ARTICLE IN PRESS

Journal of the Saudi Society of Agricultural Sciences (2015) xxx, xxx–xxx

King Saud University

Journal of the Saudi Society of Agricultural Sciences

www.ksu.edu.sa
www.sciencedirect.com

FULL LENGTH ARTICLE

The effects of drying conditions on moisture transfer and quality of pomegranate fruit leather (pestil)

Fatih Mehmet Yılmaz [a], Sultan Yüksekkaya [b], Hasan Vardin [b], Mehmet Karaaslan [b,*]

[a] *Adnan Menderes University, Engineering Faculty, Food Engineering Department, 09010 Aydın, Turkey*
[b] *Harran University, Faculty of Agriculture, Food Engineering Department, 63040 Şanlıurfa, Turkey*

Received 20 August 2014; revised 5 January 2015; accepted 8 January 2015

KEYWORDS

Pomegranate;
Fruit leather;
Drying kinetics;
Phenolic;
Ascorbic acid;
Thermal degradation

Abstract Vacuum, cabinet and open air drying of pomegranate fruit leather were carried out at various drying conditions to monitor the drying kinetics together with bionutrient degradation of the product. Drying curves exhibited first order drying kinetics and effective moisture diffusivity values varied between 3.1×10^{-9} and 52.6×10^{-9} m^2/s. The temperature dependence of the effective moisture diffusivity was satisfactorily described by an Arrhenius-type relationship. Drying conditions, product thickness and operation temperature had various effects on drying rate and final quality of the product. In terms of drying kinetics and final quality of product, vacuum drying had higher drying rate with higher conservation of phenolic, anthocyanin and ascorbic acid that is connected to faster drying condition and oxygen deficient medium. Anthocyanin content was significantly affected by drying method, drying temperature and product thickness. Scatter plot using principle component analysis enabled better understanding of moisture transfer rate and anthocyanin change under various drying conditions.

1. Introduction

Pomegranate is a highly demanded and economically important fruit crop native to the area surrounded by Anatolia, Persia, Caspian Sea and India. Pomegranate fruit supply and demand increased remarkably in recent years because of the increase of pomegranate plantation areas, elevation of pomegranate exportation rates to the European and American countries, publication of scientific reports depicting the functionality of the pomegranates (Stowe, 2011; Vegara et al., 2013; Boggia et al., 2013), and its desirable sensory

* Corresponding author. Tel.: +90 414 318 36 69; fax: +90 414 318 36 82.
E-mail address: mk385@cornell.edu (M. Karaaslan).
Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jssas.2015.01.003

characteristics such as bright red color, palatable aroma-flavor and beneficial natural compound content (Shahbaz et al., 2014). Pomegranate harvest takes place during late summer and fall seasons and harvested pomegranates are either freshly consumed or transferred to the factories for processing into various food products. There are more than 400 food products available for human consumption containing pomegranate fruit or its derivatives. Harvested pomegranates are stored in controlled or modified conditions to extend their supply time during the year. However controlled storage of the pomegranates causes increased cost and lowers producers' profit and thus most of the harvested pomegranates are processed into various products, mainly fruit juice and concentrate. Pomegranate juice can be utilized for the manufacturing of products from different sectors such as cosmetic products, fragrances, phyto-tablets, medications, alcoholic and non-alcoholic beverages besides many food-stuffs. Pomegranate fruits are also considered as functional food because of their high phenolic compound, vitamin and mineral contents (da Silva et al., 2013; Ferrari et al., 2010). Many reports showed the antioxidant activity and bioactivity of the pomegranates (Çam et al., 2009; Mousavinejad et al., 2009; Ozgen et al., 2008). Pomegranates were shown to have higher antioxidant activity than green tea or red wine (Gil et al., 2000). Pomegranate extracts were shown to inhibit proliferation of human liver cancer cell lines (Karaaslan et al., 2014a). Fruits, especially red ones, were determined as to be the dietary sources containing high amount of bioactive phenolic compounds. Thus, pomegranates have received considerable interest in recent years because of their abundant bioactive natural compound contents such as vitamin C, flavonoids, gallotannins, cyanidin, pelargonidin, delphinidin glycosides, (Mousavinejad et al., 2009; Gil et al., 2000; Seeram et al., 2006; Tzulker et al., 2007) and regular consumption of pomegranate is associated with cancer-chemotherapeutic effect (Malik et al., 2005) and prevention of chronic inflammation (Lansky and Newman, 2007). Therefore investigation and development of the novel products for the processing of excessive pomegranate fruits is necessary.

Pestil is a traditional fruit that is commonly produced in Anatolia, Armenia, Lebanon, Syria, Arabia and Persia and known with different names such as 'Bastegh', 'Qamar el deen', 'Bestil', and 'Fruit Leather'. Many fruits are used for pestil production such as grape, mulberry, apricot, pear, and kiwi-fruit. Pestil is a sweet product with high nutrient content such as mineral, vitamins and considered as a rich energy source because of its high carbohydrate content. The main steps in pestil manufacturing are production of fruit juice concentrate, pouring the pestil mix into molds at certain sample thickness and drying. The health promoting nature of the pomegranate pestil arises from its high functional compound content. The phenolic compounds and anthocyanins are the main groups contributing formation of antioxidative properties of pomegranate products. Nevertheless, very little is yet known regarding processing conditions of pomegranate pestil. The drying process and thickness of the fruit leather are the main factors influencing the quality of the final product. And thus, in the scope of this study the effects of three different drying methods which are vacuum, cabinet and open air drying, different drying temperatures (50, 60, 70 °C) and different product thicknesses (1, 2 and 3 mm) on pomegranate pestil drying rate and quality were investigated.

2. Materials and methods

2.1. Materials

Pomegranate juice concentrate (*Punica granatum* L. cv. *Hicaznar*) with 65 °Bx was kindly provided from Limkon Food Ind. and Trade Inc. (Adana, Turkey) in September 2012 and stored at 4 °C before commencement of pomegranate pestil (PP) production. Ethanol, gallic acid, 2,6-dichloroindophenol and ascorbic acid were purchased from Sigma Chemical Co. (St. Louis, Mo, USA). Folin–Ciocalteu reagent and sodium carbonate were obtained from Merck Co. (Darmstadt, Germany). All the chemicals were of analytical grade.

2.2. Preparation of pomegranate pestil

Pomegranate juice concentrate was firstly diluted to 40 °Bx with drinking water and transferred to a braiser. Then boiled water – starch mixture was added slowly to the braiser by agitating under moderate heating (~70 °C). At this point 30°Bx was reached and the concentration of the starch (wheat starch) was 5% of the mixture. The mixture was heated three more minutes. Then the mixture having 62.20 ± 2.10% (w.b.) moisture content was poured into stainless steel molds (10 cm in diameter) which were different in thickness (1, 2 and 3 mm) in such a way that molds were on clothes for a while, then the molds were removed and drying was carried out on the clothes. In the end of the drying, PP was removed from cloth by slight moistening to backside of the cloth.

2.3. Drying procedure

(1) Hot air drying was carried out within both cabinet dryer (Kendro, Germany) and vacuum dryer (Binder VD 23, Germany) at three different temperatures (50, 60 and 70 °C). Air velocity in the cabinet dryer was 1.2 m/s. A vacuum pump (KNF Neuberger N810.3FT.18, Germany) was employed to create necessary vacuum (85 kPa) in vacuum dryer. During drying, moisture loss was recorded at 10 and 15 min time intervals for cabinet and vacuum drying, respectively till samples reach 0.02 moisture ratio (MR; a unitless parameter defining the ratio of moisture content at any time during drying to initial moisture content).

(2) Sun drying was carried out under direct sun light in September 2012 in Şanlıurfa. The average and maximum outside temperatures were 26.8 and 32.8 °C, respectively and air velocity was 1.4 m/s.

Sampling was done from each experiment at the time when samples reached to 0.02 MR, and samples were stored at −20 °C in falcon tubes until analyses.

2.4. Drying curves, calculation of effective moisture diffusivity and activation energy

Fick's second law is a widely appreciated equation to be used to explain the drying process occurring in the falling rate period for majority of the organic materials (Saravacos and Charm, 1962; Sablani et al., 2000; Saravacos and Maroulis, 2001). Fick's diffusion equation for slab geometries (Crank, 1975) is as follows: