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RESEARCH ARTICLE

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MATHEMATICAL MODELING OF DRYING OF CAULIFLOWER

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ABSTRACT

Drying is a most important method to reduce the moisture content from product to increase its shelf-life. Now a day, drying of agricultural products has great attention. To avoid the problems encountered in traditional methods of drying of agricultural products, tray dryers are used. The experiment was conducted to investigate the drying behavior of Cauliflower by using a tray dryer so that to make its mathematical modeling using exponential and linear model. Blanching treatment was applied to cauliflower samples, which were dried at 50^{0}C, 60^{0}C and 70^{0}C temperatures in a tray dryer. The loss of moisture was recorded at different time intervals up to 1200 minutes. It was observed that, moisture content and moisture ratio of blanched sample was significantly less than that of un-blanched sample for a particular drying time for all the drying temperatures. The nature of drying rate curve was observed to be a non linear during the drying of Cauliflower. Exponential model was found to be the best model for describing the drying behavior of cauliflower.

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INTRODUCTION

Vegetables are important sources of essential vitamins and minerals for human consumption. Different vegetables have their own unique mix of nutrients to serve. India produces a significant portion of vegetables all over the world. Although the production of vegetables in India is high, post harvest losses in the segment are estimated to be more than 25% and level of vegetables processing is hardly 2% of the total production. High post harvest losses and huge availability during glut demands to preserve vegetables, so that their useful characteristics can be reaped during unavailability. Removal of water from foods is the essence to enhance the shelf life of vegetables and dehydration is one of the techniques, widely used to preserve the vegetables. The fundamental aspect of food dehydration is to reduce the availability of water in food to such an extent, which is not favorable for undesirable microorganism and favorable for minimized rates of chemical reactions. Dehydration not only facilitates reduction in the bulk of fresh material, easy transport because of reduced weight and volume but also increases availability of food throughout the year. Drying causes irreversible structural damage to the cellular structure of foods. Pretreatment, subsequent drying and rehydration may induce changes in the structure and composition of plant tissues, which affect the organoleptic properties upon rehydration. Several studies for drying of vegetables reported that the structure of dried food products depends on the drying methods and the drying conditions such as drying temperature, relative humidity, air velocity and initial physico-chemical characteristics of the product. Also, the quality of product in terms of sensory and other physico-chemical factors is significantly influenced by drying conditions. Cauliflower (*Brassica Oleracea*) is an important cole crop of north India and belongs to crucifer family. India produces around 32.5% of the world total production of cauliflower. In India, overall estimated per hectare cauliflower post harvest losses are 49%. Cauliflower prices become very low during main season and sometimes farmers must pay to throw away their produces because of higher perishable nature of the produce (Mudgal and Pandey, 2007). Fresh cauliflower has 92 to 94% moisture (wet basis) and it can be stored for few days at normal conditions. Drying of cauliflower can be an alternate for extending its shelf life. Dehydrated Cauliflower can be used to enhance the taste and nutritional value of various products such as rehydrated vegetable mix, soups, canned products, extruded products etc. The selection of proper drying condition is of prime importance for reduced thermal stress and to retain the key compounds in the rehydrated product. Several scientists have reported that in drying mechanism of cauliflower, optimum conditions are required to be accessed as per the desired characteristics in the dried product. The present study discusses not only about drying mechanism of cauliflower under hot air convective drying, but also about optimization of process variables depending upon quality attributes of the final product. Mathematical modeling in food drying is the use of mathematical equations to predict the behavior of drying process. Mathematical models are helpful in optimizing the drying conditions and studying complicated heat and mass transport processes. Furthermore, drying conditions and simulation model parameters are linked. Experimental error is reduced due to the drying model, and the drying process is enhanced while energy consumption is reduced and profit margins are increased as a result. The goal of this study was to shed the light on mathematical modeling and how it might be used to speed up the drying process for fresh cauliflower. Future researchers in food science and food engineering will benefit from this study, especially those working on vegetable drying models, analyses, designs and optimizations. In view of this, the present study was undertaken with the objectives to investigate drying characteristics of cauliflower, to study the effect of blanching and drying temperature on drying kinetics of cauliflower and to determine the best fit mathematical model for drying of cauliflower using exponential and linear modeling.

MATERIALS AND METHODS

A fresh and mature cauliflower available at local market was purchased and used for the experimentation purpose. Initial moisture and moisture after every time interval was measured by standard hot air oven method (AOAC, 2000). The drying of cauliflower was followed as shown in Fig. 1 and the drying characteristics (moisture content, drying rate and moisture ratio) were measured. To analyze the data, a statistical analysis was done using ANOVA and Duncan's multiple range tests, which provides valuable insights in to the effectiveness of different drying conditions and helps to draw conclusions about their impact on the quality of the dried cauliflower pieces. Various treatment combinations used for the experiment are given below.

T1 = Blanching + 500C drying
T2 = Un-blanched + 500C drying
T3 = Blanching + 600C drying
T4 = Un-blanched + 600C drying
T5 = Blanching + 700C drying
T6 = Un-blanched + 700C drying

RESULTS AND DISCUSSION

The initial moisture content of the cauliflower was observed as 94.5% (wet basis). From Fig. 1 and Fig. 2, it can be seen that as the drying time increases, moisture content of un-blanched and blanched cauliflower sample decreases up to constant value for all the drying temperatures. Also it can be seen that as the drying temperature increases from 50^0C to 70^0C, moisture content of un-blanched and blanched cauliflower sample decreases for particular drying time.

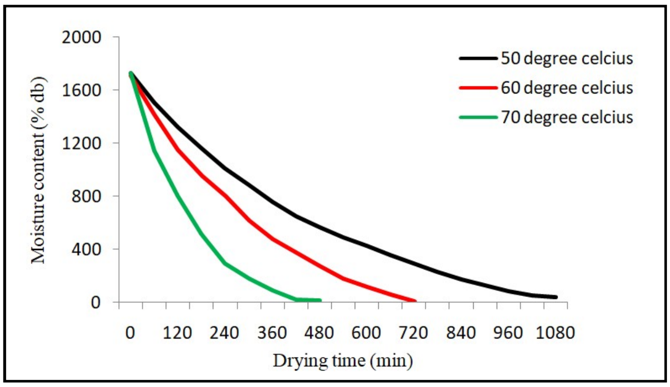

Fig. 1. Effect of drying time & drying temperature on moisture content of un-blanched cauliflower sample

The un-blanched cauliflower sample requires 1080 minutes, 720 minutes and 480 minutes for complete its drying process at 50^0C, 60^0C and 70^0C drying temperature respectively. Whereas the blanched cauliflower sample requires 1020 minutes, 720 minutes and 480 minutes for complete its drying process at 50^0C, 60^0C and 70^0C drying temperature respectively. Statistically, it was observed that drying time and drying temperature significantly affects moisture content of un-blanched and blanched cauliflower sample. This is due to the fact that, with increase in drying temperature and drying time, the sample is exposed to more and more heated air during its drying, therefore decrease in moisture takes place rapidly. Fig. 3 and Fig. 4 show the effect of drying time and drying temperature on moisture ratio of un-blanched and blanched cauliflower sample.

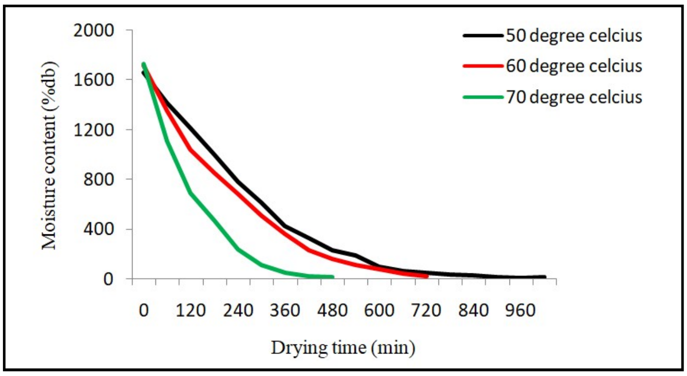

Fig. 2. Effect of drying time & drying temperature on moisture content blanched cauliflower sample

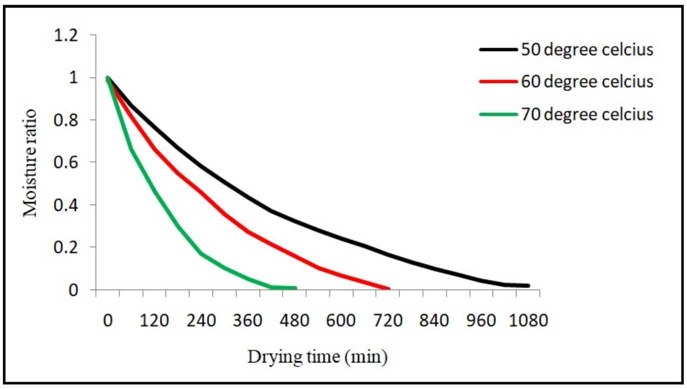

Fig. 3. Effect of drying time & drying temperature on moisture ratio of un-blanched cauliflower sample

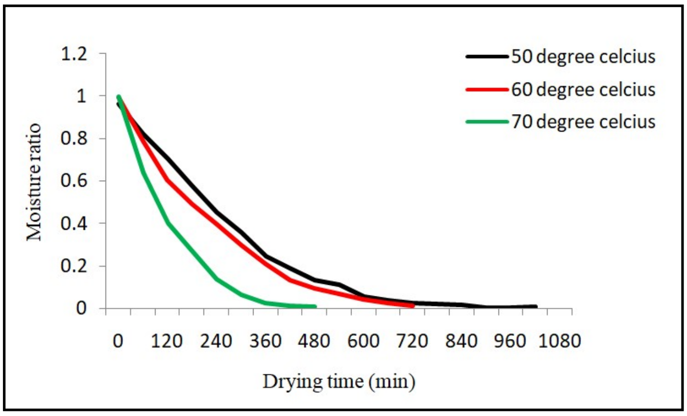

Fig. 4. Effect of drying time & drying temperature on moisture ratio of blanched cauliflower sample

It can be seen that, as drying time increases, moisture ratio of un-blanched and blanched cauliflower sample decreases up to constant value for all the drying temperatures. Also it can be seen that, as the drying temperature increases from 50^0C to 70^0C, moisture ratio of un-blanched and blanched cauliflower sample decreases for a particular drying time. Statistically it was observed that drying time and drying temperature significantly affects moisture ratio of un-blanched and blanched cauliflower sample. This might be due to rapid decrease in moisture because of increase in drying temperature and drying time. Fig. 5 and Fig. 6 show the effect of drying time and drying temperature on drying rate of un-blanched and blanched cauliflower sample. It can be seen that as the drying time increases, drying rate of un-blanched and blanched cauliflower sample decreased continuously for all the drying temperatures.

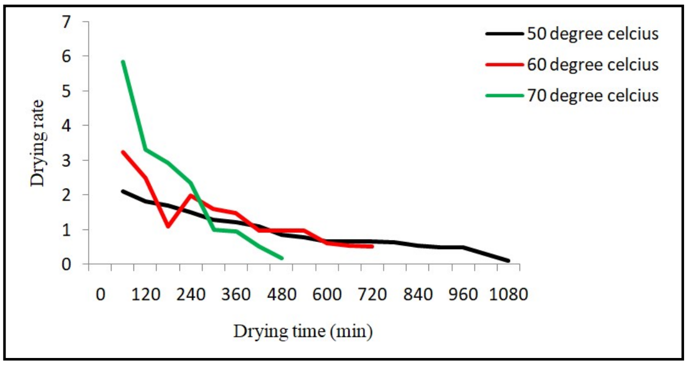

Fig. 5. Effect of drying time & drying temperature on drying rate of un-blanched cauliflower sample

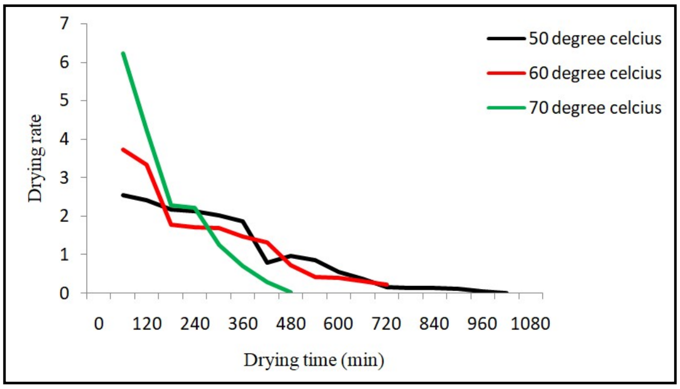

Fig. 6. Effect of drying time & drying temperature on drying rate of blanched cauliflower sample

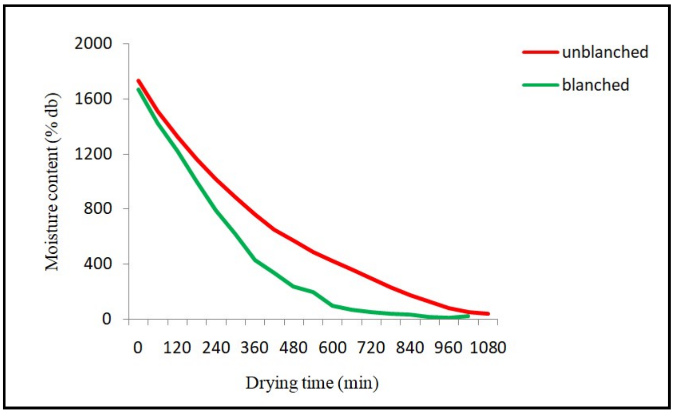

Fig. 7. Effect of drying time & treatment on moisture content of cauliflower sample at 50ºC

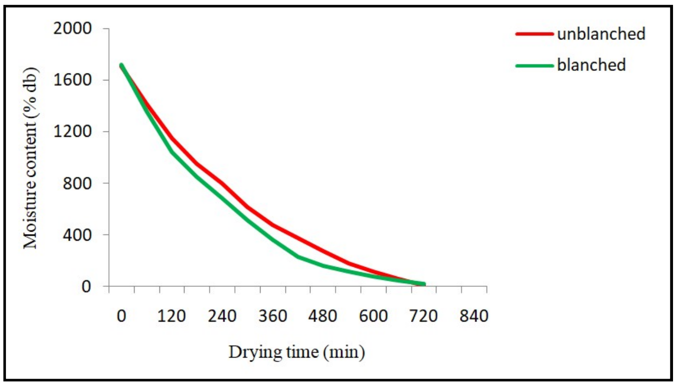

Fig. 8. Effect of drying time & treatment on moisture content of cauliflower sample at 60ºC

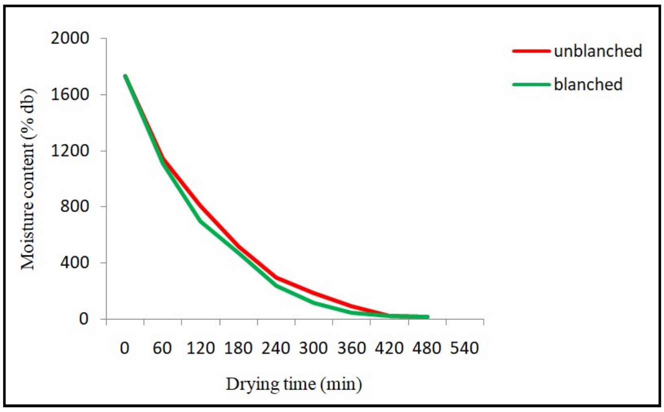

Fig. 9. Effect of drying time & treatment on moisture content of cauliflower sample at 70ºC

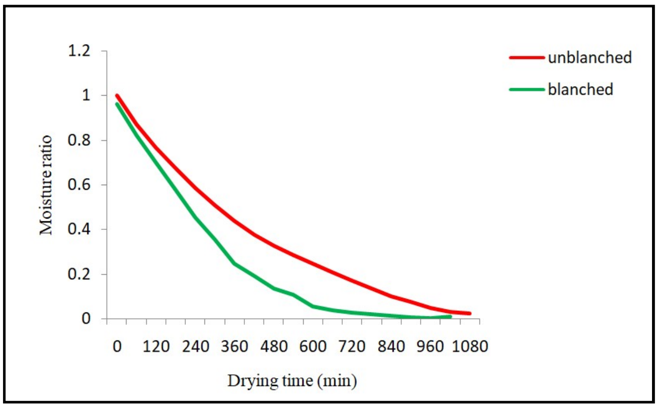

Fig. 10. Effect of drying time & treatment on moisture ratio of cauliflower sample at 50ºC

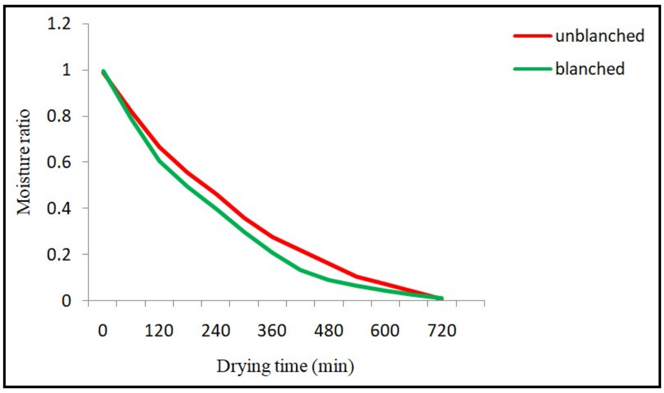

Fig. 11. Effect of drying time & treatment on moisture ratio of cauliflower sample at 60ºC

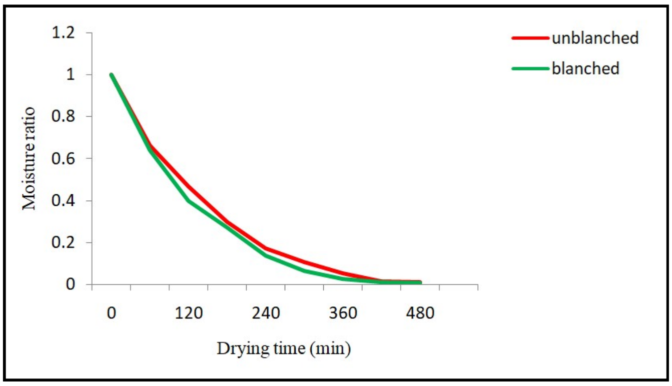

Fig. 12. Effect of drying time & treatment on moisture ratio of cauliflower sample at 70ºC

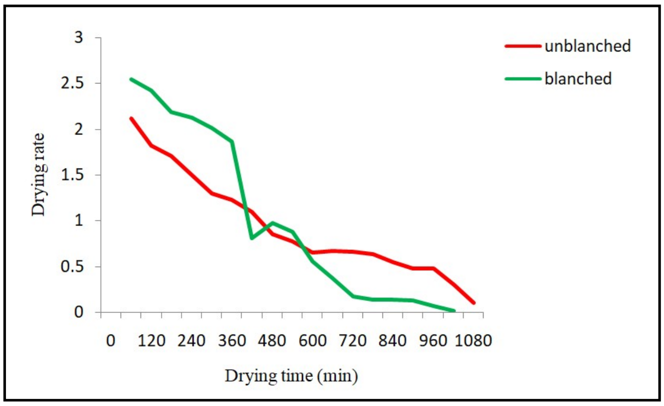

Fig. 13. Effect of drying time & treatment on drying rate of cauliflower sample at 50°C

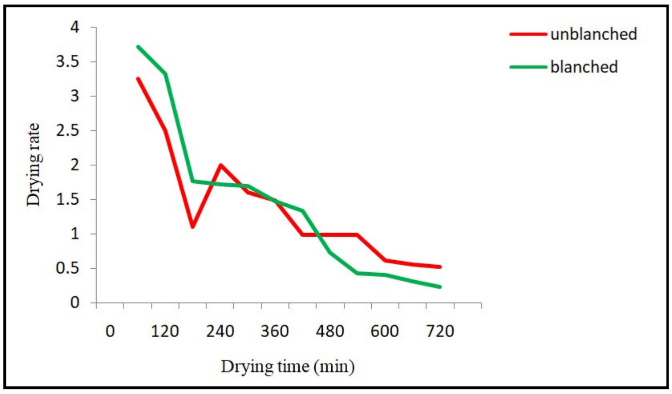

Fig. 14. Effect of drying time & treatment on drying rate of cauliflower sample at 60°C

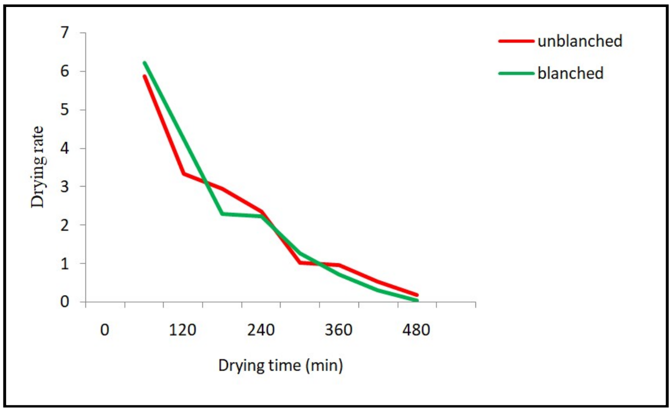

Fig. 15. Effect of drying time & treatment on drying rate of cauliflower sample at 70°C

Drying rate of un-blanched and blanched cauliflower sample reaches to its minimum value rapidly in case of 70^{0}C drying temperature. Statistically, it was observed that effect of drying time and drying temperature on drying rate was not significant in case of un-blanched cauliflower sample, whereas it was significant in case of blanched cauliflower sample.

Table 1. Comparison of different drying models

Model	Treatments	Drying Temperature (^{O}C)	Model constant (K)	R^2
Exponential model	Un-blanched	50	0.003	0.983
		60	0.005	0.966
		70	0.009	0.980
	Blanched	50	0.005	0.960
		60	0.005	0.979
		70	0.010	0.982
Linear model	Un-blanched	50	0.001	0.933
		60	0.002	0.939
		70	0.003	0.859
	Blanched	50	0.001	0.825
		60	0.002	0.888
		70	0.003	0.822

Fig. 7 to Fig. 12 shows the effect of drying time and treatment on moisture content (dry basis) and moisture ratio of cauliflower sample at 50^{0}C, 60^{0}C and 70^{0}C respectively. It can be seen that as the drying time increases, moisture content and moisture ratio of blanched and un-blanched cauliflower sample decreases up to a constant value for all the drying temperatures. Also it was observed that, moisture content and moisture ratio of blanched sample was observed to be less than that of un-blanched sample for a particular drying time for all the drying temperatures. Statistically it was observed that blanching treatment on cauliflower significantly affects on its moisture and moisture ratio at a particular drying time. The trend of significant decrement of drying rate was observed with increase in drying time for both the treatments on cauliflower sample (Fig. 13 to Fig. 15). The nature of drying rate curve was observed to be a non linear during the drying of Cauliflower. Exponential model was observed to be more precise to describe the hot air drying of un-blanched cauliflower over the selected range of drying temperatures. For all the three drying temperatures, exponential model showed R^2 value more than 0.95 and hence this model was found to be the best model for describing the drying behavior of cauliflower (Table 1).

CONCLUSIONS

1) Blanching treatment before drying of Cauliflower sample fastens the moisture removal process.
2) Exponential model is the best fit for describing the drying behavior of cauliflower.

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