Journal of Food Engineering xxx (2017) 1–9

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Applicability of ohmic heating assisted vacuum evaporation for concentration of sour cherry juice

Serdal Sabanci [a, *, 1], Filiz Icier [b]

[a] Ege University, Graduate School of Natural and Applied Sciences, Food Engineering Section, Bornova, Izmir, Turkey
[b] Ege University, Faculty of Engineering, Department of Food Engineering, Bornova, Izmir, Turkey

ARTICLE INFO

Article history:
Received 18 August 2016
Received in revised form
7 February 2017
Accepted 4 June 2017
Available online xxx

Keywords:
Fruit juice
Voltage gradient
Electrical conductivity
Heat generation

ABSTRACT

Sour cherry juice having total soluble solids (TSS) of 19.2% was evaporated up to 65% TSS at vacuum (gauge pressure of 580 mm-Hg) by applying ohmic heating at three different voltage gradients (10–14 V/cm). Total process times were determined as 40, 55, 75, and 85 min for 14 V/cm, 12 V/cm, and 10 V/cm, and vacuum evaporation (VE), respectively. The change of moisture content during ohmic assisted vacuum evaporation and VE processes were investigated by seven different empirical models. The best fitting model was Midilli model for three different voltage gradients and VE. The electrical conductivity values at different voltage gradients varied between 0.41 and 1.13 S/m for different TSS contents. The changes of EC values were examined in detail for three different regions; heating up period, first evaporation period, and second evaporation period. EC increased until a critical % TSS content (32% TSS), then remained constant for certain time (until 45% TSS) depending on voltage gradient, and then it had tendency to decrease. Ohmic heat generation increased sharply during heating period, then decreased dramatically during evaporation periods. It is recommended that ohmic heating could be alternatively used as the heat source to shorten the process times of vacuum evaporation applied for concentration of fruit juices.

1. Introduction

Sour cherry production was reported as 1,177,418 tones for 2012, 1,410,354 tones for 2013 and, 1,362,231 tones for 2014 around the world according to FAO data. Turkey also an important and placed 3rd sour cherry producer with 182,577 tones for 2014 (Anonymous, 2017). It indicates that Turkey produced the 15% of whole sour cherry stock for all around the world. The half of sour cherry production in Turkey was utilized as sour cherry juice (Damar and Ekşi, 2012).

The harvesting period of fruits is very limited, therefore the harvested fruits are processed to fruit juice, jam, and canned fruit. Fruit juices were usually concentrated to extend their shelf life. The concentrated fruit juices have higher resistance to microbial growth than non-concentrated ones due to reduction in water activity. The concentration process also reduces the volume of fruit juice, and consequently derives the reduction of transport, storage, and packaging costs (Cassano et al., 2003; Onsekizoglu et al., 2010). However, the formation of undesired components and loss in quality characteristics are identified in the case of thermal evaporation method. Novel methods like membrane concentration and freeze concentration have been investigated as alternative concentration methods. But in these cases, it was reported that high operational and installation cost were revealed in addition to the problems for reaching up to high TSS values by these methods (Cassano et al., 2007; Onsekizoglu, 2013; Ramteke et al., 1993).

The most common evaporation method that utilized in industry was vacuum evaporation process. Researches on alternative heating techniques have been done to prevent formation of undesired component and to minimize quality losses during the vacuum evaporation process. For this purpose, double or triple effect evaporators have been designed to enhance the performance characteristics of vacuum evaporation process at lower temperatures (Cemeroğlu, 2011; Geankoplis, 2003). Additionally, microwave system has been integrated to vacuum evaporation process to use the energy more efficiently and to characterize the change of total solid soluble content during evaporation period (Assawarachan and Noomhorm, 2011; Yousefi et al., 2011). In recent

* Corresponding author.
E-mail address: serdalsabanci@hotmail.com (S. Sabanci).
[1] Present address: Food Engineering Department, Faculty of Engineering, Munzur University, 62100 Tunceli, Turkey.

http://dx.doi.org/10.1016/j.jfoodeng.2017.06.004
0260-8774/

study, Bozkir and Baysal (2017) investigated the concentration of apple juice from 11% TSS to 65% TSS in vacuum microwave evaporation system under absolute 500 mbar pressure with applied power of 668 W. They reported that vacuum microwave process had higher evaporation rate, and led to lower HMF formation and quality (total phenolic content, colour, titratable acidity) losses than those obtained in rotary evaporator and rising film evaporator systems.

In the present study, the ohmic heating was integrated to vacuum evaporation system as a novel method to reduce total process time by using the energy more efficiently.

Ohmic heating has a principle of passing of alternative current through the foodstuff contacted with two electrodes and using it as a resistance. Researchers have reported the use of ohmic heating method in processing of liquid foods for different purposes such as heating (Bozkurt and Icier, 2009; Yildiz et al., 2010), pasteurization-sterilization (Achir et al., 2015; Cho and Chung, 2016), evaporation (Darvishi et al., 2015), thawing (Icier et al., 2016; Roberts et al., 2002), cooking (Bozkurt and Icier, 2010a,b; De Halleux et al., 2005; Zell et al., 2011) and distillation (Gavahian et al., 2016) etc.

It has been reported that ohmic heating provided homogenous temperature distribution during the heating of different kinds of liquid products (Icier and Ilicali, 2004a, 2004b). The relations between electrical conductivity values and temperature during ohmic heating have been described by linear model in numerous studies (Darvishi et al., 2013, 2011; Icier and Ilicali, 2005, 2004b; Sarang et al., 2008). Ohmic heating could be used as an alternative heating method since particularly shorter heating times, better conservation of quality characteristics, and higher energy and exergy efficiencies have been reported for ohmic heating compared to conventional methods (Darvishi et al., 2015; İçier, 2003).

In recent years, ohmic evaporation has been investigated to be employed under atmospheric conditions by some researchers. It has been utilized for the purposes of distillation of sea water (Assiry, 2011), pre-drying of tomato paste (Hosainpour et al., 2014), and production of tomato paste (Boldaji et al., 2015). Hosainpour et al. (2014) applied different voltage gradients (6–16 V/cm) under atmospheric conditions. They reported that ohmic heating reduced the pre- drying time of tomato paste about 80–97% compared to the oven drying at 105 °C. Similarly, Boldaji et al. (2015) applied ohmic heating (6–14 V/cm) to tomato paste until reaching 30% TSS content under atmospheric conditions. They discussed that electrical conductivity value had variations in a wide range (3.19–8.95 S/m), and this variation was related with temperature and moisture content. However, these researchers have studied with relatively small amount of sample (25 g) in a laboratory scale atmospheric ohmic heating apparatus, and conducted the concentration process up to 35% total soluble solids (TSS) content. In addition, Assiry (2011) accomplished desalination of seawater under high voltage gradient (24–87 V/cm) at atmospheric conditions, and determined the changes in electrical conductivity values.

There is limited study on the subject of vacuum evaporation and ohmic heating assisted methods in open literature. Gaily (1999) had designed a cylindrical ohmic vacuum evaporation system for pine apple juice. Similarly, Wang and Chu (2003) discussed that vacuum evaporation by ohmic heating could have evaporated more moisture than a conventional process in the same time. However, it could not be possible to get access on the detail information for these studies in open literature. Icier et al. (2017) investigated the change of electrical conductivity (EC) values during the ohmic assisted vacuum evaporation process of pomegranate juice at different voltage gradients (7.5–12.5 V/cm) up to 40% TSS content under constant absolute condition (180 mm-Hg). They reported that EC values increased as the temperature increased during the heating up period. During evaporation period, it increased up to a certain TSS content, and then it showed a decreasing pattern. There is limited information about the change of concentration and electrical conductivities during the application of ohmic heating in vacuum conditions for the purpose of concentration of fruit juices up to higher total soluble solids (TSS contents of 65%), in open literature to the best of authors' knowledge.

In this study, ohmic heating was integrated to vacuum evaporation system, and applicability of ohmic heating assisted vacuum evaporation (OVE) process at three different voltage gradients was investigated. The effects of voltage gradient on changes of total process time to reach 65% TSS, the heat generation rate, and the electrical conductivity (EC) values during the evaporation process were determined. In addition, the change of concentration of the juice depending on time was characterized for different voltage gradient applications.

2. Material and methods

2.1. Material

Sour cherry juice, in the form of non-concentrated pasteurized sample, were supplied from a fruit juice producing company, and poured into 300 ml bottles. Total soluble solids content of sour cherry juice was 19.2 ± 0.2%. Samples in bottles were frozen until their center temperatures reach to −18 °C by using air blast type freezer at −30 °C (Electrolux, Sweden). Before each replication of the evaporation process, frozen sample in the bottle was thawed until its center temperature reach to 4 °C in the refrigerator (+4 °C) for 24 h. Then, thawed sample was poured to the process vessel inside the process chamber (Fig. 1), and agitated (15 ± 1 rpm) at 25 °C and at atmospheric pressure to accomplish uniform temperature increase in the sample. The uniformity of the temperature was checked before the concentration process. The evaporation process was started when the uniform temperature of sample reached to 20 °C.

2.2. Evaporation methods

Two different evaporation methods were applied in the same custom designed system (Fig. 1). Ohmic heating integrated pilot scale vacuum chamber system consisted of a vacuum chamber, a vacuum pump, a power supply with the isolating-variable transformer (0–380 V), and a microprocessor board. It had also an integrated conventional heater (1.1 kW, Şanal, Turkey) used for vacuum evaporation process without applying ohmic heating in the same system. The inside dimensions of Polytetrafluoroethylene (PTFE) process vessel (0.160 m × 0.07m × 0.07m) and titanium electrodes (0.07m × 0.075m x 0.003m) were used for OVE. 370 ml of sour cherry samples were heated up from 20 °C to 65 °C, and evaporation process was conducted under constant absolute pressure (180 mm-Hg). The conventional heater was utilized as the heat source in vacuum evaporation (VE) method while ohmic heating assisted vacuum evaporation (OVE) was applied at three different voltage gradients (10 V/cm, 12 V/cm, and 14 V/cm) by using power supply with the isolating-variable transformer.

The temperatures were measured by immersing T-type thermocouples (Cole Palmer, UK), which their tips were coated with PTFE, into juice sample. The ohmic heating provided homogeneous temperature distribution (±0.1 °C in the sample). Custom made microprocessor recorded voltage, current, and temperature data for time period of 1 s. Sour cherry juices were evaporated until reach to TSS content of 65%.

Please cite this article in press as: Sabanci, S., Icier, F., Applicability of ohmic heating assisted vacuum evaporation for concentration of sour cherry juice, Journal of Food Engineering (2017), http://dx.doi.org/10.1016/j.jfoodeng.2017.06.004