO_4$ (8:1). The flask was swirled in order to mix the contents thoroughly then placed on heater to start digestion till the mixture becomes clear (blue green in color). It needs 2hours to complete. The digest was cooled and transferred to 100ml volumetric flask and volume was made up to mark by the addition of distilled water. Distillation of the digest was performed in Markam Still Distillation apparatus [15]. Ten milliliters of digest were introduced in the distillation tube then 10ml of 0,5N NaOH was gradually added through the same way. Distillation was continued for at least 10 minutes and NH_3 produced was collected as NHOH in a conical flask containing 20ml of 4% boric acid solution with few drops of modified methyl red indicator. During distillation yellowish color appears due to NH_4OH. The distillate was then titrated against standard 0.1N HCl solution till the appearance of pink color. A blank was also run through all steps as above. Percent crude protein content of the sample was calculated by using the following formula:

$$\% \text{ crude protein} = \%N \times 626$$

The nitrogen content %N of the sample is given by the formula below

$$\%N = \frac{T_v \times N_a \times 0.014 \times V_1}{G \times V_2} \times 100$$

where: T_v = titre value of acid (cm^3), N_a = concentration or normality of acid, V_1 = volume of distilled water used for distilling the digest ($50cm^3$), V_2 = volume of aliquot used for distillation ($10cm^3$), G = original weight of sample used

— **Determination of crude fat**

Crude fat will be determined by ether extract method using soxhlet apparatus. Approximately 1g of moisture free sample will be wrapped in filter paper, placed in fat free thimble and then introduced in the extraction tube. Weighed, clean and dry receiving beaker will be filled with petroleum ether and fitted into the apparatus. The water and heater will be turned on to start extraction. After 4 – 6 siphoning, the ether will be allowed to evaporate and the beaker will be disconnected before last siphoning. The extract will be transferred into a clean glass dish with ether washing and the ether evaporated on water bath. The dish will then be placed in an oven at 105^0C for 2hours and cooled it in a desiccator. The percentage crude fat will be determined by using the following formula:

$$\% \text{ crude fat} = \frac{\text{wt of ether extract} \times 100}{\text{wt of sample}}$$

— **Determination of crude fiber**

A moisture free and ether extracted sample of crude fiber made of cellulose will first be digested with dilute H_2SO_4 and then with dilute KOH solution. The undigested residue collected after digestion will be ignited and loss in weight after ignition will be registered as crude fiber.

≡ **Reagents:**

» Solution of sulphuric acid (0.128M) 7.1ml, 96% per 1000ml of distilled water
» Solution of potassium hydroxide (0.223M) 12.5g per 1000ml of distilled water
» Acetone (foam suppressor)

≡ **Procedure:**

About 0.153g sample will be weighed (W_0) and transferred to porous crucible. The crucible will then be placed into Dosi–fiber unit and the valve kept in "OFF" position. 150ml of preheated H_2SO_4 solution and some drops of foam–suppressor will be added to each column. The cooling circuit will then be opened and the heating elements turned on (power at 90%). When it starts boiling, the power will be reduced to 30% and left for 30minutes. Valves will be opened for drainage of acid

and distilled water will be used to rinse it thrice to completely ensure the removal of acid from sample. The same procedure will be used for alkali digestion by using KOH instead of H_2SO_4. The sample will be dried in an oven at 150^{0}C for 1hour. Then allowed to cool in a desiccator and weighed (W_1). The sample crucibles will then be kept in a muffle furnace at 55^{0}C for 3 – 4hours. Cooled in desiccator and weighed again (W_2). Calculations will be done by using the formula

$$\% \text{ crude fibre} = \frac{w_1 \times w_2}{w_0} \times 100$$

—Experimental Design

The Box B Design (BBD), Response surface Methodology (RSM) in design expert was used to design the drying experiments. Three independent variables A (air temperature, ^{0}C), B (air velocity m/s) and C (sample thickness, mm) at three levels for six dependent or responsive variables were generated.

Table 1: Factor level of the full factorial design used in the BBD study of the drying conditions.

Independent	Symbols		Levels	
Variables	Natural	Codes	Natural	Coded
Temperature	T	A	60C	−1
			62.5C	0
			65C	1
Time	t	B	3hours	−1
			5hours	0
			7hours	1
Air velocity	V.	C	1.50m/s	−1
			1.75m/s	0
			2.0m/s	1

The full model used to describe the dependent or response variable (Y) involves the linear or main interaction and curvature effects as shown in equation (1)

$$Y_r = \beta_0 + \sum_{i=1}^{k} \beta_1 A + \sum_{i=1}^{k} \beta_2 B + \sum_{i=1}^{k} \beta_3 C + \sum_{i=1}^{k} \beta_4 AB + \sum_{i=1}^{k} \beta_5 AC + \sum_{i=1}^{k} \beta_6 BC + \sum_{\substack{i=1 \\ 1<i}}^{k-1} \sum_{i=2}^{k} \beta_{ij} MN$$

where β_0, β_1, β_2, β_3, β_4, β_5 +β_6 are the regression coefficient for intercept A, B, C, are the independent variables and Y represent the response variable; $\sum$ represent the constant.

3. RESULT AND DISCUSSION

—Box–Behnken Design for Three Factors and Results

The results of the seventeen experiments analyzed according to Box–Behnken Design are shown in table 2. The estimated effects for each independent variable and the interaction between the variables were determined.

Table 2. Box–Behnken Design for Three Factors and Results

Run	Temp	time	air vel	MC	DM	ASH	CF	FAT	N	CP	CHO
1	62.5(0)	5(0)	1.75(0)	9.2	90.8	5.4	4.7	6.71	1.4	8.75	74.44
2	62. (0)	5(0)	1.75(0)	8.8	91.2	4.8	4.91	6.2	1.54	9.63	74.46
3	62.5(0)	7(1)	1.5(−1)	10.4	89.6	4.42	4.9	6.14	1.58	9.84	74.7
4	65(0)	5(0)	2(1)	10.4	89.6	3.14	5.26	7.04	1.61	10.06	74.5
5	62.5(0)	7(1)	2(!)	8.74	91.26	2.8	4.8	6.7	1.47	9.19	76.51
6	60(−1)	3(−1)	1.75(0)	9.36	90.14	4.53	4.46	6.26	1.61	10.06	74.69
7	62.5(0)	3(−1)	1.5(−1)	11.7	88.7	4.98	4.8	7.6	1.3	8.09	74.53
8	62.5(0)	3(−1)	2(1)	8.9	91.1	2.56	5.1	7.5	1.68	10.5	74.34
9	60(0)	5(0)	1.5(−1)	8.96	91.04	2.94	4.44	6.43	1.96	12.25	73.94
10	65(1)	5(0)	1.5(−1)	9.26	90.74	2.59	4.8	5.67	1.3	8.1	78.83
11	62.5(0)	5(0)	1.75(0)	9.7	90.3	4.92	5.14	6.26	1.37	8.53	75.15
12	60(−1)	5(0)	2(!)	9.24	90.76	3.2	4.96	7.4	1.75	10.94	73.5
13	62.5(0)	5(0)	1.75(0)	9.8	90.2	3.24	4.42	4.94	1.51	9.41	77.99
14	65(1)	3(−1)	1.75(0)	10.8	89.2	2.94	4.31	6.2	1.68	10.5	76.05
15	62.5(00	5(0)	1.75(0)	9.34	90.66	2.48	4.52	7.2	1.26	7.88	77.92
16	60(−1)	7(1)	1.75(0)	12.5	87.5	3.8	5.2	6.09	1.33	8.31	76.6
17	65(1)	7(1)	1.75(0)	9.6	90.4	2.59	4.16	6.93	1.54	9.63	76.69

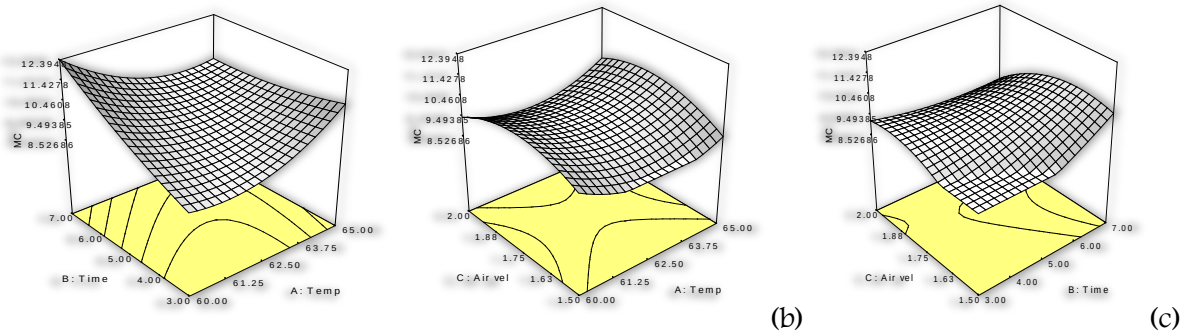
—Effects of drying condition on moisture content

The moisture content of the dried turmeric rhizome is influenced by the drying conditions on the response surface plat is depicted in Figure 1a – c. table 3 shows the ANOVA result for the moisture content by response surface second order polynomial model (equation 1). As shown in table 3 and Figure 1a – c, the effect of increasing temperature decreased the moisture contents of the dried turmeric apparently.

Table 3: ANOVA for the moisture content by response surface quadratic model

Source	coefficient estimate	Sum of Squares	DF	Mean Square	F Value	Prob> F
Model	9.368	11.76842	9	1.307602	3.738356	0.0613**
A	0	0	1	0	0	1.0000**
B	0.64	2.184533	1	2.184533	6.24545	0.0466*
C	0.2	0.213333	1	0.213333	0.609907	0.4645**
A^2	0.9435	2.967308	1	2.967308	8.483354	0.0269*
B^2	0.2535	0.214208	1	0.214208	0.612406	0.4636**
C^2	−0.8465	2.388541	1	2.388541	6.828695	0.0399*
AB	−1.085	4.7089	1	4.7089	13.46246	0.0105*
AC	0.215	0.1849	1	0.1849	0.528618	0.4946**
BC	−0.875	1.53125	1	1.53125	4.377752	0.0813**

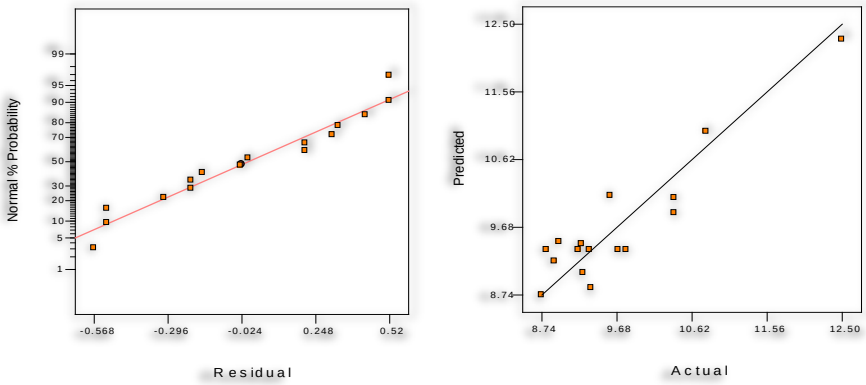
* Significant; ** Not significant; lack of fit is not significant at $P > 0.05$.



(a) (b) (c)

Figure 1: The effects of (a) temperature and time, (b) temperature and air velocity (c) air velocity and time on response surface plots of the moisture content

Figure 1a–c shows the effect of drying temperature, time and air velocity on the moisture content of the dried turmeric rhizome. It was observed that increase in the drying temperature and time leads to an increase in the moisture content of the rhizome but the moisture content decreases as the air velocity of the system increases.



(a) (b)

Figure. 2. (a) Normal probability plot of the moisture content residuals. (b) Predicted versus Actual moisture content of the dried turmeric samples

Subsequently, an increase in air velocity decreased the moisture content apparently. There was however, significant increment in moisture content as sample thickness was increased.

$$Y_{mc} = 9.368 + 0A + 0.64B + 0.2C + 0.9435A^2 + 0.2535B^2 - 0.8465C^2$$
$$-1.084AB + 0.215AC - 0.875BC. \ (R^2 = 0.8487) \quad (2)$$

It has been reported that in the drying process, the reduction of surface moisture always points to increasing the surface temperature by additional heat source or applying vacuum condition.

[16] studies that initial average moisture content of the turmeric rhizomes was 411.25% and it attained an equilibrium moisture content of 7.81% after drying for a period of 48hours. For 2 mm dried turmeric slice at 65°C, a negligible change in total moisture content was observed. The values of moisture content obtained in this experiment were in the range of values of 8.74 – 12.5mg/100g moisture content for the dried turmeric slice at 40 – 65°C. The total coefficient of determination ($R^2 = 0.848$) of the model show good prediction agreement between the experiment and stimulated values of the moisture content. The normal probability plot of the moisture content residuals (Figure 2a) and the predicted versus actual moisture plot (Figure 2b) further shows the model best fit to navigate moisture content of the dried sample.

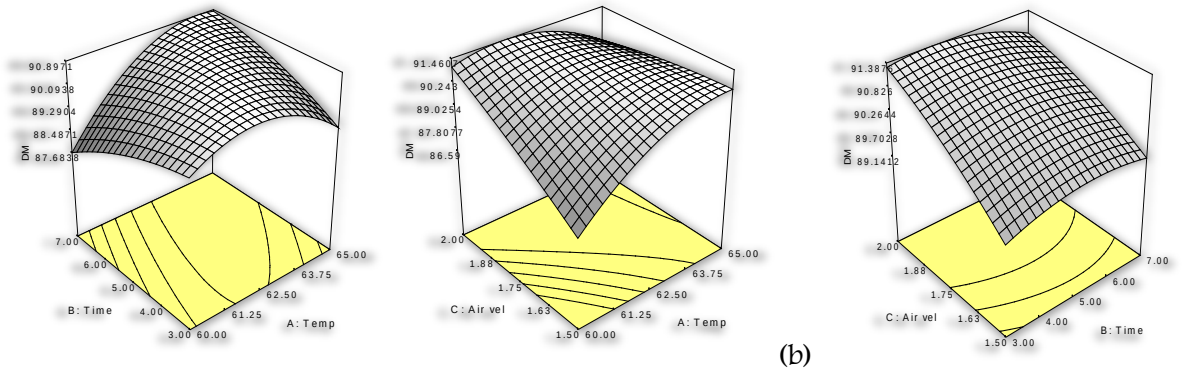
— Effect of drying condition on dry matter content

The dry matter of dried turmeric rhizome is influenced by the drying conditions on the response surface plot as shown in Figure 3a – c. Table 4 shows the ANOVA result for the dry matter by response surface second order polynomial model (equation 2). As shown in table 4 and Figure 3a – c. The effect of increasing temperature lowers the dry matter of dried turmeric significantly.

Table 4. ANOVA for the dry matter by response surface quadratic model

Source	Coefficient estimate	Sum of Squares	DF	Mean Square	F Value	Prob> F
Model	90.632	13.66145	9	1.517938	5.373376	0.0267*
A	0.61875	2.041875	1	2.041875	7.228068	0.0361*
B	–0.0475	0.01805	1	0.01805	0.063896	0.8089**
C	0.88625	4.189008	1	4.189008	14.82874	0.0085*
A^2	–1.03225	3.5518	1	3.5518	12.57308	0.0121*
B^2	–0.28975	0.27985	1	0.27985	0.990647	0.3580**
C^2	–0.17725	0.104725	1	0.104725	0.370719	0.5649**
AB	0.96	3.6864	1	3.6864	13.04955	0.0112*
AC	–1.3275	3.524513	1	3.524513	12.47648	0.0123*
BC	–0.185	0.1369	1	0.1369	0.484615	0.5124**

* Significant; ** Not significant; lack of fit is not significant at P > 0.05.



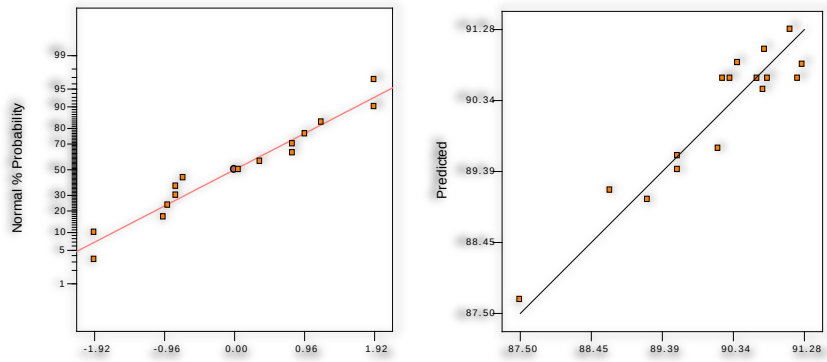
(a) (b) (c)

Figure 3: The effects of (a) temperature and time, (b) temperature and air velocity (c) air velocity and time on response surface plots of the DM

3a–c revealed the effect of temperature, time and air velocity on the dry matter (DM) of dried turmeric rhizome. It shows that increase in the temperature and time of the drying system leads to a decrease in the dry matter of the rhizome while an increase in the air in flow into the system leads to an increase in the dry matter of the turmeric

$$Y_{DM} = 90.632 + 0.61875A - 0.0475B + 0.88625C - 1.03225A^2 - 0.28975B^2 - 0.17725C^2 + 0.96AB - 1.3275AC - 185BC. \ (R^2 = 0.8896) \quad (3)$$

The values of dry matter obtained in this experiment are in the range of 87.5 – 91.2mg/100g for the dried turmeric slice at 40 – 65°C. The estimated coefficient determination ($R^2 = 0.8896$) of the model shows better prediction agreement between the experiments and motivates values of the dry matter content. The normal probability plot of the dry matter content studentized residuals (Figure 4a) and predicted versus actual dry matter plot (Figure 4b) further checked the suitability of the model as displayed in Figure 3a – c.



(a) (b)

Figure. 4:(a) Normal probability plot of the DM residuals. (b) Predicted versus Actual DM of the dried turmeric samples

Effect of drying condition on the ash content

The ash content of dried turmeric rhizome is slightly influenced by the drying conditions on the response surface plot as shown in Figure 5a – c. Table 5 shows the ANOVA result for the ash content by response surface second order polynomial model (equation 3). As shown in table 5 and Figure 5a – c. The effect of increasing temperature slightly lowers the ash content of dried turmeric significantly.

Table 5. ANOVA for the ash content by response surface quadratic model

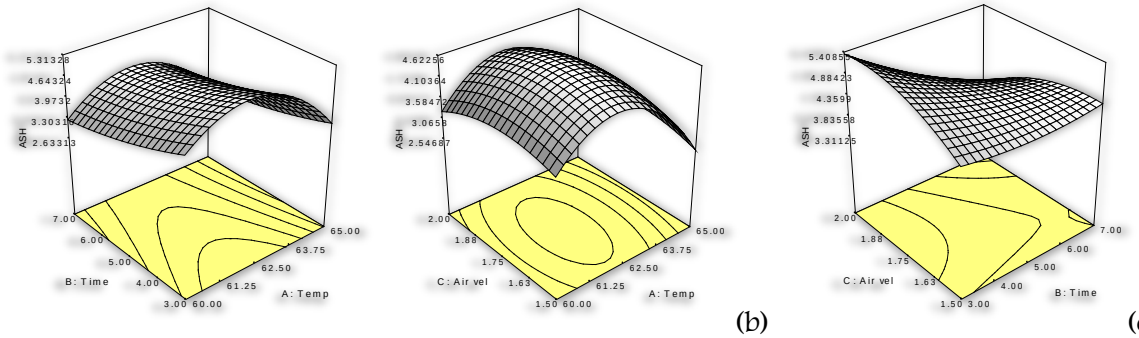
Source	Coefficient estimate	Sum of Squares	DF	Mean Square	F Value	Prob> F
Model	4.59	10.4529	9	1.161434	1.68812	0.3230**
A	–0.77083	2.852083	1	2.852083	4.145445	0.1114**
B	–0.34083	0.557603	1	0.557603	0.810465	0.4189**
C	–0.6075	0.98415	1	0.98415	1.430442	0.2977**
A^2	–1.45917	6.387502	1	6.387502	9.284104	0.0381*
B^2	0.334167	0.335002	1	0.335002	0.486919	0.5237**
C^2	–0.9025	1.629013	1	1.629013	2.367736	0.1987**
AB	0.095	0.0361	1	0.0361	0.052471	0.8301**
AC	–0.66667	0.761905	1	0.761905	1.107413	0.3520**
BC	–0.13167	0.029719	1	0.029719	0.043196	0.8455**

* Significant; ** Not significant; lack of fit is not significant at P > 0.05.

Subsequently, an increase in air velocity decreases the ash content significantly. However, there is significant increment in the ash content as sample thickness was increased.

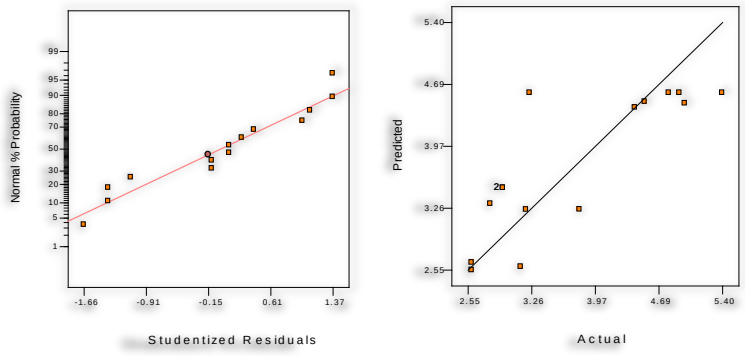
$$Y_{Ash} = 4.59 + 0.77083A - 0.34083B - 0.6075C - 1.45917A^2 + 0.334167B^2 - 0.9025C^2 + 0.095AB - 0.66667AC - 0.13167BC. \ (R^2 = 0.6773) \quad (4)$$

For 2mm dried turmeric slice at 65°C, a slight change in the total ash content was observed with the aid of a proximate analysis. The values of ash content obtained in this experiment are in the range of 2.48 – 5.40mg (100mg dry matter for the dried turmeric slice at 40 – 65°C. The total coefficient of determination of the model show good prediction agreement between the experiment and stimulated values of the ash content. The normal probability plot of the ash content studentized residuals (Figure 4a) and the predicted versus actual ash content plot (Figure 4b) further indicates the sustainability model to investigate the content of dried turmeric.



(a) (b) (c)

Figure 5: The effects of (a) temperature and time, (b) temperature and air velocity (c) air velocity and time on response surface plots of the Ash content



(a) (b)

Figure 6: (a) Normal probability plot of the Ash content residuals. (b) Predicted versus Actual Ash content of the dried turmeric samples

5a–c depicts the effect of temperature, time and air velocity on the ash content of dried turmeric rhizome. The result shows that increasing the drying temperature, time and air velocity of the system leads to a decrease in the ash content of the dried rhizome.

— Effect of drying condition on the crude fibre

The crude fibre of dried turmeric rhizome is influenced by the dry conditions in the response surface plot as shown in Figure 7a – c. Table 6 shows the ANOVA result for the crude fibre by response surface second order polynomial model (equation 4.4).

Table 6: ANOVA for the crude fibre by response surface 2FImodel

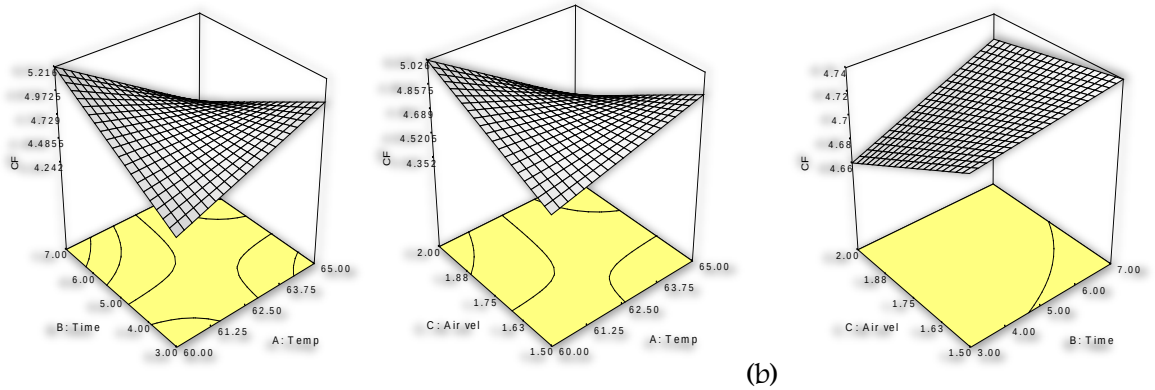
Source	Coefficient Estimate	Sum of Squares	DF	Mean Square	F Value	Prob> F
Model	4.71	0.718572	6	0.119762	3.811162	0.0818**
A	–0.095	0.016164	1	0.016164	0.51439	0.5053**
B	0.019	0.000647	1	0.000647	0.020576	0.8915**
C	–0.021	0.00079	1	0.00079	0.025135	0.8802**
AB	–0.392	0.209542	1	0.209542	6.66821	0.0493*
AC	–0.242	0.07986	1	0.07986	2.54137	0.1718**
BC	0.01	0.000136	1	0.000136	0.004339	0.9500**

* Significant; ** Not significant; lack of fit is not significant at $P > 0.05$.

As shown in table 4.5 and Figure 7a – c. The main effect of increased in temperature on crude fibre in the temperature range is very significant. Rather crude fibre is affected by air velocity. However, there is no significant increment in the crude fibre as the thickness is increased.

$$Y_{CF} = 4.71 - 0.095A + 0.019B - 0.021C - 0.392AB - 0.242AC + 0.01BC \ (R^2 = 0.8206) \quad (5)$$

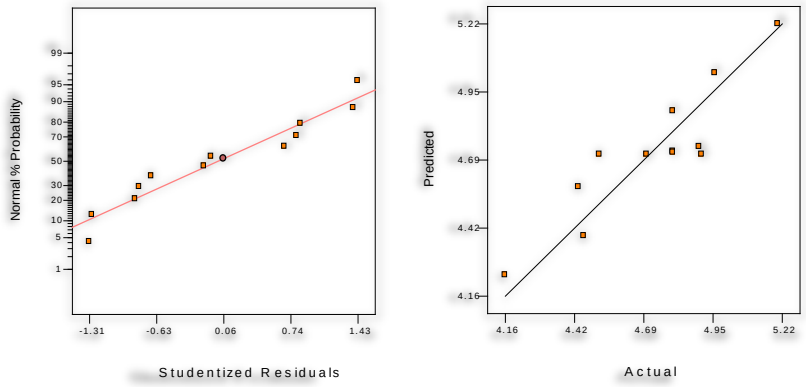
[17] studied crude fiber content and deduced that increase in drying temperature reduces the crude fibre for a sample thickness of 2mm. The values of crude fiber obtained in this experiment are in the range of 4.16 – 5.26mg/100g dry matter for the dried turmeric slice at 40 – 65°C. The total coefficient of determination (R^2 = 0.8206) of the model indicate good prediction agreement between the experiment and motivated values of the crude fibre. The normal probability plot of the crude fibre studentized residuals (Figure. 8a) and the predicted versus actual crude fibre plot (Figure 8b) further shows eligible model to steer the crude fibre of dried turmeric.



(a) (b) (c)

Figure. 7: The effects of (a) temperature and time, (b) temperature and air velocity (c) air velocity and time on response surface plots of the crude fibre

7a–c shows the effects of temperature, time and air velocity on the crude fibre of dried turmeric rhizome. It was observed that increase in the drying temperature, time and air velocity of the drying system leads to an increase in the crude fibre of the rhizome



(a) (b)

Figure. 8: (a) Normal probability plot of the crude fibre residuals. (b) Predicted versus crude fibre of the dried turmeric samples

Effect of drying condition on fat content

The fat content of dried turmeric rhizome is slightly influenced by the dry conditions in the response surface plot as shown in Figure 9a – c. Table 7 shows the ANOVA result for the fat content by response surface second order polynomial model (equation 6).

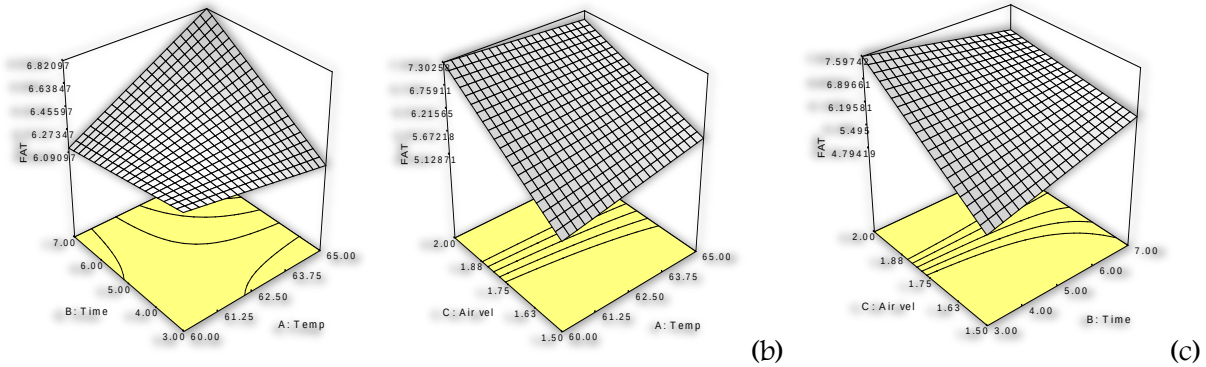
Table 7: ANOVA for the fat content by response surface 2FImodel

Source	Coefficient Estimate	Sum of Squares	DF	Mean Square	FValue	Prob> F
Model	6.335806	3.201103	6	0.533517	10.8927	0.0096*
A	0.120161	0.082634	1	0.082634	1.687119	0.2507**
B	0.14	0.0784	1	0.0784	1.600674	0.2616**
C	0.861613	2.422493	1	2.422493	49.45947	0.0009*
AB	0.225	0.2025	1	0.2025	4.134395	0.0977**
AC	–0.22532	0.113093	1	0.113093	2.308994	0.1891**
BC	–0.54	0.3888	1	0.3888	7.938038	0.0372*

* Significant; ** Not significant; lack of fit is not significant at $P > 0.05$.

As seen in table 4.6 and Figure 4.9a – c. The effect of increase in temperature on fat content is significant, rather little effect of air velocity in the fat content is significant. Hence no much increment in the fat content as sample thickness was increased.

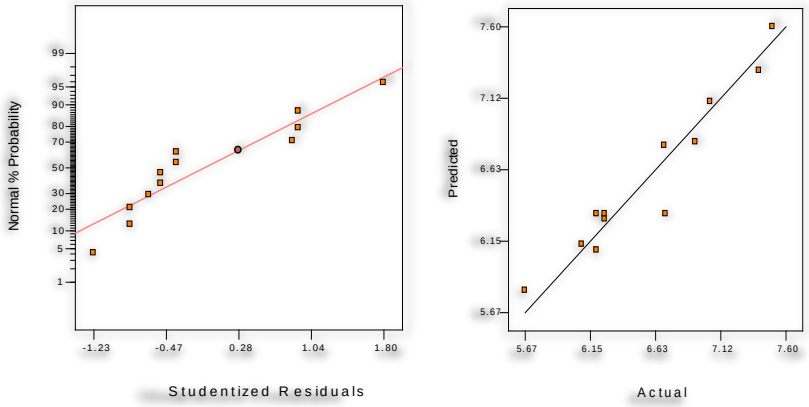
$$Y_{FC} = 6.335806 + 0.120161A + 0.14B + 0.861613C + 0.225AB - 0.22537AC - 0.54BC \ (R^2 = 0.9289) \quad (6)$$



(a) (b) (c)

Figure 9: The effects of (a) temperature and time, (b) temperature and air velocity (c) air velocity and time on response surface plots of the fat content

9a–c reveals the effects of temperature, time and inflow of air on the fat content of the dried turmeric. Increase in the fat content was observed when the drying temperature, time and air velocity was increased simultaneously.



(a) (b)

Figure 10. (a) Normal probability plot of the fat content residuals. (b) Predicted versus fat content of the dried turmeric samples

[18] studied the effect of temperature in fat content and deduced that increase in drying temperature significantly decrease the fat content of turmeric. The values of fat content obtained in this experiment are in the range of 4.9 – 7.6mg/100g dry matter for the dried turmeric slice at 40°C – 65°C. The summation coefficient determination ($R^2 = 0.9289$) of the model shows good prediction agreement between the experiment and the stimulated values of the fat content. The normal probability plot of the fat content studentized residual (Figure 10a) and the predicted versus actual fat content plot (Figure 10b) further shows eligible model to steer the fat content of dried samples.

— Effect of drying condition on nitrogen

The nitrogen of dried turmeric rhizome is slightly influenced by the drying condition in the response surface plot as shown in Figure 11a – c. Table 8 shows the ANOVA result for the nitrogen response surface second order polynomial model (equation 7).

Table 8: ANOVA for the nitrogen content by response surface quadratic model

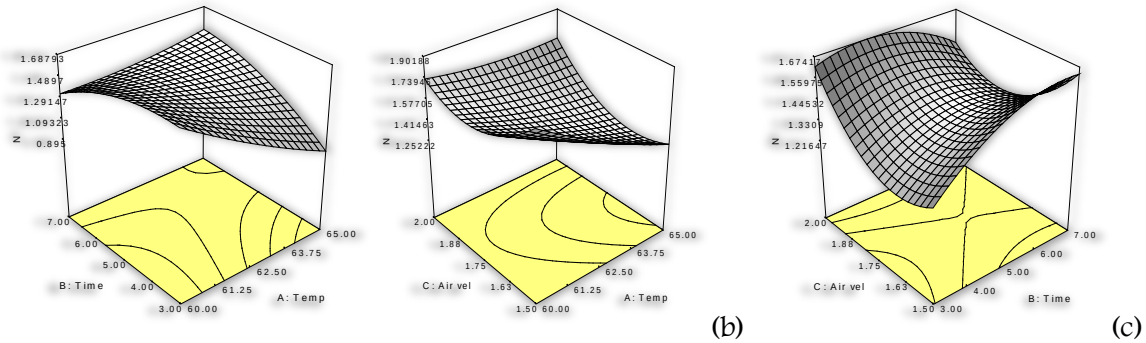
Source	Estimate	Sum of Squares	DF	Mean Square	F–Value	Prob> F
Model	1.416	0.455655	9	0.050628	3.981845	0.0533**
A	–0.16313	0.141919	1	0.141919	11.1617	0.0156*
B	0.054375	0.015769	1	0.015769	1.240189	0.3080**
C	0.04625	0.017113	1	0.017113	1.345873	0.2901**
A^2	0.037625	0.004719	1	0.004719	0.371127	0.5647**
B^2	–0.10988	0.040242	1	0.040242	3.164953	0.1255**
C^2	0.201375	0.135173	1	0.135173	10.63116	0.0172*
AB	0.23125	0.106953	1	0.106953	8.411709	0.0273*
AC	0.13	0.0676	1	0.0676	5.316642	0.0606**
BC	–0.1225	0.060025	1	0.060025	4.72088	0.0728**

* Significant; ** Not significant; lack of fit is not significant at $P > 0.05$.

As shown in table 7 and Figure 11a – c, effect of increasing temperature slightly influenced the nitrogen content of dried turmeric rhizome significantly. Also an increase in air velocity slightly decrease the nitrogen content. However, there is no significant increment in the nitrogen content as sample drying time increases.

$$Y_{NC} = 1.416 - 0.16313A + 0.054375B + 0.04625C + 0.037625A^2 - 0.10988B^2 + 0.201375C^2 + 0.23125AB + 0.13AC - 0.1225BC (R^2 = 0.8566) \quad (7)$$

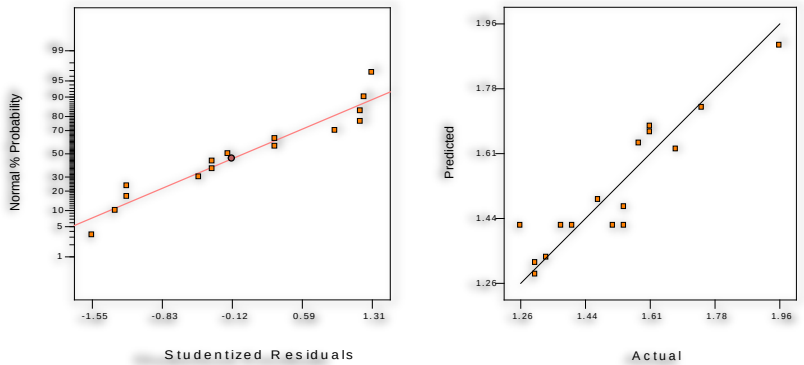
For 2mm dried turmeric rhizome at 65°C, a little change in the total nitrogen content was observed. The value of nitrogen content obtained in this experiment are in the range of 1.26 – 1.96mg/100g dry matter for the dried turmeric slice at 40e°C – 65°C. The estimate coefficient determination (R^2 = 0.8566) of the model shows good prediction agreement between the experiment and the estimated values of nitrogen content.



(a) (b) (c)

Figure 11: The effects of (a) temperature and time, (b) temperature and air velocity (c) air velocity and time on response surface plots of the nitrogen content

11a–c depicts the effect of temperature, time and air velocity on the nitrogen content of dried turmeric rhizome. The result showed that increase in the drying temperature and time results to a decrease in the nitrogen content of the turmeric while increase in the air velocity leads to a subsequent increase in the nitrogen content of the turmeric.



(a) (b)

Figure. 12: (a) Normal probability plot of the nitrogen content residuals. (b) Predicted versus nitrogen content of the dried turmeric samples

The normal probability plot of the nitrogen content studentized residual (Figure 12a) and the predicted versus actual nitrogen content plot (Figure 12b) further shows suitability model to navigate the nitrogen content of dried turmeric.

—Effect of drying condition on crude protein

The crude protein of dried turmeric rhizome is influenced by the drying condition in the response surface plot as shown in Figure 4.13a – c. Table 9 shows the ANOVA result for the crude protein response surface second order polynomial model (equation 4.7).

Table 9: ANOVA for the crude protein by response surface quadratic model

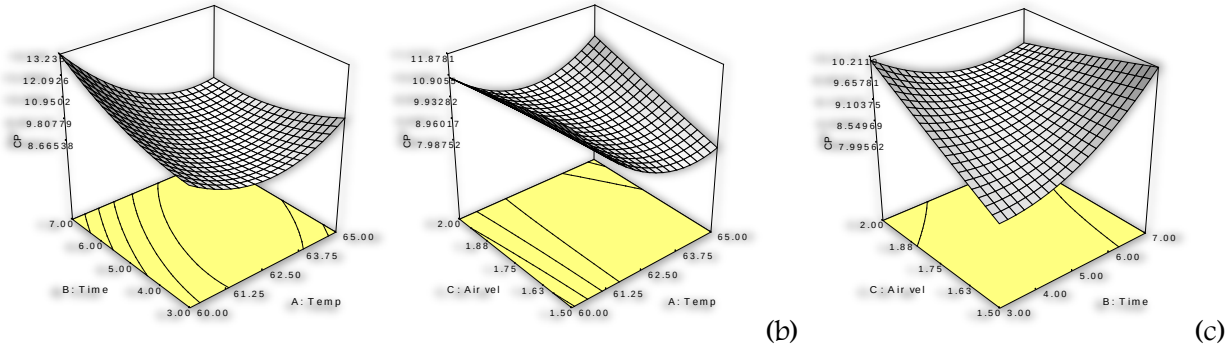
Source	Estimate	Sum of Squares	DF	Mean Square	FValue	Prob> F
Model	8.84	17.47883	9	1.942092	3.886298	0.0563**
A	−1.02438	5.596502	1	5.596502	11.19909	0.0155*
B	0.343125	0.627919	1	0.627919	1.256521	0.3052**
C	0.30125	0.726013	1	0.726013	1.452815	0.2735**
A^2	1.474375	7.245939	1	7.245939	14.49976	0.0089*
B^2	0.541875	0.978762	1	0.978762	1.958588	0.2112**
C^2	0.023125	0.001783	1	0.001783	0.003567	0.9543**
AB	−1.01125	2.045253	1	2.045253	4.092732	0.0895**
AC	0.8175	2.673225	1	2.673225	5.349359	0.0600**
BC	−0.765	2.3409	1	2.3409	4.684347	0.0736**

* Significant; ** Not significant; lack of fit is not significant at $P > 0.05$.

As shown in table 9 and Figure 13a – c, the effect of increasing temperature and air velocity influences the crude protein of dried turmeric rhizome significantly

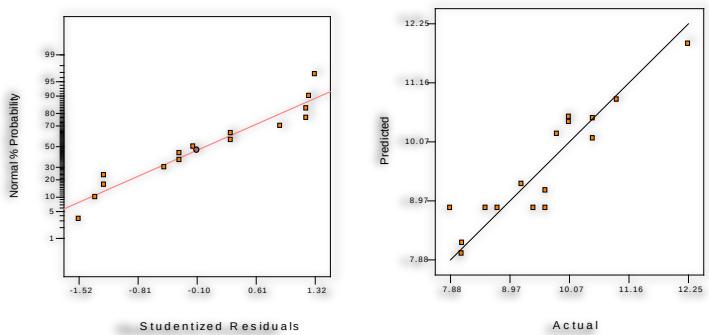
$$Y_{CP} = 8.84 - 1.02438A + 0.343125B + 0.30125C + 1.474375A^2 + 0.5 - 41875B^2 + 0.023125C^2 - 1.01125AB + 0.8175AC - 0.765BC \quad (R^2 = 0.8536) \quad (8)$$

Effect of drying temperature in crude protein and deduced that increase in drying temperature significantly decrease the crude protein of turmeric sample. The values of crude protein obtained in this experiment are in the range of 7.88 – 10.5mg/100g dry matter for the dried turmeric slice at 40°C – 65°C. The estimated coefficient determination ($R^2 = 0.8536$) of the model shows perfect prediction agreement between the experiment and the estimated values of crude protein.



(a) (b) (c)

Figure 13: The effects of (a) temperature and time, (b) temperature and air velocity (c) air velocity and time on response surface plots of the crude protein



(a) (b)

Figure 14.(a) Normal probability plot of the crude protein residuals. (b) Predicted versus crude protein of the dried turmeric samples

13a–c describes the effect of temperature, time and air velocity on the crude protein of dried turmeric rhizome. It was observed that the drying temperature has little or no effect on the crude

protein but increase in the drying time leads to an increase in the crude protein of the dried turmeric. Also increase in the air inflow in to the drying system leads to a decrease in the crude protein content of the rhizome.

The normal probability plot of the crude protein studentized residual (Figure 14a) and the predicted versus actual crude protein plot (Figure 14b) further check the suitability of the model are displayed in Figure 14a and b.

—Effect of drying condition on carbohydrate

The carbohydrate of dried turmeric rhizome is slightly influenced by the drying conditions in the response surface plot as shown in Figure 15a – c. Table 9 shows the ANOVA result for the carbohydrate content response surface second order polynomial model (equation 9).

Table 9: ANOVA for the carbohydrate content by response surface 2FImodel

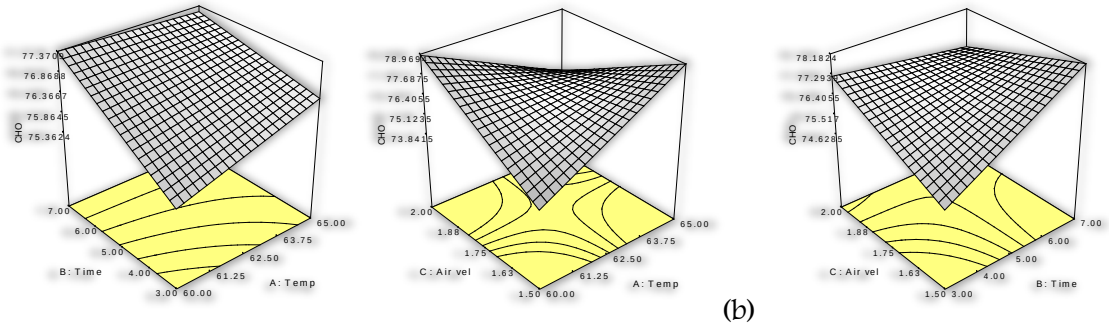
Source	Estimate	Sum of Squares	DF	Mean Square	FValue	Prob> F
Model	76.61019	21.42053	6	3.570088	2.723209	0.1757**
A	0.243519	0.346191	1	0.346191	0.264069	0.6344**
B	0.686759	2.36916	1	2.36916	1.807159	0.2500**
C	0.204722	0.143696	1	0.143696	0.109609	0.7572**
AB	–0.3175	0.403225	1	0.403225	0.307574	0.6087**
AC	–2.32046	12.373	1	12.373	9.437941	0.0372*
BC	–1.09019	1.887624	1	1.887624	1.439851	0.2964**

* Significant; ** Not significant; lack of fit is not significant at $P > 0.05$.

As shown in table 4.9 and Figure 4.15a – c, the effect of increasing temperature and air velocity slightly influenced the carbohydrate content of dried turmeric rhizome significantly.

$$Y_{CHO} = 76.61019 + 0.243519A + 0.686759B + 0.204722C - 0.3175AB - 2.32046AC - 1.09019BC \quad (R^2 = 0.8033) \quad (9)$$

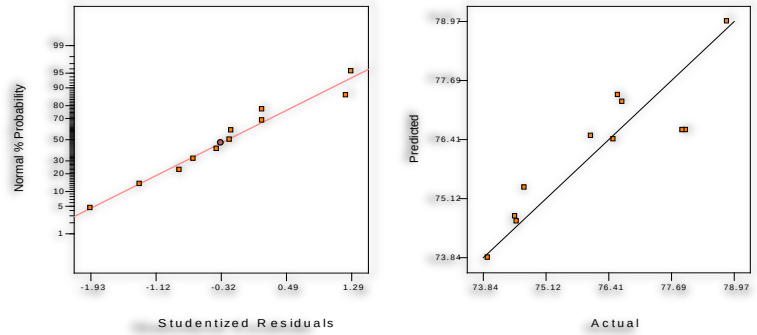
[19] studied the effect of temperature and deduced that fresh sample contain (86.08%) carbohydrate but after it is oven dried it decreases to 80.19% significantly. The values of carbohydrate obtained in this experiment ranged from 73.5 – 77.99mg/100g dry matter for the dried turmeric slice at 40^{0}C – 65^{0}C. The estimated coefficient determination (R^2 = 0.8033) of the model shows good prediction agreement between the experiment and the motivated values of the carbohydrate content.



(a) (b) (c)

Figure 15: The effects of (a) temperature and time, (b) temperature and air velocity (c) air velocity and time on response surface plots of the carbohydrate content

15a–c illustrates the effect of temperature, time and air velocity on the carbohydrate content of dried turmeric rhizome. The result reveals that increase in the drying temperature, air velocity and time of the system leads to an increase in the carbohydrate content of the rhizome.



(a) (b)

Figure 16:(a) Normal probability plot of the carbohydrate content residuals. (b) Predicted versus carbohydrate content of the dried turmeric samples

The normal probability plot of the carbohydrate content studentized residual and the predicted versus actual carbohydrate content plot further check the eligibility of the model as displayed in Figure. 16a and b.

OPTIMIZATION OF DRYING CONDITIONS

Optimum drying conditions for drying of turmeric rhizomes in tray dryer were obtained to achieve minimum moisture content, ash content, fat content, crude protein, dry matter, nitrogen, crude fibre, carbohydrate. The drying conditions selected for optimization were temperature from 60C to 65C, drying time from 3 hours to 7 hours and air velocity 1.5 to2.0 mm. optimization was done using desirability function and highest importance was given to the moisture content as this is one of important parameters, which will decide the application of these dried turmeric, desirability of 0.807 was obtained. For the other solutions the desirability was lower, therefore, they were not included. The values of drying parameters at optimum condition were drying temperature of 60.14C, drying time of 3hours and air velocity 2.0 m/s. The corresponding values of moisture content, crude fibre, crude protein, fat content, ash content, nitrogen, dry matter, carbohydrate were 8.82373%, 4.60806%, 10.6833%, 7.90919%, 4.62878%, 1.90507%, 91.9391%, 78.8798% respectively.

4. CONCLUSIONS

The proximate composition of dried turmeric rhizome was optimized in this study. The effect of three drying condition (temperature, air velocity, time) on the response variables (moisture content, crude protein, crude fibre, carbohydrate, drying matter, fat, ash, nitrogen) of dried turmeric were investigated. The prediction of the desirability model based on 95% confidence in the range of the independent variables gave optimal drying condition of 60.14°C, 3 hours and 2.0m/s for air temperature, air velocity and time. At this optimum condition, the respective values of the moisture content, ash, fat, crude fibre, crude protein, drying matter, nitrogen, carbohydrate were found to be 8.82373%, 91.9391%, 4.62878%, 4.60806%,7.90919%, 10.6833%,78.8798% respectively. The information from this work suggest that drying of the turmeric rhizome have little or no effect on the nutritional properties of the rhizome, hence preserves and extends the shelf life of the plant.

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