DEVELOPMENT OF LAB SCALE MODEL FOR DEHYDRATION OF GRAPES USING HYBRID DRYING METHODOLOGY

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Abstract: In India there is separate market for fruit production and export but most of the fruits are seasonal so drying plays an important role in fruit production and preservation. Processed food market is about 30-35 % of total food industry in India. Drying of agricultural product is important considering their original nutritional values and properties. Raisins are one of the important dried fruit throughout the world. Conventional drying methods needs more energy and more drying time and can be reduced by hybrid drying methods with good quality and less drying time period. Microwave drying is best solution because of severe reduction in drying period and the quality of final product. Any individual drying technique doesn't fulfill the all requirements so hybrid drying becomes important with combinations of drying technology. In this work microwave convective hot air dryer is developed and experimentation of drying parameters done by response surface methodology for optimization of drying parameters such as microwave power density, hot air temperature carried out on developed lab scale model.

Index Terms **- Dehydration, Raisins, Hybrid Drying, Microwave Hot Air Drying.**

I. INTRODUCTION

Grape is an important commercial crop in India. India produces 1.51% of total world production of grapes. Raisins are nothing but dried grapes with 16 to 18% moisture content. India is one of the leading raisins producer country with 7th rank all over the world. In India, Maharashtra and Karnataka states contribute 80% of raisins production. About 17 % to 20 % grapes are used for processing of raisins and about 78% consumed as a table grapes [3]. Water content in grape is 76% to 85% and lowering of the water content to 16% to 18% is energy consuming process. Traditional methods used for drying of grapes are shade drying and solar drying. Mechanical methods of drying are more energy efficient and fast drying. Now a days hot air dryers are used for mass production of raisins but the only hot air dryer requires more time and energy to dry grapes. When microwave oven is combined with hot air drying as a hybrid dryer then it is most effective and requires minimum time. For faster drying if temperature of hot air increased then undesirable changes occur in raisins in terms of the quality. The main hurdle in dehydration is hard skin of grapes. The skin is punctured by cracking the waxy layer present on the grapes with the help of various pre-treatments such as dipping in a solution of ethyl oleate and potassium carbonate or sodium hydroxides with fixed concentration and time of dipping.

Dryers use hot air resulting in slow heat transfer rate due to waxy skin layer and the browning reaction that takes place due to polyphenol oxidize enzyme [4]. Hence hybrid drying techniques are developed as using any single technique may not serve the purpose of mass production of raisins. Combination of existing drying technique with modern one is the best consideration such as microwave assisted vacuum or convective drying. In microwave drying, when material with water content comes in contact with microwaves then there will be internal heat generation due to phenomenon of polarization and ionic conduction [5]. Water is evaporated due to this heat generation and hot air is supplied uniformly over grapes sample.to remove this water vapour coming out of samples. In this study higher air flow with air velocity of 2-3 m/sec is used for uniform drying conditions. The objectives of this study work is to develop lab scale hybrid dryer and study of microwave power and hot air drying effects and their optimization for mass production hybrid dryer.

II. MATERIALS AND METHODS

Materials

Main raw materials required for drying of grapes are fresh grapes from local market and pre-treatment solutions. Before experimentation grapes were pre-treated with dipping in 25 gm potassium carbonate and 20 ml ethyl oleate solution. Grapes were dipped in the solution per 1 litre water for 3 min and then washed with tap water. If pre-treatment time exceeds then there is peeling of grape skin which is undesirable. Pre-treated grapes were kept on perforated tray and weight is checked with the help of digital balance.

Development of hybrid drying set up

Drying experiments was carried out on a developed lab scale model. Model consist of A Kenstar microwave oven modified for using as a dryer in the present study as shown in the fig.1. The microwave oven is operated at 2450 MHz and duty cycle was adjustable in increment of 100 W. This microwave oven has chamber with dimensions of 560*344*542 mm. Turntable rotates the sample holding plate to get the uniform effect over sample. Air blown through the blower is heated by an electric heater. 800 watt Heater is used in the present study and is inserted in PVC pipe as shown in the fig1.Perforations were made on the aluminum sheet enclosure where supplied air comes in contact with heater. Temperature of air is adjustable according to our requirement. A blower is used to pass the air with velocity over the perforated plate placed on the turntable. A flow regulator is mounted after blower to control the flow rate of air passing over heater. Air flow velocity is maintained at 2 m/s to 2.5 m/s in present study.

Figure 1 Modified Microwave Hybrid Dryer.

Control panel consists of temperature controller, timer, buzzer, ammeter, selector switches and indicators as shown in fig.2. PT-100 temperature sensor is inserted in chamber to measure the hot air temperature and outputs are given to the temperature controller. Hysteresis is provided according to our requirement and after attaining the desired temperature automatically heater will be OFF and after some interval if temperature lowers, heater will be automatically made ON. Timer is provided to set the time for activation time of microwave and only hot air simultaneously. After set time buzzer will blow sound automatically. Contactors and controller is mounted inside the junction box and connections are made separately for blower, heater and microwave oven on junction box.

Figure 2 Control Panel Showing All Controls and Indicators

III. EXPERIMENTATION AND METHODOLOGY

Experiments are carried out by using response surface methodology with statistical software Minitab version 18. In methodology major points covered are various pretreatment processes and controls of process parameters according to drying kinetics of grapes. Main parameters affecting the drying rate and quality of final product are microwave power density, hot air temperature, and hot air velocity. In present study air velocity kept constant .Methodology for experimentation is as follows:

a) Pre-treatment process used is 3% ethyl oleate and 2.5% Potassium carbonate at 40^0C for 3 minutes.
b) Keep weighted samples on a perforated plate and place it on a rotated turntable. Start blower and heater with set values of air velocity and hot air temperature. A regulating valve is used to control the velocity of air.
c) Start microwave for 5 minutes and then switch off for 10 minutes: In early phase of drying, moisture content is more so time of application of microwave is more than later. Provision is made on microwave oven to vary the microwave power from 100 W to 1000 W and 10 % duty cycle is made to increase the power step by step.
d) After 10 minutes microwave is made ON for 2 minutes and heated air is supplied to transfer the moisture present in the chamber for 6 to 8 minutes which brings the moisture to surface. Again microwave power is made ON when buzzer blows sound with given set time. Hot air temperature of chamber is set to 450 C to 550 C and change it after every hour. If temperature exceeds the set value PT- 100 sensor automatically turn OFF the heater and avoid the browning of grapes due to excessive heat.
e) After every 1 hour weight of samples will be recorded with the help of Electronic digital balance.
f) Repeat above process till the final desired weight of samples.
g) Final product after testing is compared with some important quality governing factors as per NAFARI standard.

IV. RESULT AND DISCUSSION

Response Surface Method:

Empirical model is built up by the Response surface methodology (RSM) which is a combination of mathematical and statistical techniques. The goal is to optimize a reaction (output variable) affected by multiple autonomous factors (input variables) through careful experiment design. An experiment is a sequence of trials, called runs, to identify the reasons behind modifications in the output reaction following modifications in the input variables. When the process factors (independent parameters) satisfy an important assumption that they are measurable, continuous, and controllable by experiments, with negligible errors, the RSM procedure was carried out as follows:

1. Series of tests were conducted to adequately and reliably measure the reaction of interest by altering input variables.
2. The optimum set of experimental parameters generating the optimum reaction value was determined.

Optimization of Drying Parameters:

Response surface method (RSM) was used to evaluate the contribution of two drying parameters viz. specific microwave power density and hot air temperature to responses drying time. Response surface method (RSM) is statistical method used in design of experiment for multivariate problems. Advantage of RSM is that it gives acceptable results with less number of experiments and states the relationship between responses and variable inputs.

Following second order polynomial equation was used for experimentation data analysis to study relationship between response surfaces to coded variables.

$$y = \beta k_0 + \sum_{i=1}^{k} \beta k_i X + \sum_{i=1}^{k} \beta k_{ii} X_i^2 + \sum_{i \neq 1 j=1}^{k} \beta k_{ij} X_i X_j + E$$

Where, y is output response, k is number of variables in the experiment, X_i are process Variables in coded format and E is random error. Higher value of regression coefficient indicate the more importance of variable affecting the process and vice versa. Analysis of variance (ANOVA) and regression analysis were conducted by using a statistical software Minitab 18, also graphs of response obtained from the software.

Response surface regression for drying time vs microwave and temperature given by equation,

Drying time = 26.00 - 6.667 M - 0.6500 T + 0.006000 T*T

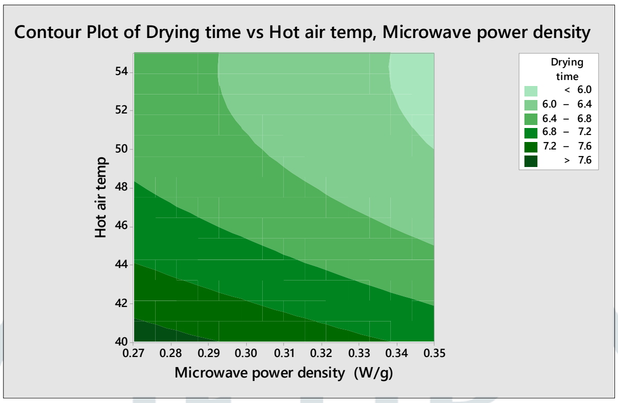

Figure 3 Contour Plot of Drying Time Vs Mw and Hot Air Temp

Response surface regression for total energy consumption vs microwave and temp given by equation,

Total energy consumption = 10.46 - 2.333 M - 0.2300 T + 0.002000 T*T

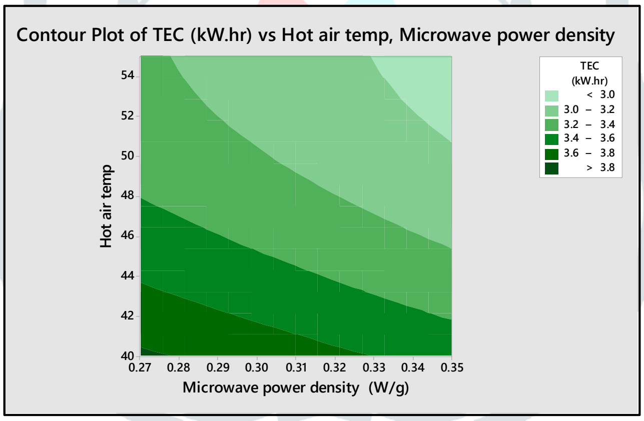

Figure 4 Contour Plot of Total Energy Consumption Vs Mw and Hot Air Temp

Where M and T are specific microwave power density in W/g and hot air temperature in ℃ respectively. In addition to specific microwave power density, optimization of convective hot air temperature is also carried out with fixed velocity of 2m/s. It should be noted from experiments that higher microwave power density as 0.35 W/g can also be used with lower hot air temperature but such combination results in more energy consumption. To study the effect of hot air temperature on drying kinetics, hot air temperature variation range from 40℃ to 55℃ with step value of 5 had been selected. Higher temperature of air contributes in rising of temperature of product which is unsafe for grapes. The optimized combination is found as specific microwave power density of 0.35W/g coupled with 50℃ hot air temperature.

Sample Analysis:

Produced raisins were given to Food testing and quality control laboratory for its analysis. Test report is as given in table 6.2. Comparative analysis for produced raisins and readily available market raisins was also carried out for two important factors such as total sugar as sucrose and moisture. Close resemblance was found between market sample and hybrid dried sample in terms of PH value, Acidity as a citric acid, which confirms feasibility of the produced raisins to market in terms of quality. It is observed that moisture content is within National Agriculture and Food Analysis Research Institute (NAFARI) standard.

Figure 5 Samples Given to Laboratory

Total sugar content as sucrose present in both samples are different, this may be because it depends on harvesting and BRIX value.

Table 1 Analytical Test Report from Laboratory

Sr.no	Parameters	Unit	Test Sample	NAFARI standard for market raisins	Range
1)	Moisture content	gm/100 gm	5.22	10.1	≤ 18
2)	Sugar content as sucrose	gm/100 gm	44.28	80.78	≥ 70
3)	PH value	----	4.0	------	3.8-4.1
4)	Acidity as a citric acid	gm/100 gm	1.36	------	1.5-2.2

V. CONCLUSION

i. Experiments are conducted with constant air velocity of 2.5m/sec and specific microwave power density vary from 0.25 W/g to 0.35 W/g and hot air temperature vary from 45 °C to 55 °C respectively. Specific microwave power density higher than 0.4 W/g is not suitable because center temperature of grapes increases than its surface temperature and grapes may burst and starts burning.

ii. If temperature of hot air exceeds 55°C then browning of raisins starts which degrades the quality of raisins. Quality of raisins sample are checked in a food testing and quality control laboratory. Close resemblance was found between market sample and hybrid dried sample in terms of PH value, acidity as a citric acid. Deviations in sugar content are because of its dependence on brix value at the time of harvesting of grapes.

iii. Optimization is done with Analysis of variance (ANOVA) and regression analysis were conducted by using a statistical software Minitab 18, and graphs of response are obtained from the software.

iv. It was found that 0.35 W/g Microwave power density and 50°C hot air temperature is safe and best suitable for faster drying and best quality for raisins. These results were found with the help of response surface method (RSM) for design of experiments.

v. Optimized parameters can be used as process parameters for mass production of raisins with scale up of parameters and same results can be assured.

VI. REFERENCES

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