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Studies of drying curves for different vegetables in cabinet dryer

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Abstract
Drying has been applied to vegetables to preserve, store and transport food products. However, drying involves not only physical changes, easily detectable by the consumer through visual evaluation, but also chemical changes. These are not always visible, but are responsible for changes in color, taste and nutritional value, which compromise the overall quality of the final product. The main chemical changes associated with drying are related to the degradation of phytochemicals, such as vitamins, antioxidants, minerals, pigments and other bioactive compounds that are sensitive to heat, light and oxygen. Furthermore, nutrient losses are certainly associated with leaching following the removal of water from the vegetable during the drying process. In this study, different vegetables (purple cabbage, broccoli, mustard leaves, spinach leaves and bottle gourd) were dried in cabinet drier and their drying times were standardized. It was concluded from the experiment that 8, 9, 4, 3 and 7 hours drying time of vegetables will be appropriate in terms of color, nutrition and retention of nutrients.

Keywords: Vegetables, dehydration, nutrition

Introduction

India's various climates ensure the accessibility of all varieties of fresh fruit and vegetables. India ranks second in fruit and vegetable production in the world, after China. In India, more than 40 types of vegetables belonging to different groups are grown in tropical, subtropical and temperate regions, such as belladonne, cucurbits, legumes, crucifers, tubers and leafy vegetables (Kumar *et al.*, 2013) [18]. According to the National Horticulture Database published by the National Horticultural Board of India, during 2018-19 India produced vegetables in an area of 10 099.82 million hectares with a production of 185883.22 tons as an efficient method to preserve and increase the shelf life of vegetables, also helping to facilitate storage and reduce transport and packaging costs. The process consists of reducing the water activity of the solid product, eliminating most of its water content. The water activity of the product is defined as the ratio of its partial water pressure to the vapor pressure of pure water at the same temperature (Serena Kundsen, 2007) [27]. Qualitatively, it is a measure of the water available in a system to support biological and chemical reactions. Water activity, glass transition temperature, and proton relaxation time of water are three concepts that have been used to determine system water performance. The relationships between the mobility of water and solids and the glass transition or water activity in food systems are critical to fully understanding the physical properties, sensory attributes and stability of food under storage conditions (Abdualrahman *et al.*, 2015) [1]. However, there is still a lack of studies linking the degradation of quality factors and molecular mobility over the useful life, with water activity being the simplest parameter to evaluate. Since microbial growth at room temperature generally requires water activity values between 0.90 and 1.00, dehydration is necessary to achieve the maximum acceptable level.

Water activity value for safe storage of vegetables is 0.60. Various drying methods have been proposed for preserving vegetables (Singh *et al.*, 2008) [29]. The oldest and most traditional is to place agricultural products on beaten earth, pavement or floor exposed to the sun. Although solar-based methods have economic benefits and are therefore widely used in tropical countries, product quality parameters and food safety issues often become difficult to monitor and control. Furthermore, products are vulnerable to contamination from dirt and dust, harmful insects and losses from birds and animals (Derossi *et al.*, 2008) [10].

Technological advances allied to scientific discoveries have been an engine for the food industry that seeks the development of new methodologies to meet the requirements of international standards in terms of food safety and at the same time provide an attractive product for the consumer (Boyer and Liu, 2004) [6]. Drying processes that are often used in the food industry employ at least one drying step, which results in products with a low residual liquid content, which gives high stability over long storage periods (Ahmed *et al.*, 2001) [2]. Conventional convection drying consists of using an air oven with a heater, a shielded propeller fan to distribute the hot air, and a drying chamber with one or more sample trays directly exposed to continuous hot air (Figiel, 2007) [114. A weighing system can be connected directly to the sample trays and weight changes due to moisture evaporation during dehydration can be recorded by connecting the scale to a computer with a data acquisition program. In general, large quantities of dried vegetables are obtained using industrial convective dryers (Farzaneh *et al.*, 2011) [13]. However, some drawbacks associated with this technique should be noted, such as the low processing speed, the significant loss of product quality and the high energy consumption due to the use of high temperatures.
The use of low drying temperatures can be a strategy to minimize and slow down harmful reactions and thus improve the quality of dry products. However, this approach can increase turnaround times such that drying costs become unacceptable. Therefore, taking into account the demand for innovative products in the market, this study was conducted to develop dry powder and its value-added products. The aim of this research is to focus on the drying time and behavior of different vegetables.

Materials and Methods

Raw materials

The vegetables *viz*., purple cabbage, broccoli, mustard leaves, spinach leaves and bottle gourd harvested at their optimum stage were obtained from the local market or from the local farm, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, H.P and used to conduct this study.

Methods and procedure

The drying experiments were conducted in a cabinet dryer previously described by Doymaz (2009) [11] at the University of Horticulture and Forestry Dr. YS Parmar, Nauni, Solan, H.P. The dryer was started approximately 60 minutes prior to the drying experiments to obtain steady state conditions before each drying cycle. The vegetables (leaves, flowers and slices (100 g)) were then arranged in a single layer on a perforated pan (2.4 cm thick). The drying experiments were conducted at a temperature of 60 ° C and an air velocity of 2 m / s. Moisture loss was recorded at 1 hour intervals during the drying process and weighed using a digital electronic balance. The drying process was stopped when the moisture content of the samples was balanced. The dried samples were then packaged in polyethylene bags, which were then heat sealed and stored at a refrigerated temperature. All drying experiments were performed in duplicate and the average moisture content at each value was used to draw the drying curves.

Physico-chemical analysis

The physico-chemical characteristics of raw vegetables and powders were obtained using standard analytical techniques (Ting and Rouseff, 1986; AOAC, 1996 and Ranganna, 2009) [30, 4, 26]. The total soluble solids (TSS) content of fresh and processed products was determined using a manual refractometer and sugars were estimated using the Lane and Eynon method as described above (Ranganna, 2009) [26]. Acidity was determined by titrating aliquots against 0.1 N NaOH to a pink end point using phenolphthalein as an indicator (Ranganna, 2009) [26]. Total phenols were extracted in 80% ethanol and calculated with the Folin-Ciocalteau reagent (AOAC, 1996) [4]. The antioxidant activity was analyzed by the free radical scavenging activity (Brand-William *et al*. 2005) [7].

Statistical analysis

Data obtained the chemical characteristics of fresh and processed products were statistically analyzed following the Completely Random Design (CRD) detailed earlier (Cochran and Cox, 1992) [8]. The determinations were made in triplicate for each attribute.

Result and Discussion

Data on the physico-chemical characteristics of fresh vegetables are presented in Table 1. Moisture content of purple cabbage, broccoli, mustard leaves, spinach leaves and bottle gourd were found to be (90.46 ± 0.87%), (87.94 ± 0.50%), (89.32 ± 0.02%), (90.02 ± 0.02%) and (96.29 ± 0.03%) respectively. The results were found to be similar to those observed by Hanif *et al.* (2006) [16] and Ogbede *et al.* (2015) [25]. Ash content was found to be highest in (6.89 ± 0.03%) mustard leaves and lowest in (0.59 ± 0.02%) bottle gourd. The antioxidant activity of vegetables were observed in 69.98 ± 0.01, 50.12 ± 0.01, 31.56 ± 0.03, 40.87 ± 0.12 and 29.73 ± 0.01 per cent respectively. The results of the antioxidant activity were almost on par with the observations of Kusznierewicz *et al.* (2008) [19] and Leja *et al.* (2010) [21]. Crude fibre was observed to be highest in mustard leaves and lowest in bottle gourd.

Table 1: Physico- chemical characteristics of raw vegetables

Parameter	Purple cabbage	Broccoli	Mustard leaves	Spinach	Bottle gourd
Moisture (%)	90.46 ± 0.87	87.94 ± 0.50	89.32 ± 0.02	90.02 ± 0.02	96.29 ± 0.03
Ash (%)	0.83 ± 0.15	0.96 ± 0.17	1.38 ± 0.12	6.89 ± 0.03	0.59 ± 0.02
Antioxidant activity (%)	69.98 ± 0.01	50.12 ± 0.01	31.56 ± 0.03	40.87 ± 0.12	29.73 ± 0.01
Crude fibre (%)	3.26 ± 0.13	2.42 ± 0.50	6.37 ± 0.02	2.12 ± 0.03	0.75 ± 0.28
Total phenols (mg GAE/ 100 g)	153.94 ± 0.02	149.8 ± 0.11	8.34 ± 0.03	41.03 ± 0.01	323.75 ± 0.02

Data on the physico-chemical characteristics of fresh powders are presented in Table 2. Moisture content of purple cabbage, broccoli, mustard leaves, spinach leaves and bottle gourd powders were found to be (8.60 ± 0.10%), (3.45 ± 0.01%), (5.28 ± 0.02%), (4.65 ± 0.02%) and (6.69 ± 0.01%) respectively. Similar results were reported by (Doymaz, 2009) [11] and Kaur *et al.* (2007) [17]. Ash content and crude fibre was found to be highest in mustard leaves and lowest in bottle gourd. The antioxidant activity and total phenolic content was observed to be highest in purple cabbage as compare to other vegetables, which were found to be in agreement with the reported values elsewhere Negi and Roy (2000); Neeha and kakade and (2014) and De Oliveira *et al.* (2015) [24, 23, 9].

Table 2: Physico- chemical characteristics of vegetable powders

Parameter	Mean ±Standard deviation				
	Purple cabbage	Broccoli	Mustard leaves	Spinach	Bottle gourd
Moisture content (%)	8.60 ± 0.10	3.45 ± 0.01	5.28 ± 0.02	4.65 ± 0.02	6.69 ± 0.01
Ash content (%)	5.23 ± 0.02	6.83 ± 0.20	11.05 ± 0.01	10.70 ± 0.10	2.35 ± 0.02
Crude fibre (%)	4.00 ± 0.50	12.20 ± 0.10	21.12 ± 0.02	20.02 ± 0.02	3.20 ± 0.10
Antioxidant (%)	51.23 ± 0.01	13.20 ± 0.10	36.40 ± 0.10	49.87 ± 0.01	30.12 ± 0.02
Total phenolic content (mg/ 100 g)	132.30 ± 0.10	9.70 ± 0.20	8.23 ± 0.02	11.70 ± 0.10	12.00 ± 1.00
Fat (%)	3.21 ± 0.02	1.84 ± 0.01	3.16 ± 0.01	3.50 ± 0.10	0.20 ± 0.10
Protein (%)	11.01 ± 0.01	31.72 ± 0.01	23.59 ± 0.01	21.50 ± 0.20	1.20 ± 0.10
Carbohydrates (%)	74.07 ± 0.01	46.59 ± 0.01	35.80 ± 0.10	39.63 ± 0.01	86.37 ± 0.01

Standardization of drying time for vegetables

Drying rates are defined as the amount of water removed per unit of time relative to the moisture content. It is evident that the drying rate continuously decreases with the moisture content. At the start of the drying process, the drying rate was very high and the drying rate continued to decrease as the moisture content approached the equilibrium moisture content. These included Madamba *et al*. (1996) [22] for garlic, Lee *et al*. (2004) [20] for chicory root slices, Akpinar (2006) [3] for aromatic plants and Erenturk *et al.* (2004) [12] for rosehip. No period of constant drying rate was observed in the drying curves and the whole drying process occurs in the period of descending drying. The data presented in Fig 1 show the drying time of purple cabbage, broccoli, mustard leaves, spinach leaves and bottle gourd there was a weight loss of 15.59, 13.60, 24.65, 26.32 and 33.25 per cent respectively after one hour, while after two hours there was almost the 50% weight loss, which is 73.10 per cent, 70.50 per cent, 49.89 per cent, 50.15 per cent and 77.68 per cent respectively in respective vegetables, Similar findings were reported by Doymaz (2009) [11] in spinach, and Gupta and Nath (1984) [15] have also reported the same results in spinach leaves and mint. There was no weight loss after complete drying Therefore 8, 9, 4, 3 and 7 hours drying will be done and selected these results were in agreement to those observed by Awogbemi *et al.* (2009); Negi and Roy (2004) and Singh *et al.* (2008) [5, 24, 29].

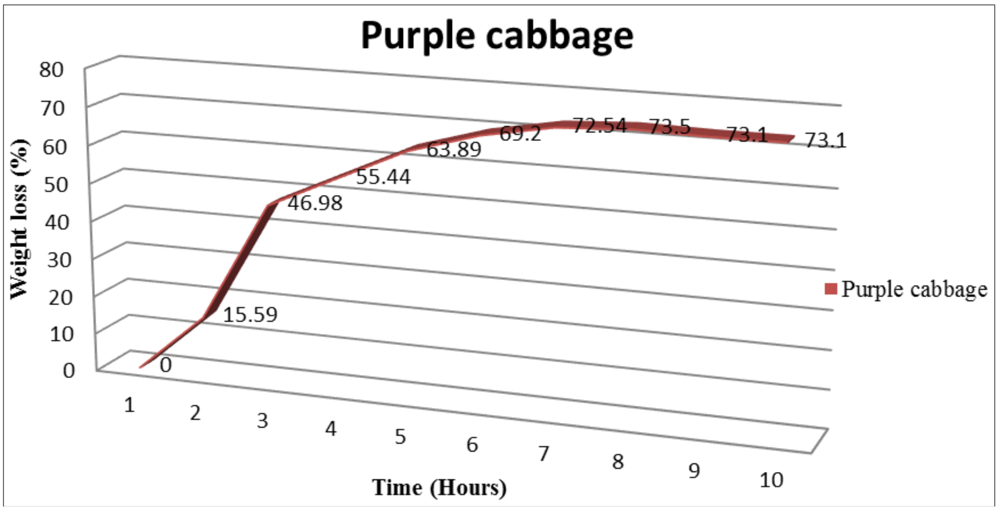

Fig 1: Drying curve of purple cabbage

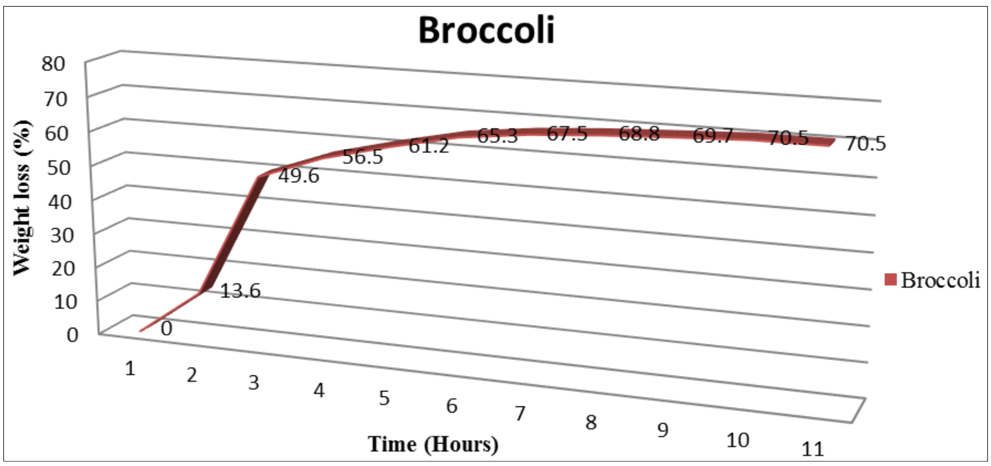

Fig 2: Drying curve of broccoli

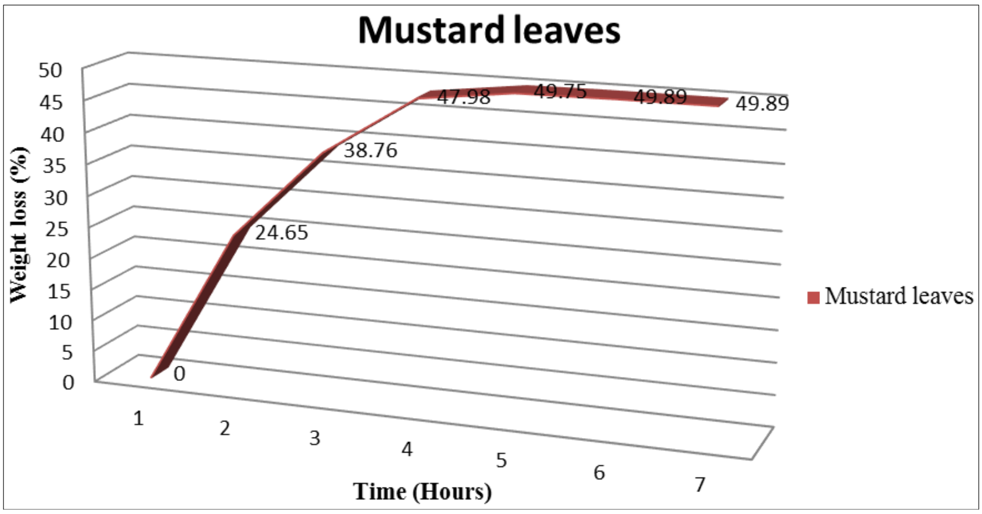

Fig 3: Drying curve of mustard leaves

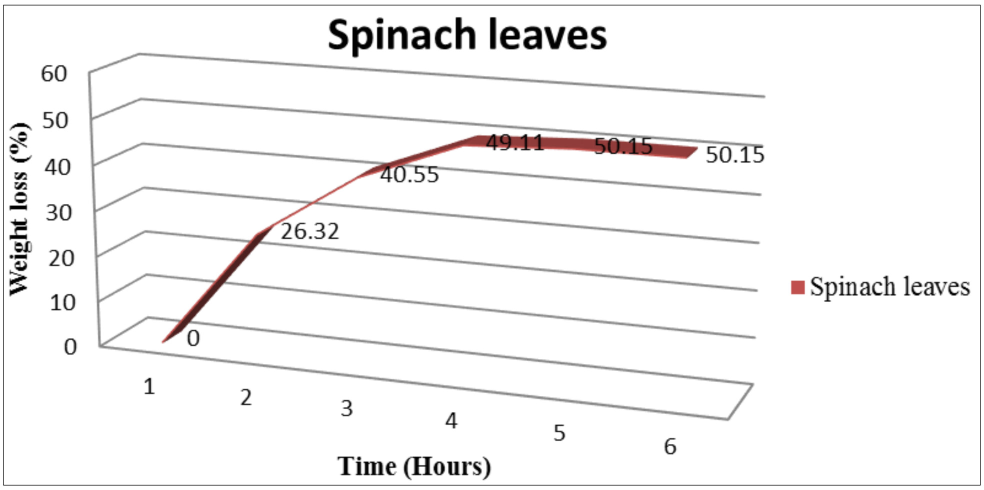

Fig 4: Drying curve of spinach leaves

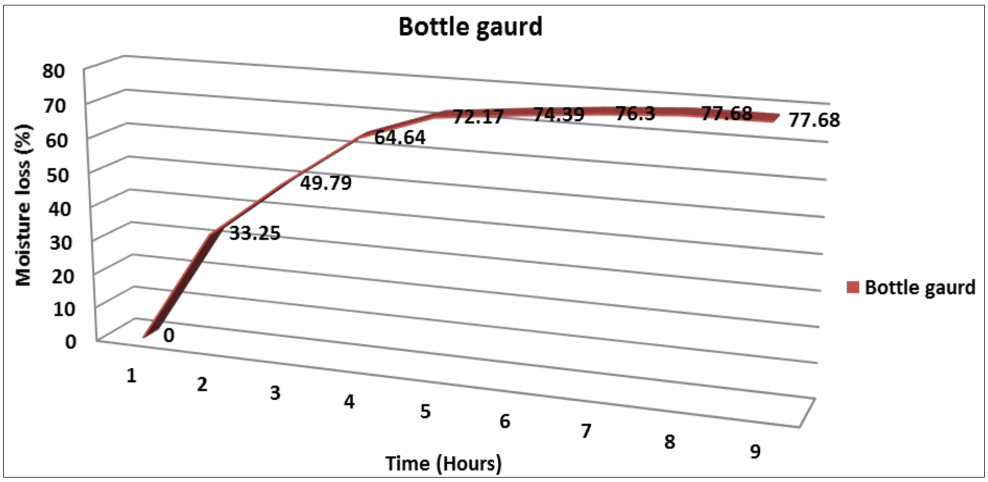

Fig 5: Drying curve of bottle gourd

Conclusion

The study concluded that the whole drying process of purple cabbage, broccoli, mustard leaves, spinach leaves and bottle gourd pieces took place in a falling rate period. It was concluded from the experiment that drying time of purple cabbage, broccoli, mustard leaves, spinach leaves and bottle gourd there was a weight loss after one hour, while after two hours there was almost the 50% weight loss, which is 73.10 per cent, 70.50 per cent, 49.89 per cent, 50.15 per cent and 77.68 per cent respectively in respective vegetables. There was no weight loss after complete drying Therefore 8, 9, 4, 3 and 7 hours drying will be done and selected.

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