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Research Paper

Microwave Assisted Fluidized Bed Drying of Potato Cubes

Engineering

KEYWORDS : microwave drying, fluidized bed drying, potato cubes

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ABSTRACT

The experiments were conducted to study the effect of microwave power, inlet air temperature and inlet air velocity on drying characteristics vis-à-vis on quality attributes of potato cubes dried in a microwave assisted fluidized bed dryer (MAFBD). The results were compared with those dried in the same fluidized bed dryer (FBD) but without microwave. MAFBD offered about 1.8 to 3.6 times reduction in drying time and yielded superior quality product.

INTRODUCTION

The major disadvantages of hot air convection drying of foods are low energy efficiency and long drying time. The use of high drying temperatures results in degradation of the quality parameters of the product such as colour, nutritional value and taste [1]. FBD offers the advantage of good mixing, high heat and mass transfer coefficients and hence increased drying rates [2], resulting in shorter drying times [3, 4]. Microwave drying is rapid, more uniform and energy efficient compared to conventional hot air drying since most of the electromagnetic energy is converted into heat. In microwave processing the energy is transferred directly to the sample producing a volumetric heating [5]. However, microwave drying has some major drawbacks that include uneven heating, possible textural damage, and limited product penetration of the microwave radiation into the product. In most of the studies, therefore, microwave has been applied in conjunction with other drying methods, such as, hot air convection, vacuum and FBD, etc. Fluidized bed and microwave drying compensate some of the drawbacks of each other.

The potato (Solanum tuberosum L.) is an important food crop commonly grown for its starchy tubers. India ranks third in the World in production of potato. The demand of dehydrated potato is ever increasing due to population growth and food habit changes. MAFBD, due to intensive heat and mass transfer between the drying air and particles being dried, may result in shortening of the drying time and yield a superior quality product. Therefore, present work was aimed to study the suitability of applying MAFBD method on potato cubes.

MATERIALS AND METHODS

The independent variables of MAFBD drying experiments were drying air temperature (50-70 °C), inlet air velocity (20-24 m/s) and microwave power (360-720 W). The levels of these independent variables were selected by applying Face Centered Central Composite Design (FCCD). Lower and higher levels of independent variables were chosen on the basis of preliminary trials. The factorial points and axial points were replicated two times and centre point five times. Response surface methodology (RSM) was applied to various responses (viz. rehydration ratio and drying time) using Design Expert® 7.1.1 software. The second-order polynomial response surface model (Eq. 1) was fitted to each of the response variables (Yk)

$$Y_k = b_{k0} + \sum_{i=1}^{3} b_{k} X_i + \sum_{i=1}^{3} b_{kii} X_i^2 + \sum_{i \neq j=1}^{3} b_{kij} X_i X_j \qquad (1)$$

Where bk0, bki, bkii and bkij are the constant, linear, quadratic, and cross-product regression coefficients, respectively and Xi's are the coded independent variables of microwave power, drying temperature and inlet air velocity.

Experimental Setup for Microwave Assisted Fluidized Bed Drying

A domestic kitchen microwave oven of LG, Model: MC 9287 BQ was used for the development of experimental MAFBD system (Fig.1). The oven was modified by accommodating a cylindrical fluidization chamber made of polycarbonate of inner diameter 114 mm and height 230 mm, in the oven cavity. Both the ends were provided with flat polycarbonate covers with holes of 41 mm and 34 mm diameter, respectively, at the centre of lower and upper covers for fitting inlet and exhaust pipes for air. Holes of required sizes were made at the centre of both top and bottom faces of oven cavity so that inlet and exhaust pipes might be passed through them.

Water-washed potatoes (variety kufri chipsona -I) were peeled and cut into cubes of size 7mm X 7mm X 7mm using electric slicer (Topaz 195, Sirman, Italy) and a domestic potato-finger cutter. Potato cube of this size was found to be the largest which could be fluidized by the air of selected range of inlet velocity. Cubes were blanched in boiling water for two minutes followed by cooling by submerging in cold water and spreading over blotting paper sheet to remove surface water.

For each experiment, approximately 200g accurately weighed blanched samples were taken. MAFBD consisted to two stages of drying, namely, first using only hot air until moisture content reached 150% dry basis (d.b.) and in second stage microwave of desired power was used until moisture content reached 7±0.5% (d.b.). The tempering period between the two stages was 30 min. The removal of initial moisture by convection drying alone and final, tightly bound moisture, by microwave plus convective drying may substantially reduces drying time and prevents overheating by microwave by shortening exposure-time [6].

The sample was weighed at a time interval of 5 minutes for determining the weight loss and subjected to drying until it attained the final moisture, indicated by no weight-loss in two consecutive observations. The dried sample was cooled in a desiccator followed by packaging in LDPE pouches and heat sealing. Packaged samples were utilized for the determination of rehydration ratio. Table-1 shows the combination of levels of independent variables in experimental runs.

Moisture content of sample was determined by standard hot air oven method [7] and rehydration ratio by taking weight- ratio of sample after and before rehydration. The rehydration was carried out by boiling 2g of dried cubes in 80 ml of distilled water for 5 minutes.

RESULTS AND DISCUSSION

Effect Independent Variables on Drying Time

The initial moisture contents of fresh samples were found to be in the range of 487.89% and 495.84% (d.b.). At initial stage of drying (up to 15- 20 min) the moisture content of sample decreased rapidly with increase in drying time. Thereafter, it decreased slowly till the end of first stage, terminated at moisture content of 150% (d.b.). However, in the second stage of drying carried out in combination with microwave, an increase in drying rate was recorded due to application of microwave. At a giv-

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en microwave power level, the drying occurred relatively faster with increased velocity of drying air due to the increase in mass transfer rate which resulted in shorter drying time.

The least drying time of 62.5 min with a final moisture content of 6.90 %(db) was obtained in drying with 24 m/s air velocity at 720 W microwave power and 70°C temperature. Drying time varied from 62.5 to 123 min (Table-1). The quadratic regression model, in coded terms, is as given below.

YDT =100.00-11.95 * X1-16.20* X2-4.80* X3 -7.00* X22 (2)

All independent parameters had negative correlation with drying time (Eq.2). The air temperature had the strongest correlation followed by the microwave power. Drying time decreased with the increase in microwave power for the obvious reason that at high microwave power, the evaporation of moisture will be faster. The experimental data (Table-1) followed the same trend but showed a minor deviation from the predicted values calculated by applying Eq.2. The maximum experimental and predicted values were 123 min and 111.95, respectively at the same air velocity and microwave power of 22m/s and 360W. The lowest experimental and predicted values varied greatly and were 82 and 88.05 min, respectively at the same drying condition i.e. microwave power of 720W and air velocity 22m/s. In FBD the samples took much longer time with an average value of 226.5 min.

Effect on Rehydration ratio (RR)

RR is the capacity of the dehydrated product to absorb water in the favorable condition and regain the size and shape as it was before drying. The RR is a complex function of the product density, compactness and permeability of the dehydrated product tissues. Dehydrated product having high water permeability, linear and volumetric shrinkage ratio and lower value of the bulk density ratio will have high rehydration ratio as they are indicative of more void space available for moisture absorption. The quadratic regression model, in coded terms for RR is given as follows:

Y RR =2.85+0.081* X1+0.19 * X2-7.2*x 10* $^{-3}$ **X3+ - 0 . 2 1 * X32 (3)

Linear terms of air temperature and microwave power had positive correlations with RR, whereas the air velocity had a negative correlation. Also, air temperature had the stronger correlation with RR as compared to microwave power (Eq.3).

The RR increased with increase in drying temperature. At microwave power 540 W, air temperature 60°C and velocity 22m/s the experimental value of RR was 2.961 which increased to 3.038 by increasing the drying temperature to 70°C and decreased to 2.645 when temperature was decreased to 50°C at the same air velocity. At air temperature of 60 oC, when velocity reduced to 20 m/s from 22 m/s, RR marginally reduced to 2.594, it also reduced when the velocity was increased to 24 m/s. This indicates that the effect of inlet air velocity was not significant over RR. The maximum experimental and predicted values were observed at different combinations and were 3.135 (at 720W, 60 oC, 22 m/s) and 3.04 (at 540W,70 oC, 22 m/s), respectively. Similarly, the minimum experimental and predicted values were also observed at different combination of independent variables and were 2.276 (at720W, 50 oC, 24 m/s) and 2.356 (at 360W, 50 oC, 20 m/s), respectively. FBD dried sample exhibited an inferior RR with a value of 1.662.

CONCLUSION

On the basis of the results obtained from this study, the best combination of independent variables for drying potato cubes was 720 W microwave power, 60 oC air temperature and 22 m/s air velocity. At this combination, the moisture content, drying time and rehydration ratio was 7.50 % (d.b.), 82.0 min and 3.135, respectively. The study has indicated that MAFBD not only shortened the drying time of potato cubes, many-folds, but also resulted in a better rehydration property as compared to those dried by FBD method.

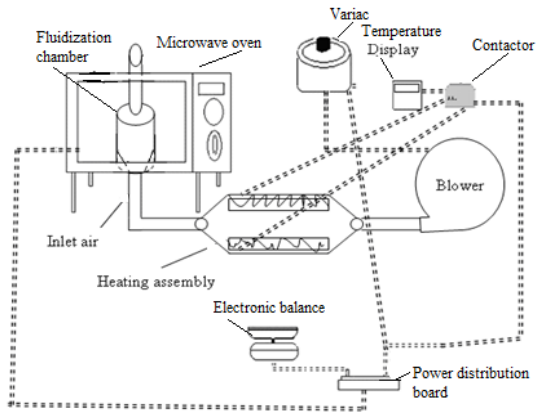


Fig 1: Microwave assisted fluidized bed drying system

TABLE 1: Effect of operational parameters on dependent variables

Independent variables			Dependent variables		
Microwave Power, W (Code:X_1)	Inlet Air Temperature, °C (Code:X_2)	Inlet Air Velocity, m/s (Code:X_3)	Moisture Content, % (db)	Rehydration Ratio	Drying Time, min
360 (-1)	50 (-1)	20 (-1)	7.05	2.396	123.0
		24(1)	6.85	2.504	115.0
	60(0)	22(0)	6.85	2.295	123.0
	70(1)	20(-1)	7.05	2.762	93.5
		24(1)	6.85	2.994	84.0
540 (0)	50 (-1)	22(0)	6.65	2.645	108.5
	60(0)	20(-1)	6.50	2.594	105.0
		22(0)	6.92	2.961	97.4
		24(1)	7.15	2.485	96.5
	70(1)	22(0)	6.55	3.038	69.0
720 (1)	50 (-1)	20(-1)	6.55	2.704	104.5
		24(1)	7.25	2.276	95.0
	60 (0)	22(0)	7.50	3.135	82.0
	70 (1)	20(-1)	6.95	2.760	75.0
		24(1)	6.90	2.886	62.5
0	60	22	6.85	1.662	226.5

Coded values are given in parentheses

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