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Effect of carbonic maceration on infrared drying kinetics and raisin qualities of Red Globe (*Vitis vinifera* L.): A new pre-treatment technology before drying

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ABSTRACT

Effects of carbonic maceration (CM), dipping in alkaline emulsion of ethyl oleate solution (AEEO) and dipping in AEEO then freezing at −18 °C for 12 h (AEEO + Freezing) on infrared drying kinetics of red grapes and properties of raisins were investigated. The results indicated that the raisin of CM treated samples had the shorter production time, the highest total phenol content, the best oxidation resistance ability, and the best rehydration ratio, which increased by −31%, 28.43%, 73.9% and 32.24%, respectively, as compared to the raisins from fresh samples. CM treated samples had the greatest incremental of lenticel size, followed by AEEO + Freezing and AEEO samples. The bigger the lenticel size, the greater was the drying rate.

Industrial relevance: The carbonic maceration (CM) technique before drying – a new pre-treatment technology presented in this paper – can greatly increase the drying rate and improve the quality of products, meanwhile, it is free of any chemical reagents, which is friendly to the environment. So CM process technology prior to drying is of commercial potential if it is used in industry.

1. Introduction

Drying to produce raisins from Red Globe grape (*Vitis vinifera* L.) is a very slow process, due to the thick structure of grape peel (Mahmutoğlu, Emír, & Saygi, 1996). In order to shorten drying time, several pre-treatments before drying, such as blanching (Chan, Lim, & Wong, 2009), freezing (Pangavhane, Sawhney, & Sarsavadia, 1999) and dipping in ethyl oleate or citric acid (Al-Khuseibi, Sablani, & Perera, 2005; Doymaz & Kocayigit, 2011), have been suggested.

The main aim of this work was to develop an efficient and safe pre-treatment in view of the increasing interest in minimally using chemical reagents on food products. At this point, the carbonic maceration process – a novel pre-treatment – is presented. Invented by Flanzy, Flanzy, and Benard (1987), carbonic maceration involves placing the intact grape clusters into a closed tank with a carbon dioxide-rich atmosphere. CM technique has been used in cabernet, grape juice and sugar production (Alnia, Zabihi, Esmaeilzadeh, & Kalajahi, 2010; Gunes, Blum, & Hotchkiss, 2005). Now we use it in raisin-making of Red Globe grapes because an intracellular fermentation and a CO_2 impregnation in the fruits and vegetables occur under the rich CO_2 anaerobic conditions, which make the plant tissue loose while keeping the fruit intact, thus enhancing the drying rate (Liu, Guo, Zhao, & Wang, 2012). In addition, the CM process does not need any chemical reagents and it is an environment-friendly pre-treatment method.

Fruits lose water as vapour during drying. The major portion of water loss from fruits evaporates through stomata or lenticels (Makeredza, Schmeisser, Lötze, & Steyn, 2013). Lenticels are pores on vascular plants that are necessary for the exchange of gases to and from the plant. Lenticel movement occurs during the stress injury conditions such as high temperature, drought and anaerobic treatment, which induces change of the lenticel size (Meidner & Mansfield, 1965), thus affecting the drying rate. Therefore, in this study, the lenticel sizes of red grapes were focused on for the first time in the field of drying.

The purpose of this work was to compare the effect of CM pre-treatment with two other conventional pre-treatments, namely, AEEO and AEEO + Freezing, on infrared drying kinetics of red grapes and on the properties of the raisins. Infrared drying was used as the base drying approach.

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2. Materials and methods

2.1. Materials

Fresh Red Globe grapes (*V. vinifera* L.) were purchased from a local supermarket, Beijing, China. The fresh grape berries with uniform size and colour and without surface damage or diseases were selected as experimental materials and stored at 4 ± 0.1 °C and relative humidity (RH > 95%) until used in the experiment. The average weight of red grape berries was 10 ± 0.46 g each with diameter of 15 ± 0.97 mm. The initial moisture content was 7.62 ± 0.08 g water/g dry matter (db) according to the AOAC (1990).

2.2. CM pre-treatment

Before CM, the grape berries were dried for 6 h at 70 °C in an infrared oven (Senttech Infrared Science and Technology Company, Taizhou, Jiangsu, China) to remove the partial water, otherwise, the grape peel will fracture during the maceration. In addition, three bunches of grape berries (about 100 g each) were put into three maceration tanks each, and in each tank 105 g of yeast solution was added, then CM of the grapes was carried out under 0.3 MPa at 40 °C for 12 h, which was optimized by preliminary tests. The yeast solution consisted of 5 g of dry wine yeast (purchased from Angel Yeast Co., Ltd., Yichang, Hubei, China) and 100 g of Red Globe grape juice, which was extracted by a juice extractor (JYL-B060, Jiuyang Co. Ltd. Xuzhou, Jiangsu, China).

2.3. AEEO pre-treatment

The fresh grape berries were dipped in AEEO which was prepared by dissolving 5 mL ethyl oleate in 500 mL water and adding 15 g potassium carbonate for 5 min at room temperature before further used.

2.4. AEEO + Freezing pre-treatment

After AEEO, the samples were then packed in a plastic bag and placed in a refrigerator at −18 °C. After 12 h freezing, the samples were thawed at room temperature (about 25 °C) for 1 h before further use.

2.5. Infrared drying

Infrared drying (ID) of grapes was carried out at 70 °C in an infrared oven (Senttech Infrared Science and Technology Company, Taizhou, Jiangsu, China). The oven is heated by three infrared pipe lamps with a power level of 225 W each. The initial moisture contents of fresh and CM pre-treated red grapes were 7.62 ± 0.08 (dry basis) and 4.83 ± 0.03 (dry basis), respectively. Red grape berries (about 100 g) were evenly spread in a plastic basket and put into the oven cavity, where a temperature probe (platinum resistance thermal sensor, pt100) was located at about 30 mm above the grape samples, which was connected with a heating control unit. The samples were retrieved from the cavity and weighed every interval until they reached 0.25 ± 0.01 g water/g dry matter. Each experiment was repeated in triplicate.

2.6. Drying rate (DR)

DR (g water/(g dry matter ∗ h)) was calculated as follows,

$$DR = (M_{t+dt} - M_t)/dt \tag{1}$$

where M_t *and* M_{t+dt} are the moisture contents (db) at measuring time t and $t + dt$.

2.7. Rehydration ratio

Rehydration ratio (*RR*) was determined by soaking known weight (15–20 g) samples in 300 mL of water at room temperature (about 25 °C). At the end of the rehydration period, that is, 24 h, which was found to be adequate for the dehydrated grape berries to reach a constant weight, the berries were weighed after removing excess water with the help of absorbent paper. The *RR* was computed as follows (Mazza, 1983),

$$RR = \frac{M_r}{M_d} \tag{2}$$

where, M_r and M_d are the mass (g) of rehydrated and dehydrated samples, respectively.

2.8. Cell permeability

Cell permeability was determined according to the method described by Cao (2007). Conductance values of exudates were measured by using the DDS-11A type conductivity meter (Shenzhen Tong'ao Technology Co. LTD., Guangzhou, China).

Cell permeability (C_p) was calculated as follows,

$$C_p = \frac{C_1}{C_0} \times 100\% \tag{3}$$

where C_1 is the conductivity of extraction of the living tissue, and C_0 is the conductivity of extraction of dried samples after different pre-treatments.

2.9. Colour

Fresh samples were smashed into a slurry and the dried samples were crumbled into even pieces so that colour measurement could be conducted uniformly. A Hunter Lab-scan colorimeter was used (MS/S-4500L, Hunter Associate Laboratory Inc., VA, USA) to determine colour value according to Vega-Galvez, Lemus-Mondaca, Bilbao-Sainz, Fito, and Andres (2008). Colour was expressed in *L* (whiteness or brightness), *a* (redness/greenness) and *b* (yellowness/blueness). Three replicate measurements were performed and results were averaged. The total colour difference (△*E*) was calculated as follows (Gnanasekharan, Shewfelt, & Chinnan, 1992),

$$\Delta E = \left[(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2\right]^{0.5} \tag{4}$$

where, L_0, a_0 and b_0 are the values of fresh red grape. *L*, *a* and *b* were the values of raisins of red grape.

2.10. Total phenol content (TPC)

The TPC of raisin was assayed according to the Folin–Ciocalteu method of Singleton and Rossi (1965). In brief, the grape extract (0.4 mL) prepared in different concentrations was mixed with 2 mL of Folin–Ciocalteu reagent and 1.8 mL of sodium carbonate (7.5%) in test tubes. The tubes were kept at room temperature for 1 h after the solution in the tubes was manually shaken to homogeneous state. The absorbance at 765 nm was measured and used to calculate the phenol contents.

2.11. Determination of scavenging free radical capability

Antioxidant activity was evaluated by measuring the radical scavenging effect of grape methanol extracts on the 2,2-diphenyl-1-picrylhydracyl (DPPH) as reported previously by Singh, Murthy, and Jayaprakasha (2002) and Bamdad, Kadivar, and Keramat (2006).