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Novel approach towards microwave drying of basil leaves

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Abstract
Basil is a medicinal plant and is added at the end of selected preparations, as heating destroys its flavour. The fresh herb can be kept for a short period in plastic bags under refrigerated conditions, or a longer period in the freezer. This technique of preservation of basil leaves is not affordable for farmers. Basil has a short life; generally, the senescence of leaves takes place during summer. An investigation was carried out to overcome the above-said problem of drying basil leaves. A novel method was proposed to dry basil leaves known as Intermittent and Stepwise Decreasing Microwave Power Drying (ISDMPD). The total drying time required for drying of fresh basil leaves (809.09 kg/kg dm initial moisture content) was found to be 6.25 min to achieve a final moisture content of 3.004 kg/ 100 kg dm ensuring a little change in colour with ΔE of 4.83, as compared to the colour of a fresh one.

Keywords: Basil, drying, microwave, intermittent, decremental

Introduction
Holy basil is commonly known as *Tulsi* (Hindi) and *Tulasi* (Sanskrit). It is used in ayurvedic medicine since ancient times. It belongs to the family Lamiaceae, which is indigenous in different subcontinent of India. It is an extremely valued culinary, medicinal, and aromatic herb. As it is beneficial for curing many different types of diseases and having high healing power it is mentioned as the "Elixir of Life" in Ayurveda. Nadkarni and Nadkarni (1982) [1] studied that the extract from *tulsi* leaf is beneficial for curing bronchitis, rheumatism, and pyrexia. Committee, 2016 [2] found that *Tulsi* is also used in dealing with epilepsy, cough, skin diseases, asthma, inflammation, headache, wounds, parasitic infection, etc. *Ocimum tenuiflorum* (*Ocimum sanctum* L.) is classified into two subtypes *Rama Tulsi* and *Krishna Tulsi* [3, 4]. *Ocimum gratissimum* commonly called *Vana* (wild/ forest) *tulsi*, having dark green-colored leaves [5, 6]. Animal studies and several in vitro demonstration of *tulsi* leaf showed powerful pharmacological actions like adaptogenic [7, 8], anticancer [9-11], immunomodulatory [12-14], metabolic [15, 16], anti-inflammatory [17, 18], antioxidant [19, 20], hepatoprotective [21, 22], radioprotective [23, 24], antimicrobial [25-28] and antidiabetic effects [29-31] as reviewed in previous literature [32-38].

Linalool, methyl cinnamate, eugenol, methyl eugenol are important volatiles found in various varieties of basil. The majority of findings by different researchers have revealed the destruction of these precious volatile compounds during the drying process. Nykanen and Nykanen [39] in 1987 showed that essential oil decreased up to 35% to 45% during drying of sweet basil at ambient temperature. Di Cesare *et al*. (1994; 2000; 2001; 2002; 2003) [40-44] found high retention of eucalyptol, linalool, eugenol, and methyl eugenol during microwave drying in *Ocimum basilicum* L. than air- and freeze-dried sample with blanching. The significant difference in concentrations of linalool and methyl chavicol were found in air-dried basil samples as compared to that in fresh samples, on other hand, there was an increase by 2.5 times in linalool and 1.5 times in methyl chavicol in vacuum dried samples as compared to that in air-dried samples [45]. Different studies on drying methods on volatilities of leaf [46,] and spearmint [47] also have given such reasonable inconsistency. Sedani and Pardeshi (2018) [48] studied stepwise decreasing microwave power drying of dill leaves. It was found that using a decreasing level of power, helps reduce heatstroke to dill leaves during microwave power drying.

Since basil is heat-sensitive, there is a need for a drying technique that will preserve its colour and nutritional value during the drying process. Hence, an investigation was carried out to overcome the problems that occurred during the drying process of basil leaves.

A new method was proposed to dry the basil leaves named "Intermittent and Stepwise decremental Microwave Drying of Basil leaves".

Experimental section
Materials and Method
Sample preparation
Basil leaves were collected from Dr. PDKV, Akola. The Basil leaves were washed and trimmed. The surface moisture was removed before drying.

Experimental setup and plan of an experiment for basil leaves
Experimental Setup consists of Microwave oven of IFB Company with 900W rated power (model no. 30SC4), Stopwatch for measuring laps time, and weighing balance with a precision of 0.001g. Central composite rotatable design (CCRD) was used for carrying out this experiment. In this study, two variables i.e., ON time and OFF time with range 22 s to 90 s and 15 s to 45 s, respectively, were taken. These ranges were selected on basis of preliminary trials as suggested by Sedani (2019) [49]. The experimental design was applied after the selection of the ranges. Thirteen experiments were performed with 2 variables and five levels. Experiments were randomized to minimize the effects of unexplained variability in the observed responses due to extraneous factors. The central point in the design was repeated five times to calculate the reproducibility of the method [50].

The pulse ratio [49, 51, 61] was estimated by the Eq. 1 given below,

$$\text{PR (Pulse Ratio)} = \frac{\text{ON time} + \text{OFF time}}{\text{ON time}} \quad (1)$$

Table 1: Treatment combinations for intermittent and stepwise decremental microwave power drying of basil leaves

Sr. No.	Coded values		Actual values		Response 1	Response 2
	X_1	X_2	ON time	OFF time	FMC (kg/ 100 kg dm)	ΔE
1	-1	-1	22	15	94.4499	2.77994
2	-1	1	22	41	191.764	1.00077
3	1	1	72	41	26.6442	10.9786
4	1	-1	72	15	8.11528	14.7487
5	-1.414	0	10	28	301.196	0.631903
6	1.414	0	90	28	2.71552	16.4671
7	0	-1.414	50	10	4.2781	8.25775
8	0	1.414	50	45	74.3079	2.36006
9	0	0	50	28	6.29741	3.25761
10	0	0	50	28	8.10755	4.16589
11	0	0	50	28	7.71741	3.99986
12	0	0	50	28	10.2111	4.32689
13	0	0	50	28	9.84726	3.00046

Moisture
The moisture content of the fresh and dehydrated basil was determined by the AOAC method [52]. The moisture content of the Basil was computed using the following equations,

$$\text{Moisture content (\% wb)} = \frac{M_1 - M_2}{M_1} \quad (2)$$

Where M_1 is the weight of the sample before oven drying (g), M_2 is the weight of the sample after oven drying (g). The samples were placed in Hot Air Oven. The weight M_2 was taken after allowing the samples to cool down up to atmospheric temperature, by keeping the samples in desiccators having filled with silica gel in its bottom portion. The samples were weighed using an electronic weighing balance with an accuracy of 0.001 g. The equilibrium moisture content was assumed zero for microwave oven drying [53] as removal of moisture continues with time and subsequently, the product may get burnt [54]. The moisture content (% wb) was converted into moisture (% db) as below;

$$\text{Moisture content (\% db)} = \frac{100 \times \text{moisture content (\% wb)}}{100 - \text{moisture content (\% wb)}} \quad (3)$$

Color analysis
The color (L, a, and b-value) was measured using Chromameter (CR-400). Hunter L, a, b color scales based on the Opponent-Color Theory were used for measuring color. This theory assumes that the receptors in the human eye perceive colour as the following pairs of opposites.

- L scale: Light vs. dark where a low number (0-50) indicates dark and a high number (51-100) indicates light.
- a scale: Red vs. green where a positive number indicates red and a negative number indicates green.
- b scale: Yellow vs. blue where a positive number indicates yellow and a negative number indicates blue.

The *L* value for each scale, therefore, indicates the level of light or dark, the value redness or greenness, and the *b* value yellowness or blueness. All three values are required to completely describe an object's colour. A three-dimensional representation of L, a, b colour space is shown in Fig 2 below [55].

Fig 2: Hunter scale for color measurement

$\Delta a = a_{fresh} - a^*$ (4)

$\Delta b = b_{fresh} - b^*$ (5)

$\Delta L = L_{fresh} - L^*$ (6)

$\Delta E = \sqrt{\Delta a^2 + \Delta b^2 + \Delta L^2}$ (7)

Where, ΔE = Change in color of dried sample concerning fresh sample of basil Leaves. a^*, b^*, L^* = value of dried samples.

Statistical analysis

The data were analyzed for its stepwise regression analysis in the trial version of Design-Expert 12 Software.

Results and Discussion

Effect of process parameter on final moisture content (kg/100 kg of dm) on intermittent and stepwise decreasing microwave power drying (ISDMD) of basil leaves

Values of Final Moisture Content (FMC) (kg/ 100 kg dm) during ISDMD of basil leaves at different combinations of ON time (A) and OFF time (B) are shown in Table 1. It varied between 2.715 kg/ 100 kg dm and 301.196 kg/ 100 kg dm within the combination of variables studied.

The ANOVA (Table 2) for final moisture content indicated that the model was highly significant (P<0.0001). A reasonably good fit was obtained with a high coefficient of determination (R^2 = 0.9999), which showed that the model developed was adequate for the experimental data. The lack-of-fit test was also found non-significant which indicates that the model is highly suitable to represent the experimental data. Adjusted R^2 (0.9998) was in reasonable agreement with predicted R^2 (0.9988), which indicates that non-significant terms are not included in the model. The reduced Quartic model was fitted to the experimental data. The relationship obtained with actual values of temperature and time using stepwise elimination regression was as follows,

$$\text{Final Moisture Content} = -60.231 - 3.04521\text{A} + 29.38347\text{B} - 0.64535 + 0.092293\text{A}^2 - 0.4441\text{B}^2 + 0.01097\text{AB}^2 - 5.7\text{E}-06\text{A}^2\text{B}^2 \quad (8)$$

The comparative effect of ON time (s) and OFF time (s) on final moisture content (kg/ 100 kg dm) could be observed by the F values in the ANOVA (Table 2). The term A and B represents ON time and OFF time in Table 2. From Eq 8 it was found that OFF time has a positive effect on final moisture content. The final moisture content increases take the curvilinear path with an increase in B. Moisture content of the samples decreased after applying microwave with increasing pulse ratio (Eq. 1) from 1 to 4. From Fig. 2 (A) it was found that final moisture content is highly affected by B than A. This result could be due to moisture and temperature redistribution in the tissue when the microwave field was kept off and, consequently, facilitated moisture removal when the microwave field was kept on. The same results are reported by Aghilinategh *et al.* (2015) [56]. As basil is highly heating sensitive, it generates a brown spot during drying at the initial stage itself before reaching desired moisture content. In intermittent drying, temperature and moisture differences were decreased in different parts of the product and their diffusion became more uniform, significantly decreasing the damage to dried products [57]. Similarly, Sedani and Pardeshi (2018) [48] found that during microwave drying of dill leaves, brown spots were developed on the green plant leaves due to prolonged drying at low power and burns before reaching to desired final moisture content. The variations of final moisture content during ISDMD of basil with different combinations of ON time and OFF time were graphically shown in the surface and contour plot (Fig. 2 A).

Table 2: Anova for reduced quartic model for final moisture content of basil leaves

Source	Sum of squares	Df	Mean square	F-value	P-value
Model	1.003E + 05	7	14331.90	6915.80	< 0.0001**
A-ON- time	43807.45	1	43807.45	21139.13	< 0.0001**
B-OFF- time	5073.42	1	5073.42	2448.16	< 0.0001**
AB	2119.74	1	2119.74	1022.87	< 0.0001**
A^2	29383.47	1	29383.47	14178.89	< 0.0001**
B^2	1450.20	1	1450.20	699.79	< 0.0001**
AB^2	3588.48	1	3588.48	1731.61	< 0.0001**
A^2B^2	153.59	1	153.59	74.12	0.0003*
Residual	10.36	5	2.07		
Lack of Fit	0.0214	1	0.0214	0.0083	0.9318^{NS}
Pure Error	10.34	4	2.59		
Cor Total	1.003E + 05	12			
R^2	0.9999				
Adjusted R^2	0.9998				
Predicted R^2	0.9988				
Std. Dev.	1.44				
Mean	57.36				
C.V.%	2.51				

**p<0.001, *p<0.05, ^{NS} Non significant

Effect of process parameter on change in colour (ΔE) for intermittent and stepwise decreasing microwave power drying (ISDMD) of basil leaves

A value of ΔE during ISDMD of Basil leave at different combinations of ON time and OFF time was shown in Table 1. It varied between 0.63 and 16.46 within the combination of variables studied. The ANOVA (Table 3) for ΔE indicated that the model was significant at P<0.0001. A reasonably good fit was obtained with the coefficient of determination (R^2) = 0.9927, which showed that the model developed was adequate for the experimental data. The lack-of-fit test was also found non-significant which indicates that the model was highly suitable to represent the experimental data. Adjusted R^2 (0.9854) was in reasonable agreement with predicted R^2 (0.9278), which indicates that non-significant terms are not included in the model. A reduced cubic model was fitted to the experimental data. The relationship was obtained with actual values of ON time and OFF time using the stepwise elimination regression method as follows,

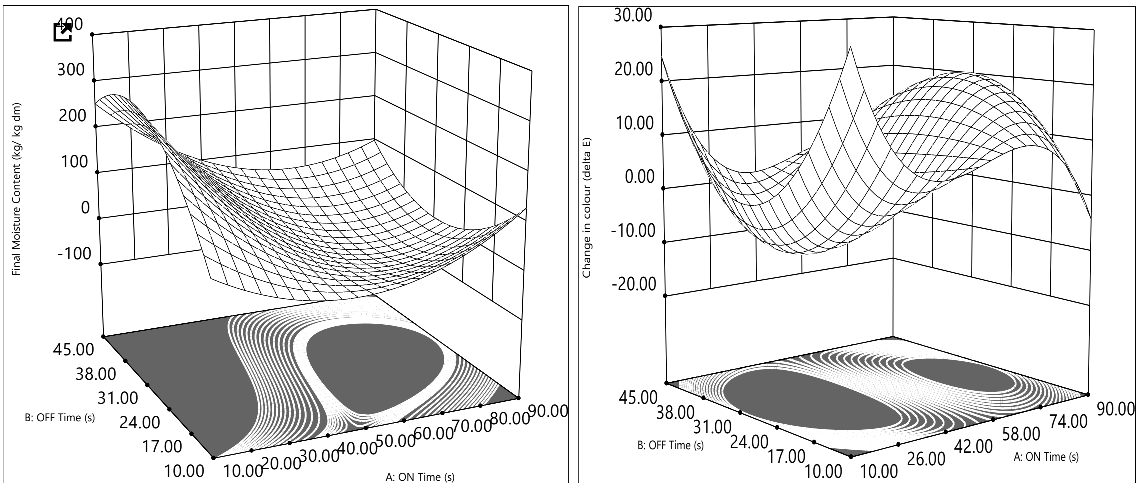
$$\text{Change in colour } (\Delta E) = 13.34019 - 0.43719A - 0.55603B + 0.011497A^2 + 0.009063B^2 - 3.1E-05AB^2 - 5.4E-05A^3 \quad (9)$$

The comparative effect of ON time (s) and OFF time (s) on ΔE could be observed by the F values in the ANOVA (Table 3). The term A and B refers to ON time and OFF time respectively, in Table 3. The effect of A^2 was found to be most prominent and significant (P<0.0001) followed by B (P<0.001). The effect of A was significant (P<0.005) over ΔE of the product during ISDMD of basil leaves. The positive coefficients of the first-order terms and negative quadratic terms of A and B (Eq. 9) indicated that ΔE increases in a quadratic way with the increase of this process variable. The increase in B also results in a decrease in ΔE. The variations of ΔE for ISDMD of basil leaves with different combinations of ON time and OFF time were graphically shown in the surface and contour plot (Fig. 2 B). The energy absorbed by leaves at high ON time was large enough to vaporize water and continuously increases the product's temperature. Therefore, the burnt spot could be found at the last stage of drying. A similar effect was reported during microwave vacuum drying of basil leaves by Therdthai and Zhou (2009) [58] and microwave drying of dill leaves [48].

Table 3: Anova for the reduced cubic model for change in colour for basil leaves

Source	Sum of squares	Df	Mean square	F-value	P-value
Model	317.45	6	52.91	136.21	<0.0001***
A-ON time	11.46	1	11.46	29.51	0.0016**
B-OFF time	25.89	1	25.86	66.66	0.0002***
A^2	34.87	1	34.87	89.77	<0.0001***
B^2	3.87	1	3.87	9.96	0.0197*
AB^2	5.35	1	5.35	13.78	0.0099**
A^3	6.71	1	6.71	17.28	0.0060**
Residual	2.33	6	0.3884		
Lack of Fit	0.9582	2	0.4791	1.40	0.3468NS
Pure Error	1.37	4	0.3431		
Cor Total	319.78	12			
R^2	0.9927				
Adjusted R^2	0.9854				
Predicted R^2	0.9278				
Std. Dev.	0.6233				
Mean	5.84				
C.V.%	10.66				

***p<0.001, **p<0.01, *p<0.05, NS Non significant



A **B**

Fig 2: The contour and response surface plots showing the effect of (A) Final moisture content and (B) Change in colour during ISDMD of basil leaves

Optimization of intermittent and stepwise decremental microwave power drying of basil leaves

Numerical and graphical optimization was carried out for the process parameters for the experiment discussed in Table 1 for ISDMD of basil leaves. To perform this operation, the Design-Expert program (Version 12.0) of the STAT-EASE software (Design Expert, 2019) was used for simultaneous optimization of the multiple responses. Table 4 shows that the software generated optimum conditions of independent variables with the predicted values of responses and desirability values. Solution No.1, having the maximum desirability value (0.717) was selected as the optimum conditions of ISDMD of basil leaves. The superimposed contours of all responses for ON time and OFF time (Fig. 3) and their intersection zone for minimum FMC (kg/100 kg dm) and minimum ΔE indicated the ranges of variables that could be considered as the optimum range for best product quality.

The optimum values of process variables obtained by numerical optimization

ON time = 50 s OFF time = 25 s

Table 4: Solutions generated by the software for ISDMD of basil leaves

No.	On time	Off time	Final moisture content	ΔE	Desirability
1	50	25	2.74	4.36	0.717*
2	48	16	3.12	5.34	0.624
3	44	10	0.39	7.62	0.508

*selected

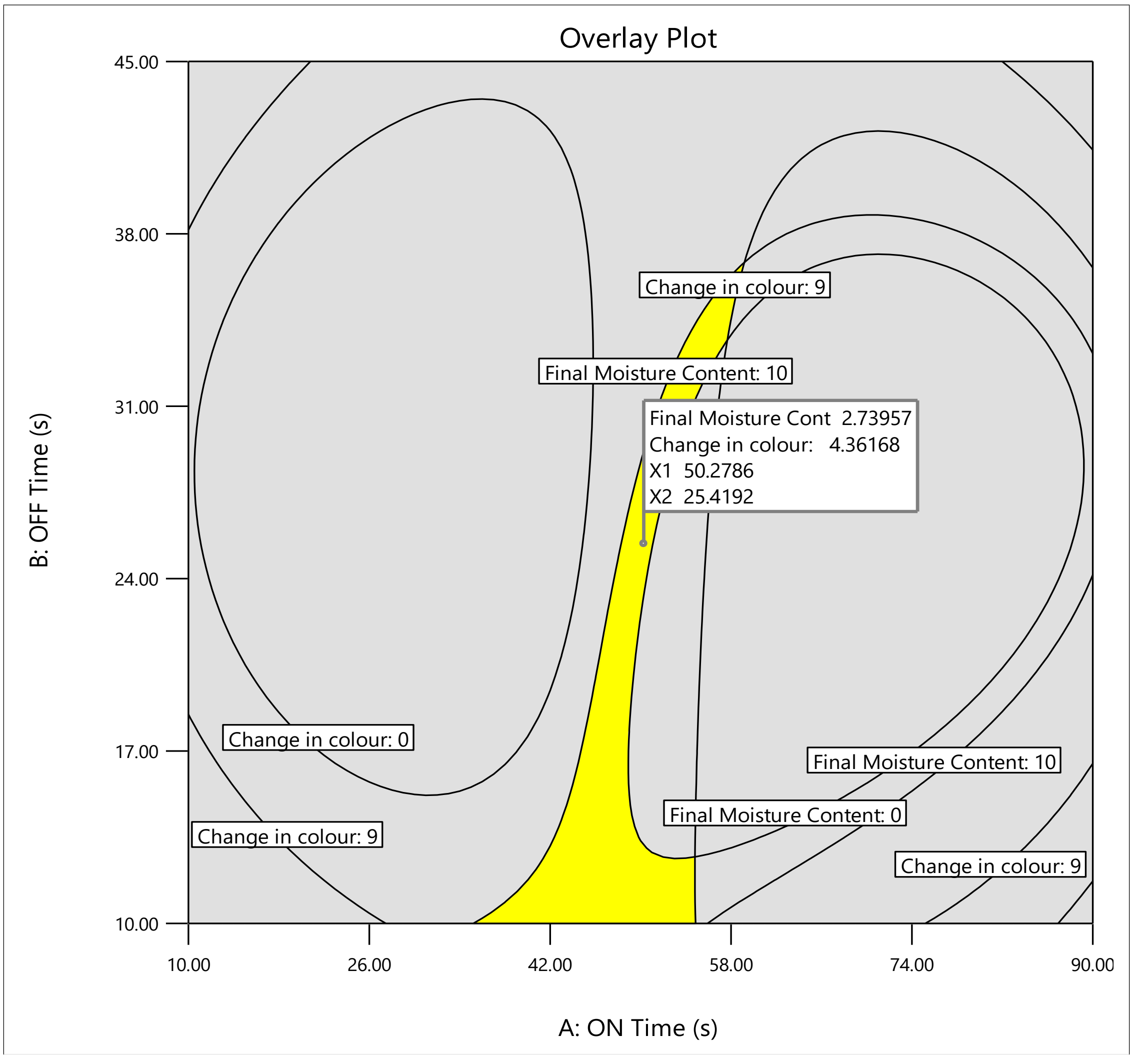


Fig 3: Superimposed counters for final moisture content and change in color for ISDMD of basil leaves

Verification of the model for intermittent and stepwise decreasing microwave power drying (ISDMD) of basil leaves

ISDMD of basil leaves experiments were conducted at the optimum process condition as shown in Table 4 and the quality attributes of the resulting product were determined. The observed experimental values (mean of 5 measurements) and values predicted by the equations of the model are presented in Table 5. The values of C.V. (<10%) and closeness between the experimental and predicted values of the quality parameters indicated the suitability of the corresponding models [59-61].

Table 5: Comparison between predicted and actual response variables at optimum process conditions for ISDMD of Basil leaves

Response	Predicted value	Actual value (± SD)	Variation %
Final moisture content (kg/100 kg dm)	2.74	3.004 (±0.3640)	8.78
ΔE	4.36	4.83 (±0.2909)	9.81

Conclusion

Intermittent and Stepwise Decreasing Microwave Power Drying (ISDMD) of basil leaves at decreasing microwave power levels (900W, 720W, 540W, 360W, and 180W) and by allowing drying for specified ON-time (54s) at each microwave power level and by allowing OFF-time (27s) between two successive ON-time periods at varied and decreasing microwave power level, the desired final moisture content with minimum variation in color (ΔE) was achieved in case of basil leaves considered for experimentation. The total drying time required was 375s. The final moisture content of 3.004 kg/ 100kg dm with 4.83 ΔE was achieved.

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