OPTIMIZATION OF DRYER PROCESS PARAMETERS FOR IVY GOURD DRYING USING RESPONSE SURFACE METHODOLOGY

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The current research examines drying process parameters for ivy gourd slices since it is a good source of iron, vitamin C, protein, and fibre. The considerable effect on drying of ivy gourd using different tray perforations like oval, circular, and hexagonal at different process parameters, namely air temperature (40, 50 and 60°C), air velocity (0.5, 1 and 1.5m/s), time variation (20, 30 and 40min) and thickness of slice (2, 4 and 6mm). On experimentation, the optimum conditions were found in oval tray perforation at drying temperature 60°C, slice thickness 2mm, drying time 20min and air velocity 0.5m/s. At these optimum conditions, Moisture Content (MC) was found to be 1.76. Additionally, Response Surface Methodology (RSM) is utilized to optimize drying parameters on MC. Verification of these experimental values with the empirical model is assessed with the help of correlation coefficient(R^2) which was estimated to be 0.993. A significant effect of drying vegetables can be seen in their nutritional content. From the performed analysis an increased nutrition retention was observed.

Key words: *Hot air oven drying, Drying parameters, Moisture content, Optimization, Response Surface Methodology.*

1. Introduction

One of the most popular methods for preserving agricultural products like fruits and vegetables is drying. It decreases the amount of water content, significantly reducing the chance of microbial growth and undesirable chemical reactions leading to increased shelf life [1]. Simultaneous actions of heat and mass transfer throughout the complex unit of action drying must be ensured especially during transitory conditions [2]. Hot air drying and natural drying (in the sun or shade) are the two most prominent drying techniques due to their cost effectiveness, out of which natural drying has a few limitations like high weather dependence, high chances of contamination by surroundings, longer drying period and many more [3]. Therefore, the technique of hot air drying (cost-effective) is sought out as a solution to the above-mentioned limitations, also ensuring hygiene and consistency during the process of drying.

Convective hot air-drying methodology ensures the qualities of fruits and vegetables and has been the subject of several investigations by researchers: seedless grapes [4], Sichuan pepper [5], green microalgae [6], potato strips [7], cranberries [8], green peas [9], savory leaves [10] and carrots [11]. When compared with low production, the inefficiency in preserving food supplies have been the major reason for developing countries to face food scarcity. Inefficient and uneconomical preservation techniques have resulted in partial utilization of medicinal and therapeutic benefits of vegetables [12]. Although being a storehouse of many nutraceutical properties, ivy gourd remains to be undertreated. India is found to be one of the major producers of ivy gourd (*Coccinia grandis*), a tropical plant belonging to the pumpkin family [13]. They contain chemicals which help in reducing blood sugar levels, healing skin wounds, reducing swelling (inflammation) and rebuilding skin tissues [14]. Even though having a high amount of medicinal, nutritional and food value, there seems to be minimum research work on ivy gourd drying. The relation between drying efficiency, slice thickness, drying time and drying temperature during the drying process is not known so far. Being a collection of statistical and mathematical techniques, RSM explains how test variables affect treatment results [15,16]. The above-stated technique depends on fitting of an experimental set of data to a polynomial equation. They are used in determining the interrelationships among test variables. Moreover, they are utilized in addressing the cumulative impact of all test factors for any response. The main intent of RSM is to simultaneously optimize the different levels of process variables in order to obtain the best system performance [17]. Vegetable drying has a profound effect on its nutrition content. This is mainly influenced by drying temperature, storage methods and its pre-treatment methods [18]. Reducing the drying time and oxygen concentration along with maintaining a minimal temperature minimizes nutrition losses.

The following research gap motivates to explore more on the optimization of hot air dryer to make their outcomes reachable to researchers and industrialists. Hence the present study focuses on using RSM as a tool for enhancing factors like processing conditions, air temperature, velocity of air, time variation, thickness of slice and tray perforation to obtain desired samples of ivy gourd with minimum MC. The main objectives of the proposed study are mentioned below:

- To develop a hot air oven dryer with different perforated trays for drying agricultural food products.
- Conduction of experimental analysis on the developed hot air oven dryer with many input processing parameters to find optimum ivy gourd MC.
- Utilization of RSM approach to optimize the process parameters of the dryer to dry ivy gourd.
- To carry out the analysis of nutritional retention for dried ivy gourd slices.

2. Materials and methods

2.1. Experimental setup

Hot air oven dryer proposed in this study features a four-tray setup. It is designed to operate based on the principles of convective force, ensuring efficient drying through the movement of hot air. This setup includes a vent at the top to facilitate air circulation. Additionally, it is equipped with a solar panel and battery system, providing a sustainable power supply to the dryer. This combination of convective drying and renewable energy makes the setup environmentally friendly and energy-efficient. The effective air circulation chamber is made up of food grade Stainless Steel (SS) 304 having corresponding length, breadth and height of the chamber as 360 mm, 400 mm and 360 mm. The experimental setup's schematic representation is presented in Fig. 1. The trays are also made up of food-graded SS 304, where the size of each tray is about 350 mm in length and breadth with a thickness of 1.5 mm. Trays are placed on top of one another separated by a distance of 70 mm. Different tray perforations like oval, circular, and hexagonal used in this research are shown in Fig. 2. The major and minor axis of the oval perforation in a tray is 7 mm and 3.6 mm respectively and the area is found to be 79.17 mm². The circular perforation tray has a diameter of a circle of 10 mm and its area is found to be 78.54 mm². Finally, the hexagonal tray has the side of a hexagon as 5.5 mm and the area is calculated as 78.59 mm². The surface area of the perforation in the different trays is maintained in such a way approximately equal to 79 mm² for comparative analysis. The blades of the fan are designed in a way to allow even air circulation throughout the chamber. The experiment was performed at different temperatures of drying like 40, 50 and 60 °C, air velocities like 0.5, 1 and 1.5 m/s and time variations of 20, 30 and 40 min. These ranges were selected to cover the common conditions used in drying processes while also allowing for the exploration of optimal drying parameters specific to ivy gourd. For measuring temperature, a digital thermometer with an accuracy of ±1°C is used. Air velocity was measured using an anemometer with an accuracy of ±0.5 m/s to ensure consistent airflow during the drying process. A relative humidity range throughout the drying an experiment was recorded between 50 and 60 %. The MC of the samples during experiment is expressed in Eq. (1) [19].

$$MC = \frac{m_a - m_b}{m_a} X\ 100 \qquad (1)$$

Where, m_a represents mass of fresh sample and m_b represents mass of dried sample.

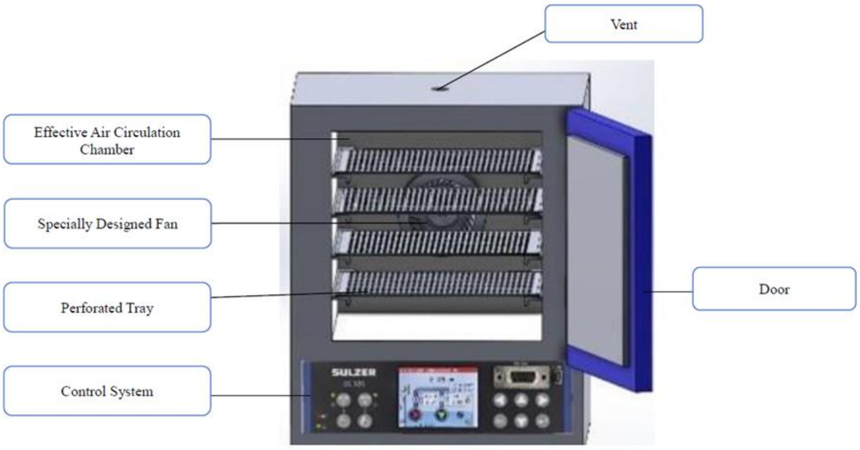
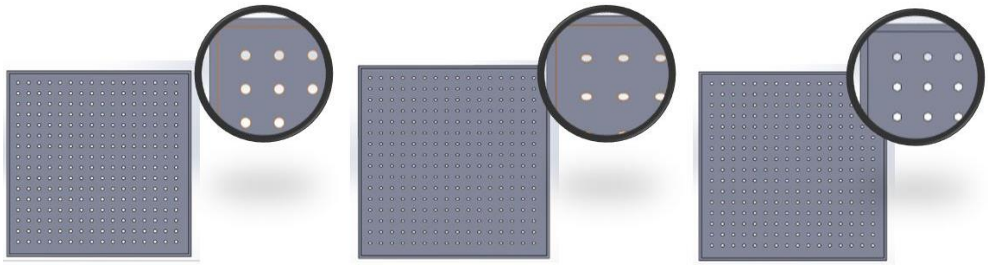


Figure 1. Experimental setup's schematic representation



Circular Oval Hexagon

Figure 2. Tray perforations

2.2. Sample Preparation

Fresh samples of ivy gourd were collected and washed thoroughly to remove all sorts of dust and debris from it. Around 100 kg of ivy gourd was used for experimentation. The samples were selected based on physical appearance like shape, size and color. The samples used for the experiment are then sliced evenly using a mechanical slicing machine (Nemco 55200AN-6 Easy Vegetable Slicer) at different thickness like (2, 4 and 6 mm) as shown in Fig. 3. The samples are prepared in accordance with the general guidelines for vegetable drying found in Codex Alimentarius Standard CAC/RCP 8-1976 (Recommended International Code of Practice for the Processing and Handling of Dried Fruits and Vegetables). Fresh samples were collected for MC analysis. The initial weight of the fresh samples was measured before drying. This weight represents the sample's weight with all the moisture intact. The samples were placed in a laboratory oven and heated at a specific temperature for a designated period, ensuring all moisture was evaporated. The drying process is performed until the sample reaches a constant weight, meaning that no more moisture is being lost. After drying, the samples were removed from the oven and allowed to cool in a desiccator. The final weight of the dried sample was then recorded. This represents the sample's dry weight (completely moisture-free). To ensure accuracy, the process was repeated for multiple samples. The average of the initial and final values of the MC from different trials was then calculated to obtain the average initial MC for the fresh sample. After calculating the MC from different samples, the average initial MC of the fresh sample was determined to be 74% on a wet basis (w.b).

Figure 3: Ivy guard samples before drying

2.3. Uncertainty Analysis

The crucial part of the experiment is to evaluate the uncertainty values for observed and calculated variables. Quantifying the output variability imposed by input variability is the goal of uncertainty analysis [20,21]. Most often, quantification is carried out by the estimation of statistical quantities of interest such as population quantiles, mean and median. This estimation depends upon techniques of uncertainty propagation [22]. Due to the limited sample size, the estimated quantities should be made sure that they are provided with their associate confidence intervals. Therefore, as a means to evaluate the uncertainties of dependent and independent variables, a square root method as indicated by Eq. 2 is used in the study [23]. Table 1 indicates the variable's experimentation related uncertainty.

$$X = \left[\left(\frac{\partial C}{\partial m_1} m_1\right)^2 + \left(\frac{\partial C}{\partial m_2} m_2\right)^2 + \left(\frac{\partial C}{\partial m_3} m_3\right)^2 + \cdots + \left(\frac{\partial C}{\partial m_n} m_n\right)^2\right] \tag{2}$$

Where X is the uncertainty, m_n is the measured value of uncertainty and C is the calculated value of parameter.

Table 1. Uncertainties of variables during the experimentation

Parameter	Uncertainty
Mass	± 0.00025 g
Air velocity	± 0.02 m/s
Temperature	± 1^{o}C
Moisture Content	± 0.035 % w.b

2.4. Experimental design and Statistical analysis

In RSM, a 4x3 Central Composite Rotatable Design (CCRD) was successfully utilized due to its effectiveness in evaluating the interaction between multiple factors and optimizing conditions with a minimal number of experiments for analyzing individual and combined effects of temperature of drying, velocity of air, thickness of slice and drying time on the MC for obtained ivy gourd samples. Design-Expert Software Version 13 is being utilized with four factors considered at three levels [24]. Four axial points and six replications at the center points, comprising 30 experiments were employed in CCRD to determine all parameters. The values of independent variables are coded as (-1, 0, 1), where -1, 0 and 1 signifies the least, moderate and high levels respectively [25]. Statistical tools, such as Analysis of Variance (ANOVA), were employed to ensure the reliability and significance of the results. Table 2 presents variables that are independent and coded along with their corresponding code and actual levels. Equation (3) represents the response variable second-order polynomial model as follows:

$$M = \beta_0 + \sum_{i=1}^{2} \beta_i N_i + \sum_{i=1}^{2} \beta_{ii} N_i^2 + \sum_{i=1}^{2} \sum_{j=i+1}^{2} \beta_{ij} N_i N_j \tag{3}$$

Where, M = Response variable (MC, % w.b); β_0 = Constant term; $\sum_{i=1}^{2}\beta_i$ = Sum of linear term coefficients; $\sum_{i=1}^{2}\beta_{ii}$ = Sum of quadratic terms; $\sum_{i=1}^{2}\sum_{j=i+1}^{2}\beta_{ij}$ = Sum of interaction term coefficients; N_iN_j = independent variables.

The development of ANOVA included the determination of effect and regression coefficients for each linear, quadratic and interaction component. By stating p-values (Prob.>F) at a significance level of 5%, the statistical significance of each term in the polynomial was determined [26]. The generation of response surface plots along with their contour plots was made possible by means of a statistical Design-Expert tool.

Table 2. Values of independent variables along with their corresponding levels.

Variables	**Units**	**Code**	**Levels**		
			-1	**0**	**1**
Drying temperature	^{o}C	N1	40	50	60
Slice thickness	mm	N2	2	4	6
Drying time	min	N3	20	30	40
Air velocity	m/s	N4	0.5	1	1.5

2.5. Experimental Procedures

As presented in Tab. 3, the prepared samples were subjected to different treatments otherwise called experimental runs. For every treatment, a specified drying temperature (say 40, 50 and 60 ^{o}C), slice thickness (say 2, 4 and 6 mm), velocity of air (say 0.5, 1 and 1.5 m/s) and finally time variation (say 20, 30 and 40 min) are being set according to the factor combinations. For every experimental run, MC was recorded.

Table 3. Moisture content results for processed ivy gourd observed under varying drying process parameters

Run order	**Drying temperature (^{0}C)**	**Slice thickness (mm)**	**Drying time (min)**	**Air velocity (m/s)**	**Moisture Content (%)**		
					Circular tray	**Oval tray**	**Hexagonal tray**
1	-1	-1	-1	-1	2.34	2.04	8.76
2	1	-1	-1	-1	2.38	1.76	7.64
3	-1	1	-1	-1	15.86	2.84	9.52
4	1	1	-1	-1	7.01	2.93	9.33
5	0	0	0	-1	9.50	6.77	8.74
6	-1	-1	1	-1	14.41	7.32	10.23
7	1	-1	1	-1	20.39	4.41	9.72

8	-1	1	1	-1	7.97	2.24	8.22
9	1	1	1	-1	9.86	6.81	12.74
10	0	0	-1	0	11.46	4.63	10.55
11	0	-1	0	0	8.08	5.11	11.12
12	-1	0	0	0	9.52	6.32	12.64
13	0	0	0	0	12.58	5.55	8.62
14	0	0	0	0	12.46	5.32	8.23
15	0	0	0	0	12.49	5.61	8.94
16	0	0	0	0	12.35	5.74	8.28
17	0	0	0	0	12.55	5.81	8.76
18	0	0	0	0	12.66	5.77	8.82
19	1	0	0	0	14.62	7.61	12.78
20	0	1	0	0	3.02	1.96	6.03
21	0	0	1	0	13.52	3.54	16.72
22	-1	-1	-1	1	2.93	1.92	2.90
23	1	-1	-1	1	3.76	2.32	3.74
24	-1	1	-1	1	3.18	2.18	3.19
25	1	1	-1	1	3.35	2.76	3.36
26	-1	-1	1	1	3.36	2.11	3.94
27	1	-1	1	1	2.64	2.72	3.68
28	-1	1	1	1	3.10	2.16	3.94
29	1	1	1	1	2.96	2.73	2.97
30	0	0	0	1	2.66	2.28	2.68

2.6. Optimization

To obtain the MC in the ivy gourd with a minimum percentage of moisture, the graphical and numerical techniques of optimization are executed using the Design-Expert software. The traditional graphical procedure is utilized to get the lowest moisture level. The systems were represented graphically using mathematical models for prediction. In order to determine the ideal combinations for drying time, drying temperature, air velocity, and slice thickness for their drying, plots of response surface for response factors were employed.

2.7. Nutrition Analysis

Fresh and dried samples of ivy gourd (Coccinia grandis) for each tray perforation were analyzed for its best moisture reduction content. As per the AOAC (Association of Official Agricultural Chemists) in a testing center, the nutrition retention examination was carried out by performing a nutrition analysis on various parameters like retention of carbohydrate, protein, calcium, iron, vitamin C and ash content [18,27].

3. Results and discussion

The outcomes of variations in MC were examined during the drying of ivy gourd using a developed hot air oven dryer by varying drying time, velocity of air, slice thickness and drying temperature. The drying parameters were optimized using the RSM approach and the experimental results were satisfactorily fit by an equation of second order. Additionally, nutrition retention analysis has been carried out to ensure the nutrition content in the dried ivy gourd.

3.1. Experimental results on moisture content

The numerical values of MC (% w.b) were found within the range of 1.76 to 20.39. Tables 4 and 5 represents the analysis of 2FI model regression and ANOVA findings respectively. The response of model F - values was found to be 3.82 proving the model to be significant. Simultaneously the MC exposed a significant lack of fit. These results demonstrated the validity and fit of the model used to estimate the MC of dried ivy gourd. ISO 665:2000 (Oilseeds — Determination of moisture and volatile matter content) is used as a reference for determination, a critical parameter in vegetable drying processes.

Table 4. Analysis of 2FI model regression

Regression term	Values
R^2	0.7811
Adjusted values of R^2	0.5768
Predicted values of R^2	-0.5987
Precision of Adequacy	7.0434
Standard Deviation	1.25
Mean	4.04
Coefficient of Variation (%)	30.90

The R^2 was considered to be 0.7811 showing the adequacy of the model. The created model for MC effectively described and accounted for 78.11% of the total variation, according to the high value of R^2 attained for the response variable. The adequate precision value was noted to be 7.0434. The study's appropriate precision, which is greater than 4.0, indicates that the model is more reliable and precise.

Table 5. ANOVA findings for moisture content of ivy gourd

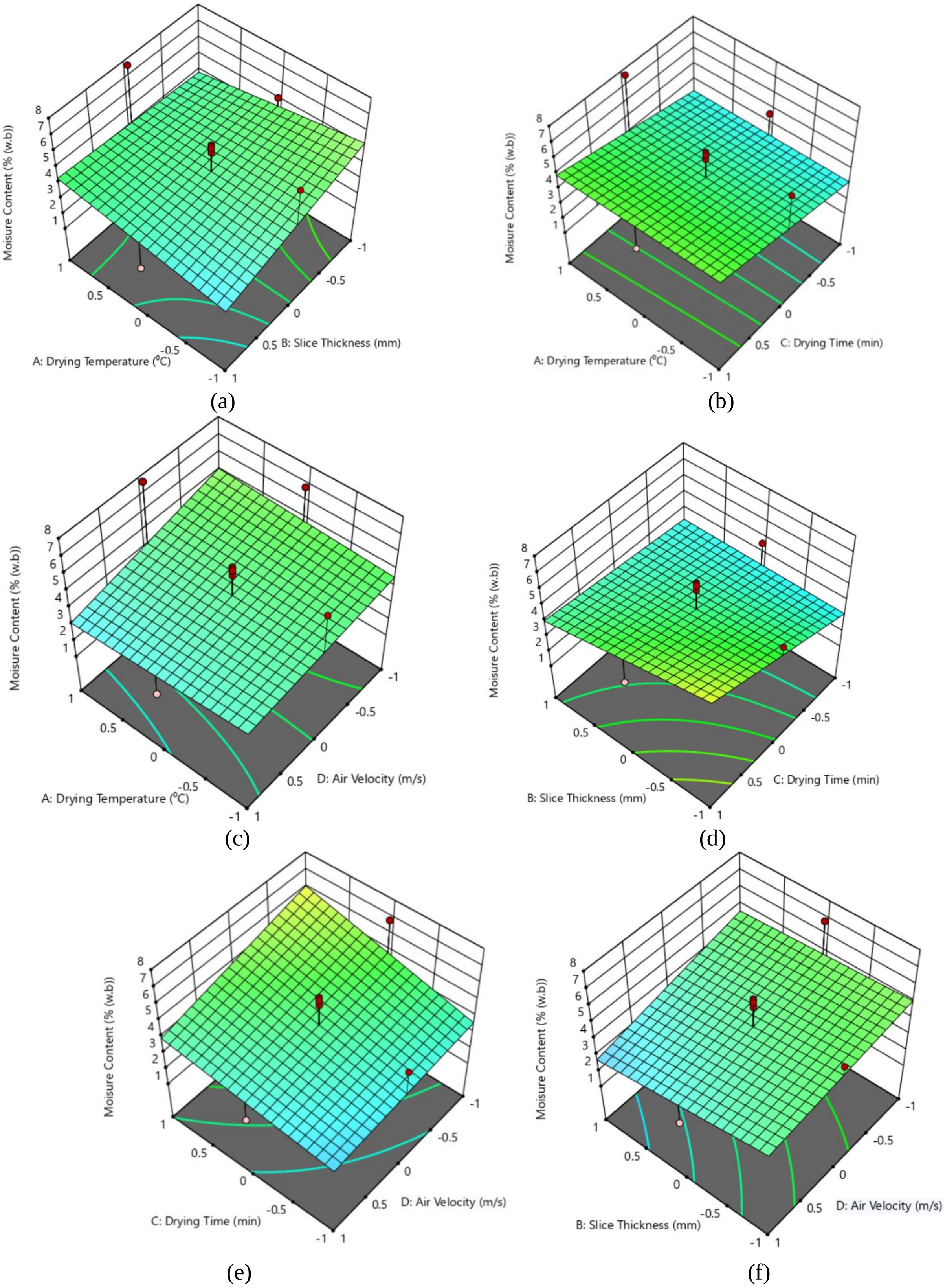
Sources	**Summation of Squares**	**DF**	**Mean Square**	**F-Value**	**p-Value**	
Model	83.51	14	5.96	3.82	0.0072	significant
A-Drying Temperature	0.4119	1	0.4119	0.2640	0.6149	
B-Slice Thickness	1.31	1	1.31	0.8407	0.3737	
C-Drying Time	8.01	1	8.01	5.13	0.0387	
D-Air Velocity	11.15	1	11.15	7.15	0.0174	
AB	4.20	1	4.20	2.69	0.1216	
AC	0.0814	1	0.0814	0.0522	0.8224	
AD	0.1004	1	0.1004	0.0644	0.8032	
BC	2.02	1	2.02	1.30	0.2729	
BD	0.0179	1	0.0179	0.0115	0.9161	
CD	4.11	1	4.11	2.63	0.1256	
A^2	6.54	1	6.54	4.19	0.0586	
B^2	8.76	1	8.76	5.61	0.0317	
C^2	4.30	1	4.30	2.76	0.1175	
D^2	1.87	1	1.87	1.20	0.2910	
Residual	23.40	15	1.56			
Lack of Fit	23.02	9	2.56	40.58	0.0001	significant
Pure Error	0.3782	6	0.0630			
Cor Total	106.91	29				

Where, A indicates drying temperature, B indicates thickness of slice, C indicates drying time and D indicates velocity of air.

3.2. Effects of process variables on moisture content during drying

The water quantity that evaporates from the sample when it is heated in any way is specified by the primary food processing criteria known as MC. Equation (4) shows the regression equation that describes how drying process factors affect MC in relation to the actual value of the variable. This method allowed us to examine the relationships between the variables and ensure the accuracy of the derived model.

$$MC = 4.14400 - 0.014625\,A - 0.460180\,B + 0.880180\,C - 0.716115\,D + 0.689996\,AB - 0.062496\,AC - 0.280828\,AD - 0.521246\,BC - 0.232078\,BD - 0.342922\,CD \tag{4}$$



(a) (b) (c) (d) (e) (f)

Figure 4. Plots of response surface for dependent variable (Moisture Content) while drying ivy gourd

The results of ANOVA show that linear terms like temperature of drying (A) and thickness of slice (B), and drying time (C), and velocity of air (D) had a significant effect on MC. From the response surface plots (Fig. 4), values of MC increased when thickness of slice and drying temperature increased whereas the same decreased with drying time. Linear positive terms of the response surface plot illustrated that rise in temperature of drying, thickness of slice, velocity of air and drying time led to an increased MC in ivy gourd. Positive interaction terms with temperature of drying and drying time, along with slice thickness and drying time, signified that raised levels led to an increase in the product's MC. The negative interaction terms with temperature of drying and slice thickness, temperature of drying and air velocity, slice thickness and air velocity and drying time and air velocity, showed that raised levels led to a decrease in the product’s MC.

The plots of the response variable (Fig. 4) were effectuated to assess how these four factors collectively affect the product’s MC while drying. Keeping the third variable as a focal point of the fitted model, response plots were obtained as a function of two variables. It is noticed from the response variable of surface plots (Fig. 4(a), 4(c) and 4(e)), that an increase in slice thickness and air velocity led to a gradual decrease in MC during the drying process. Furthermore, a rapid decrease in the MC was observed during the primary phases of drying. After that, the reduction of MC from samples of ivy gourds slowed down over a period of time, in accordance with the thickness of the product (Fig. 4(b), 4(d) and 4(f)). Finally, a decrease in moisture level was seen with drying temperature (Fig. 4(b) and 4(c)) along with drying time (Fig. 4(a), 4(d) and 4(f)) during the entire drying process. Researchers have observed similar outcomes with oven drying of Cucurbitaceae (Pumpkin family) [13,14]

3.3. Numerical optimization of drying process parameters

At an economic point of view, the criterion for variables were set in a way, where independent variables like drying temperature, thickness of slice, drying time and velocity of air were found minimal. Constraint optimization measures were taken at the least possible MC for ivy gourd samples. For every factor and response, the preferred goals have been tabulated (Tab. 6). Numerical optimization of drying parameters for ivy gourd reaches the highest desirability where the importance of ‘3’ was assigned equally to all drying variables along with their responses.

Table 6. Parameters for numerically optimizing the drying process: criteria and results

Dehydration criteria	Unit	Lower limit	Upper limit	Optimization goal	Relative Importance	Output
Drying temperature	^{0}C	40	60	Range	3	50
Slice thickness	mm	2	6	Range	3	2
Drying time	min	20	40	Range	3	20
Air velocity	m/s	0.5	1.5	Range	3	1
Moisture Content	% w.b	1.76	7.61	Minimize	3	2.271
Desirability						0.993

3.4. Model verification for drying ivy gourd

Drying experiments were carried out at an optimal drying process parameter with drying temperature 50°C, thickness of slice 2 mm, drying time 20 min and velocity of air 1 m/s in order to evaluate the model's suitability to predict its outcomes based on both experimental data and practical feasibility. Table 7 shows the predicted values of model equation along with the actual experimental value. The experimental values that were actually observed were found to be very similar to the MC predictions. From the above findings, it can be inferred that the proposed model is sufficient enough for evaluating the behavior of drying parameters in ivy gourd.

Table 7. Optimal drying process variables

Drying temperature (^{0}C)	**Slice thickness (mm)**	**Drying time (min)**	**Air velocity (m/s)**	**Predicted moisture content (% w.b)**	**Measured moisture content (% w.b)**
50	2	20	1	2.271	2.287

3.5. Quantification of nutrition values in fresh and dried ivy gourd

The product's energy content after drying reveals its carbohydrate content. Not much carbohydrate loss is analyzed during the process of drying. It is known that vegetables are rich in calcium content and the retention of calcium is dependent on temperature. So higher temperatures can cause a reduction in calcium [28]. Table 8 gives the results of the nutritional analysis. Noticeably during the drying process, there is no effect on retention of iron content. Due to the sensitivity to heat, vitamin C is influenced by two important parameters drying time and temperature. Finally, the mineral content in dried products is indicated by its ash content which is usually higher at high drying temperatures.

Table 8. Results of nutritional analysis

	Carbohydrate (g/100g)	**Protein (g/100g)**	**Calcium (g/100g)**	**Iron (g/100g)**	**Vitamin C (g/100g)**	**Ash content (g/100g)**
Fresh Sample	5	1.60	59.8	3.40	3.55	0.60
Run 1 (circular tray sample)	65.4	18.4	670	34.9	18.3	12.3
Run 2 (Oval tray sample)	63.2	19.6	495	33.6	12.7	26
Run 30 (Hexagonal tray sample)	62.3	3.8	532	34.3	12.1	13.1
Confirmation	63.8	17.3	546	35.2	13.3	13.9

Oval tray perforation was the most effective for maximum moisture loss, and the model predictions closely matched experimental data with a correlation coefficient of 0.993. Nutritional retention after drying was 95.53%.

4. Conclusions

In the present study, dust and debris-free samples of ivy gourd were collected and stored in a cold room for experimentation. The MC of these ivy gourd samples was found to be 74% on a wet basis. Four tray hot air oven dryer was used for drying of ivy gourd at different process parameters (drying temperature, slice thickness, air velocity and drying time). Three different tray perforations (oval, circular and hexagonal) were used, performing 30 experiments for each perforation. The RSM was utilized for optimizing the drying parameters of ivy gourd to improve and employ them for commercial purposes. From this study, it is concluded that drying temperature and drying time are prominent factors affecting MC in ivy gourd samples during drying and were nearly related to slice thickness and air velocity.

ANOVA has statistically significant effects on the factors relating to drying. The prediction of MC in ivy gourd is acquired by second-order polynomial model. Oval tray perforation is found to yield maximum moisture loss at optimum conditions having drying temperature as 60^{o}C, thickness of slice as 2 mm, drying time as 20 min and velocity of air as 0.5 m/s resulting in MC of 1.76 % w.b. The empirical model and experimental findings were confirmed using the correlation coefficient, which was found to be 0.993 for the proposed model. Nutrition of the ivy gourd was retained at 95.53% towards its before and after drying to a g/100g.

These optimized parameters can be used in industries commercially to enhance the drying performance of hot air oven dryers for drying agricultural products. Similar study can be employed on different sanative medicinal fruits and vegetables.

Nomenclature

M – Response variable
ma – Mass of fresh sample $[kg]$
mb – Mass of dried sample $[kg]$
β_0 – Constant term
$\sum_{i=1}^{2}\beta_i$ – Sum of linear term coefficients
$\sum_{i=1}^{2}\beta_{ii}$ – Sum of quadratic terms
$\sum_{i=1}^{2}\sum_{j=i+1}^{2}\beta_{ij}$ – Sum of interaction term coefficients
N_iN_j – Independent variables

Abbreviations

ANOVA	Analysis of Variance
CCRD	Central Composite Rotatable Design
MC	Moisture Content
RSM	Response Surface Methodology
w.b	wet basis
2FI	2 Factor Interaction

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