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Deformation of potato during convective drying

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Keywords: Convective drying, deformation during drying, shrinkage, wind tunnel type convective drier, non-dimensional drying parameters.

Abstract. Deformation of potato is estimated by experimentally during convective drying. Size of the potato slice is 4cm x 2cm x 2cm. The percentage changes in length, breadth and width of potato are estimated during drying. Shrinkage of the object during drying is estimated. Air velocity chosen for this present analysis is 2 m/s and the range of air temperature is selected as 40 to 70 ºC. The product experiences the maximum dimension changes upto 30% in length and 47.5 % in both breadth and width wise. The parameters are non dimensionalised to get generic solution.

Introduction

Convective drying of moist object is a simultaneous heat and mass transfer problem. During convective drying the moist object is getting heated and losing its moisture content upto its equilibrium moisture content. During the continuous dehydration process the length, breadth and width of the object are changed as the product is exposed to hot air.

The numerical models of convective drying essentially includes the effect of deformation of the object. Very few numerical models found with the effect of deformation of object during drying. The major reason is that there is not much deformation studies of object during drying in literature. Changes in structure, volume, density and porosity were experimentally found by Wang and Brennan [1]. By using light microscopy test, thay captured the interior view of the object during different stages of drying. They found that changes in size of the object affects other physical properties density, shrinkage and porosity. A review of modelling of shrinkage during convective drying of food materails was performed by Mayor and Sereno [2]. The aim of his work is to give a physical description of the shrinkage mechanism and present a classification of the different models proposed to describe this behaviour in food materials undergoing dehydration. Simal et al. [3] proved the numerical model with deformation model close to experimental results of transient moisture distribution of cylinder shaped moist materials. Their numerical model without considering the shrinkage and deformation of object during drying has given erratic solution.

The changes of length, breadth and width of the potato are estimated at air flow velocity 2 m/s. The air temperature range selected for this present analysis is 40 to 70 ºC. Transient distribution of mass of the object is estimated at every 20 minutes. From that moisture content distribution are estimated. Length, breadth and width of the object is measured every 20 minutes, therefore the change in dimension are estimated and results are plotted. It is expected that the outcome of this experimental results will be useful for numerical drying models.

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Experimental setup and procedure

The initial moisture content of the object is estimated by $M_0 = \frac{m_{initial} - m_{final}}{m_{final}}$ kg/kg of db

A hot air oven is used for finding the initial moisture content of moist object. The sample moist object was selected as potato and it was shaped as 4 cm x 2 cm x 2 cm. It was wrapped by an Aluminium paper and was kept in a hot air oven (Hot Air Sterilizer Oven- YSI-431) where the temperature was maintained at 105 °C. It was noticed that 83% of initial moisture content in terms of mass exists in the moist object and it was quantified as 4.8862 kg/kg of db.

An experimental setup for convective drying was developed to find the transient moisture distribution of moist object. It is a wind tunnel type convective drier consists of centrifugal blower, inlet/outlet section of blower, diffuser section, settling chamber with heaters, contraction section and test section. The other accessories are honeycombs, U type heaters, Auto transformer dimmerstat portable type (15D-3P), Multi function hygrometer probes (TESTO, Part no: 0635 1535), TESTO indicators, (Part no: 435-1) and OHAUS's model Adventurer Basic level Electronic Single Pan Balance (Model AR 3130). Size of the potato slice is 4 cm x 2 cm x 2 cm. The air velocity chosen for this analysis are 2, 4 and 6 m/s.

Potato slice is kept inside the test section and the required air flow velocity and temperature are maintained inside the test section. Mass, length, breadth and width of the object are measured every 20 minutes. From the observed data the transient moisture content, change in dimensions and shrinkage are estimated. Mass of the object is measured upto its equilibrium moisture content. Velocity of drying air, upstream and downstream humidity and temperature of drying air is measured with TESTO multi function instrument with probes. Mass of the object is measured by OHAUS electronic balance. For confirming the accuracy of experimental results uncertainty analysis and repeatability test are performed. Repeatability tests are essential to ensure the accuracy of the experimental results. The repeatability tests are done under the conditions of, the same observer, the same measurement procedure, the same measuring instrument used under the same conditions (2 m/s and 60 ^{0}C), the same location and repetition over same time duration (20 min). Three trials are done for 2 m/s and 60 ^{0}C in different days for finding the transient moisture content. It is observed that the set up produces an excellent repeatability data. The closeness of agreement between independent results is obtained with the same method on identical test, under the same conditions. The average and maximum difference in the transient mass of the object between the three tests is noticed as 0.106 g and 0.208 g respectively and the percentage difference with actual is 0.9% and 1.73% respectively. See more about experimental setup design, procedure, uncertainty analysis and repeatability test in the author's previous work [4].

Length, breadth and width of the object is measured by a vernier caliper. Percentage change in length (dL), percentage change in breadth (dB), percentage change in width (dH) are calculated by, respectively,

$$dL = \frac{L_{initial} - L_{at\ t\ min}}{L_{initial}} x100\%$$

$$dB = \frac{B_{initial} - B_{at\ t\ min}}{B_{initial}} x100\%$$

$$dH = \frac{H_{initial} - H_{at\ t\ min}}{H_{initial}} x100\%$$

Results and discussion

Figure 1 shows the change in dimesnion of moist object at non dimensional moisture content over different air temperatures 40 to 70 °C. Fig. 1(a) shows the variation at 40 °C. The moisture content decreases from the object, the change in dimensions of the object increased. During drying the product loses its moisture content continuously, therefore the interior structure of the object shrinks proportionally. Similar type of variation found in all other temperatures (50 to 70 °C).

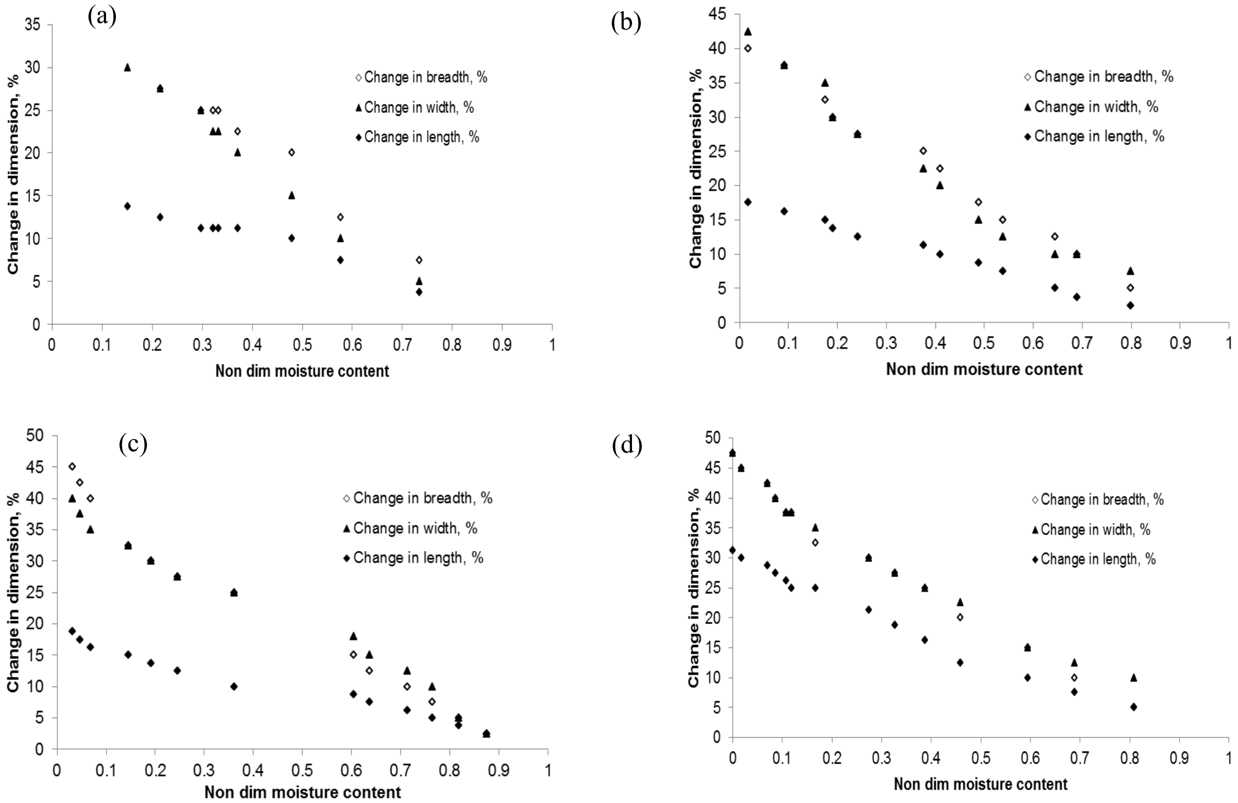


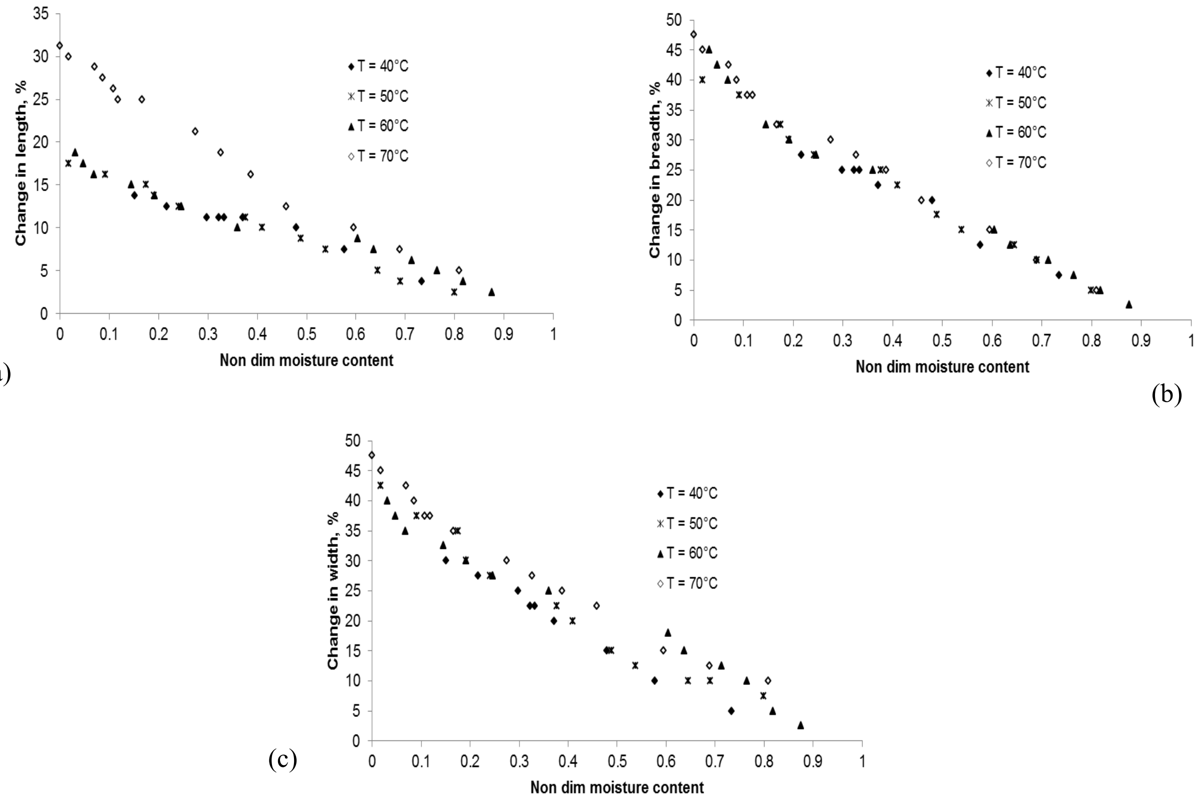
Fig. 1. Change in dimension of the object over non dimensional moisture content at different air drying temperatures, (a) 40 °C, (b) 50 °C, (c) 60 °C and (d) 70 °C

Table 1 gives the maximum change of length (dL_{max}), breadth (dB_{max}) and width (dH_{max}) in %. It is noticed that the maximum change of the length is varied upto 15% and the breadth and width varied upto 30% approximately at 40 °C. The maximum change of breadth and width is almost equal in different cases as breadth and width of the object is equal (2 cm).

Table 1: Maximum change of dimension of the object in %

Air temperature, °C	Maximum change of length (dL_{max}) in %	Maximum change of breadth (dB_{max}) in %	Maximum change of width (dH_{max}) in %
40	20	27.5	30
50	30	40	45
60	30	45	40
70	31.25	47.5	47.5

The change in length over different air temperature is given in Fig. 2 (a). The higher air temperature eliminates more amount of moisture from the object during drying. Therefore, change of length increased in the higher air temperature (70 °C) compare to other lower air temperatures (40 to 60 °C). Similar type of variations found in the otehr cases of change in breadth (Fig. 2b) and width (Fig 2c).



(a) (b) (c)

Fig 2. Effect of air temperature of the product over non dimensional moisture content on (a) change in length, (b) change in breadth and (c) change in width.

Table 2 shows the percentage volume loss of the object at different air drying temperatures and different air flow velocity. It is observed that the volume loss experienced by the sample varies between 74.13 to 84.67% for temperatures range of 40 to 70 °C and velocity range of 2 to 6 m/s. It shows that the maximum volume loss (84.67%) was found at temperature of 70 °C and velocity of 6 m/s. The higher temperature and higher velocity eliminate more volume of moisture from the moist object.

Table 2. Volume loss of the object in % with different air temperature and velocity

Drying air temperatures, °C	**Volume loss of the object in % Air velocity =2 m/s**
40	74.13
50	80.62
60	81.25
70	81.56

The shrinkage of the product is estimated from V/V_0, where V_0 is the initial volume of the product (16 cm^2) and V is the volume of the object at different time. Shrinkage variations with respect to non-dimensional moisture content at various temperatures are plotted in Fig 3. There is not much deviation found with different air temperatures at higher moisture regions. When the lower moisture content region there are some variation of shrinkage is noticed. The variation of shrinkage is noticed as linearly decreasing trend when the moisture content decreased.

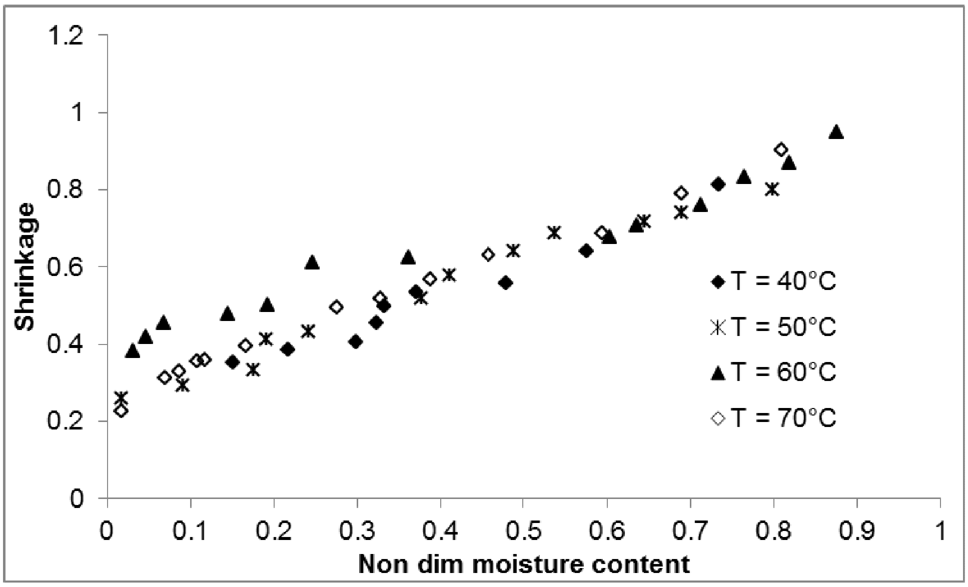


Fig. 3. Variation of shrinkage with non dimensional moisture content at various drying temperatures.

Conclusion: The deformation of potato during drying was analysed experimentally. An experimental setup for convective drying is developed. Mass and physical dimensions of the potato were measured every 20 minutes during drying. The product changed its length upto 30% and breadth and width are changed upto 47.5%, almost half of its dimension. In volume wise the potato has the maximum voulme loss of 81.56 % at 70 ^{0}C. By using this experimental procedures one can estimate the deformation of other biological products (apple, banana, garlic, mango, coconut and so on). It is concluded that the deformation and shrinkage of the product during drying is more important for any type of mathematical models.

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