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The Effect of Drying Kinetic on Shrinkage of Potato Slices

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ABSTRACT

Objective: Potato is the fourth important food crop after wheat, rice and maize. Shrinkage of food materials has a negative consequence on the quality of the dehydrated product. The main objective pursued in this paper is to investigate the shrinkage amount of potato slices during drying process using vacuum-infrared method. **Methods:** In this work, the effect of the infrared radiation powers (100, 150 and 200 Watt) and absolute pressure levels (20, 80, 140, 760 mmHg) at different thickness (1, 2 and 3 mm) on bulk volumetric shrinkage were investigated. **Results:** Data analysis showed that shrinkage percentage decreased with decrease of sample thickness and increase of infrared power. It was found that either thickness or infrared power had any significant effects ($P < 0.01$) on shrinkage of potato slices in this drying system. The regression model is a three-variable linear that Coefficient of determination is 0.532 and implies that the model can explain 53.2 % of the volume ratio changes.

1.INTRODUCTION

Potato (*Solanum tuberosum L.*) is one of the unique and most potential crops having high productivity, supplementing major food requirement in the world. It is rich in carbohydrates, proteins, phosphorus, calcium, vitamin C and β-carotene and has high protein calorie ratio. Amongst the world's important food crops, Potato is the fourth important food crop after wheat, rice and maize because of its' great yield potential and high nutritive value. The ratio of protein to carbohydrate is higher in potato than in many cereals and other tuber crops (Marwaha et al., 1999). It constitutes nearly half of the world's annual output of all root and tuber crops and has always remained in the top ten since last twenty years. India ranks fourth in area with 14 lakh hectares and the third largest country in the world in production of potato after China and Russian federation with a production of 294.94 million tonnes and productivity of 17.86 tonnes per hectare.

Drying is one of the oldest and known methods of preserving fruits and vegetables. In drying operation, possibility of microbial corruption and velocity of other detrimental reactions is lessened to a great extent due to the reduction of moisture. Moreover preserving product, drying reduces volume and weight of product as well. Drying is generally carried out for two main reasons, one to reduce the water activity which eventually increases the shelf life of food and second to reduce the weight and bulk of food for cheaper transport and storage. Drying methods can be broadly classified into solar drying and mechanical drying. One method of mechanical drying is infrared drying under conditions of vacuum. In infrared drying, special infrared lamps are used to extract

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moisture from the material being dried. In this method, the air surrounding wet matter flows using a suction device (vacuum pump) to remove humidity released by the matter from its vicinity in order for it to face less resistance while avoiding material surface saturation with dump. In conditions of vacuum due to lack of oxygen in dryer ambiance and unwanted reduction of reactions in food, the quality of dried food in this method is higher than the others (Motevali et al., 2011). Also applying vacuum in food drying causes expansion of air and vapour and creates puff state in the matter. Using fruits dried chips has highly been developed in recent years. Chip of fruits and vegetables, which are classified at the group of dried fruits and nut and consumed as refreshments, has nutritional value. In drying fruits and vegetables chips, size and tissue of materials will tolerate noticeable change due to the exit of moisture in a way that change in size and type of shrinkage of product leaves high effect on marketability and desirability of the product.

One of the most important physical changes that the food suffers during drying is the reduction of its external volume. Loss of water and heating cause stresses in the cellular structure of the food leading to change in shape and decrease in dimension. Shrinkage of food materials has a negative consequence on the quality of the dehydrated product. Changes in shape, loss of volume and increased hardness cause in most cases a negative impression in the consumer (Mayor and Sereno, 2004). The removal of water during drying of biological products leads to cellular structural modifications due to reduced tension inside the cells. This phenomenon causes alterations in the shape and dimension of products. Such changes, according to Yan et al. (2007), affect the physical properties of products (including volume shrinkage rate) and modify the final texture and transport properties of dry foods. Shrinkage during dehydration of fruits and vegetables occurs when the viscoelastic matrix contracts into the space previously occupied by the water removed from the cells (Aguilera, 2003). Shrinkage has been studied by direct measurements with a calliper or micrometre or by changes in related parameters such as porosity and density. Park (1998) and Hernandez et al. (2000) proposed a linear relation for shrinkage of foods as a function of moisture content. Hatamipour and Mowla (2002) reported a linear correlation for volume change and empirical relation for axial contraction of carrots during drying in a fluidized bed dryer with inert particles.

The objectives of this research were to experimental study of drying kinetics considering the shrinkage of potato slices in a vacuum-infrared dryer.

2. MATERIALS AND METHODS

2.1. Experimental set-up

A laboratory scale vacuum-infrared dryer, developed at the Agricultural Machinery and Mechanization Engineering Laboratory, Shahid Chamran University (Iran) has been used. A schematic diagram of the apparatus for combined vacuum and infrared radiation drying system is shown in Fig. 1. The dryer consists of a stainless steel drying chamber, which is designed to withstand lower level of pressure; a laboratory type piston vacuum pump (JY IA-2, China), which was used to maintain vacuum in the drying chamber; an infrared lamp with power of 250 W (OSRAM, Slovakia), which was used to supply thermal radiation to a drying product; and a control system for the infrared radiator.

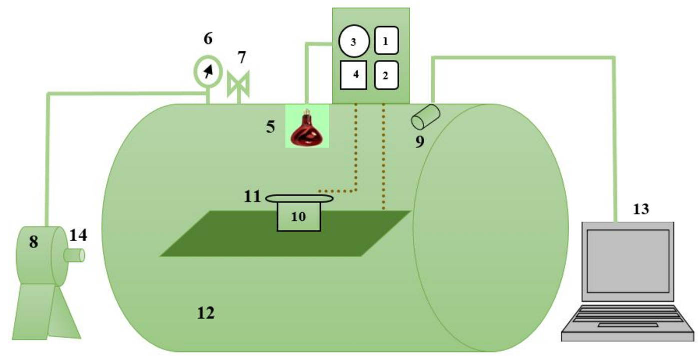

Fig. 1. A schematic diagram of a vacuum-infrared drying system: 1) humidity sensor; 2) thermocouples; 3) infrared lamp power controller; 4) voltmeter; 5) infrared lamp; 6) vacuum gauge; 7) vacuum break-up valve; 8) vacuum pump; 9) camera; 10) electronic weight scale; 11) sample tray; 12) drying chamber; 13) laptop; 14) air outlet duct.

2.2. Sample Preparation

Fresh potatoes to amount of 30 kg were purchased from a local market in Hamadan province (Iran). The samples were stored in refrigerator to prevent undesirable effect at about 4-6°C and relative humidity of about 85%. Potatoes were peeled, washed, and cut into sliced with thickness of 1, 2 and 3 mm by a manual slicer. The initial moisture content of the fresh samples was 77% (wet basis, wb), which was determined in triplicate by using a convection oven at 70° C for 24 h (AOAC, 1990). Experiments of drying of potato slices were performed in a vacuum chamber with absolute pressure levels 20, 80, 140 and 760 mmHg; infrared power of 100, 150 and 200 Watt. The distance between the infrared lamp and the sample tray was adjusted to 15 cm. The change of the mass of the sample during drying was detected continuously using an electronic weight scale (Lutron, GM- 1500P, Taiwan) with the accuracy of ±0.05 g. The temperatures of the drying chamber and of the drying sample were measured continuously using thermocouples (SAMWON ENG, SU-105KRR). At beginning of experiments, relative humidity and temperatures of the drying chamber were set on 35% and 50°C. The drying experiments were performed until the sample moisture content of 6-7% (w.b.) was obtained.

2.3. Theoretical Principle

To find a suitable mathematical model, the moisture content data at different thickness, absolute pressure levels and infrared power were converted to the moisture ratio (MR, dimension less) expression by using following equation.

$$MR = \frac{M_t - M_e}{M_o - M_e} \quad (1)$$

Where: MR is the moisture content ratio; M_t is the moisture content at any drying time wet basis (kg $_{water}$/kg $_{wet\ material}$); M_e is the equilibrium moisture content wet basis (kg $_{water}$/kg $_{wet\ material}$); M_o is the initial moisture content in wet basis (kg $_{water}$/kg $_{wet\ material}$);

2.4. Measurements of potato slices shrinkage

The shrinkage percentage is a drying quality assessing parameter and it must be least for better drying as it directly affects the rehydration quality of the dried product. The shrinkage percentage was calculated after determining the size of the potato slices before and after drying using liquid displacement method (Mohsenin, 1986). In this method for decrease of liquid absorption by dried sample from the toluene was used. For each measurement, three slices were randomly selected. Shrinkage of potato slices at the end of drying process was calculated using the following equation (Koc et al., 2008).

$$\%SKG = \left(1 - \frac{V}{V_0}\right) \times 100 \quad (2)$$

Where V_0 and V denote the initial and dried volume of the same potato slice, respectively.

4. RESULTS AND DISCUSSION

Linear regression is an approach for modelling the relationship between a scalars dependent variable Y and one or more explanatory variables denoted X.

Table 1.

Regression coefficients of the shrinkage ratio measured by liquid displacement

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	73.810	3.472		21.260	0.000
Thickness	4.696	0.913	0.622	5.145	0.000
Absolute pressure	-0.002	0.014	-0.019	-0.160	0.874
Power	-0.058	0.018	-0.381	-3.154	0.003

a. Dependent Variable: Shrinkage

With the use of results achieved over the three Repeaters; Table 1. Shows linear regression model to determine an empirical relationship between the shrinkage ratios measured using liquid displacement method and variable factors obtained. The regression model is a three-variable linear that Coefficient of determination is 0.532 and implies that the model can explain 53.2 % of the volume ratio changes.

Y= 73.810 + (4.696*T) - (0.058*IP)

Which in this equation, T is the slice thickness, IP is the infrared power and Y is the shrinkage value.

Fig. 2 and 3. Effect of thickness and infrared power on the potato slices shrinkage shows. In that, with decrease of sample thickness and also increase of infrared power, the shrinkage percentage was decreased.

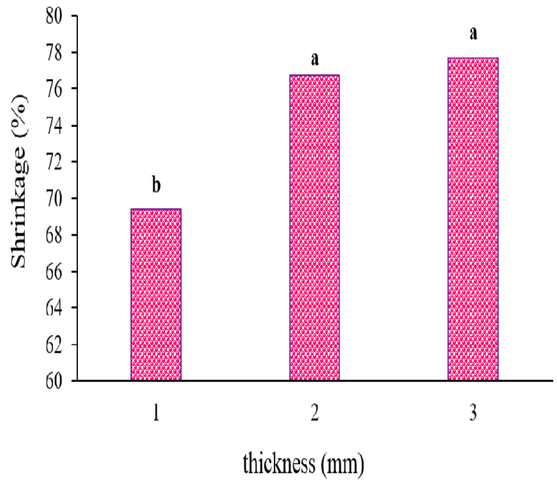

Fig. 2. Effect of thickness on the shrinkage percentage of potato slices in vacuum-infrared drying system

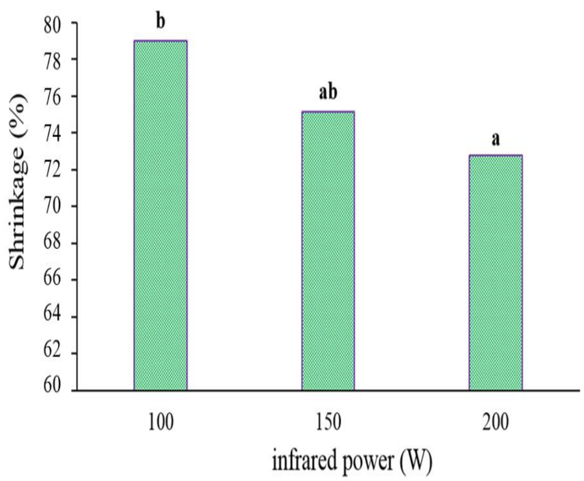

Fig. 3. Effect of infrared power on the shrinkage percentage of potato slices in vacuum-infrared drying system

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