Journal of Food Engineering 190 (2016) 94–100

Contents lists available at ScienceDirect

Journal of Food Engineering

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

Effects of ohmic pretreatment on crude palm oil yield and key qualities

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ARTICLE INFO

Article history:
Received 29 February 2016
Received in revised form
10 May 2016
Accepted 23 June 2016
Available online 25 June 2016

Keywords:
Crude palm oil
Free fatty acid
Ohmic heating
Pretreatment
Yield

ABSTRACT

Pretreatment is an important step that can increase the oil yield and improve the extraction efficiency of palm oil production. However, the conventional pretreatment method widely employed in the palm oil industry requires a relatively long time and high energy. In this research, ohmic heating was employed to pretreat oil palm fruit and the effects were studied of heating conditions on the hardness of the oil palm fruit, yield and qualities of the extracted crude palm oil. Oil palm fruits were ohmic heated using various heating conditions (temperature: 60–100 °C; voltage: 0–150 V; heating time: 2–10 min). Crude palm oil was then extracted from the heated samples using a screw extruder and determined for its qualities (free fatty acid, moisture content and deterioration of bleachability index). The results revealed that the voltage, temperature and heating time significantly affected the hardness of the pretreated oil palm fruit. Increasing the voltage, temperature and heating time resulted in an increase in the yield (maximum at 46%w/w) and improved the oil qualities. It was also found that ohmic pretreatment can reduce the heating time to 8 min and decrease the energy consumption of the process to 0.12 kW-h/kg. The results suggested that ohmic heating can be used as an alternative method for oil palm fruit pretreatment.

1. Introduction

Pretreatment is an essential process in crude palm oil (CPO) production. The process usually involves heating oil palm fruits until the outer shell (or mesocarp) of the fruits becomes soft in order to facilitate separation and the extraction process. Pretreatment helps not only to increase the oil yield but also to reduce the quantity of free fatty acid (FFA) which is formed by hydrolysis and accelerated by lipase and causes undesirable flavors and aroma (Osawa et al., 2007).

Sterilization is the method that is widely used to pretreat oil palm fruit. At the beginning of the process, oil palm fruits are loaded into a closed vessel that is connected to the steam pipeline. Heat is transferred from steam to the oil palm fruits at 140 °C for about 75–90 min (Vincent et al., 2014). It is important that an adequate amount of heat is supplied to the palm fruits to inactivate lipase and control the free fatty acid content (Ngando Ebongue et al., 2006). Then, the oil palm fruits are conveyed to a separator machine to remove the very hard palm kernel from the mesocarp. The separated mesocarp is then passed into an extractor where the CPO is finally extracted.

Though the process of sterilization is simple and convenient, the main disadvantages are it consumes a large amount of energy and requires a long heating time, so that many alternative methods have been used to pretreat oil palm fruits such as continuous sterilization, dry heating and microwave heating (Chow and Ma, 2007; Hadi et al., 2012; Sivasothy et al., 2005). However, each method still has some disadvantages. For example, while continuous sterilization offers a significant reduction in labor and manpower, it may require high investment and a long operation time (Chow and Ma, 2007; Vincent et al., 2014). Recently, microwave heating was employed to pretreat oil palm fruits and the heating time was reduced to less than 10 min. However, the process had relatively low energy efficiency (Cheng et al., 2011). Choto et al. (2014) employed radio-frequency heating (RFH) to pretreat oil palm fruits and reported that RFH effectively reduced the incremental rate of free fatty acid (FFA) in extracted palm oil during a storage period of 8 d. The energy efficiency of the RFH process was slightly higher than that of microwave heating. Nevertheless, it was still low as the maximum value was found to be only around 30%.

Ohmic heating is a rapid volumetric heating method. In this process, electric current is passed into a foodstuff and heat occurs

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http://dx.doi.org/10.1016/j.jfoodeng.2016.06.021
0260-8774/

inside the food due to its internal electric resistance. No heating medium is required in ohmic heating thus high energy efficiency is obtained with a tunable heating rate (Varghese et al., 2014). Moreover, according to Lakkakula et al. (2004), ohmic heating could also improve the oil yield in the extraction process. However, no research reports on the effect of ohmic heating on the yield and quality of extracted CPO are available. Thus, in this study, ohmic heating was employed to pretreat oil palm fruits. The effects of the voltage, temperature and heating time on the oil palm fruit texture, yield and quality of CPO extracted from oil palm fruit as well as the energy consumption of the process were investigated.

2. Material and methods

2.1. Oil palm fruit collection

Fresh “Tenera” oil palm fruits were collected from an oil palm plantation in Ratchaburi province, Thailand. The average weight of one fruit was 14 ± 2.0 g with an average diameter of 2 ± 0.5 cm. The color of fruit samples used in this research was specified to be mostly orange in order to control variation among samples. All chemicals used in this research were analytical reagent grade and purchased from Ajax Finechem (New Zealand).

2.2. Ohmic heating apparatus

The ohmic heating system consisted of a voltage regulator (0–250 V, 50 Hz), a rectangular, ceramic, ohmic cell and a temperature controller equipped with a 3-wire RTD platinum sensor (see Fig. 1). The temperature, voltage and electric current were recorded using a data logger (Sangchaimeter, RP3430, Thailand). First, about 300 ml of water was poured into the ohmic cell and preheated. Then, 220 g of oil palm fruit were placed into the preheated water and held at a constant temperature (60, 80 and 100 °C) for 0–10 min under two different voltages (75 or 150 V). At the voltage higher than 150 V, the electrode corrosion was observed, probably due to too high electric current density. Therefore the maximum voltage was set to 150 V. It should be noted here that the oil palm fruit was raised to the same temperature as the water temperature within about 20 s. For comparative purposes, groups of oil palm fruit samples having the same weight were also heated in a water bath at the same temperature and for the same holding time.

2.3. Measurement of texture

The maximum hardness of the treated sample was measured using a texture analyzer (Lloyd, LR5K, UK) with a load cell of 500 N. Each sample was compressed to 7% of its original height using a 35 mm circular plate at a speed of 60 mm/min.

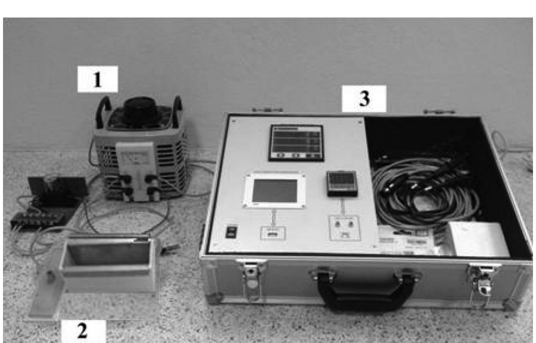

Fig. 1. Ohmic heating system.

In order to examine the sample morphology, the sample was cut into small pieces (about 1 cm in length) and the photographs were taken using a light microscope (Olympus, CHS, Japan).

2.4. Extraction of crude palm oil (CPO)

CPO was extracted from the mesocarp of the samples using a screw-press extruder and impurities were removed using a 10 μm filter. Yields of CPO were reported in %w/w calculated from the ratio between the weight of CPO and the weight of the mesocarp used in the extraction process. Samples were collected in dark-brown glass bottles and kept at −18 ± 2 °C.

2.5. Analysis of free fatty acid (FFA) content

FFA was analyzed by titration using a modified method described by AOCS (1992). Firstly, the CPO sample was diluted in neutralized ethanol solvent. Then, 0.1 N sodium hydroxide solution was dropped into the diluted sample and phenolphthalein was used as an indicator to detect the end point. The percentage of FFA content was calculated using Eq. (1):

$$FFA\ (\%w/w) = \frac{V \times N \times 25.6}{m} \tag{1}$$

where V and N are the volume and concentration of the employed sodium hydroxide solution, respectively, and m is the mass of the sample used (5 g). The percentage of FFA in CPO was calculated as palmitic acid and interpreted as the weight of NaOH (in milligrams) required to counteract acid from the 5 g sample.

2.6. Determination of moisture content

About 10 g of crude palm oil sample was placed in an aluminum can and kept in an oven at about 110 °C and the moisture content was determined using Eq. (2):

$$MC\ (\%w/w) = \frac{m_b - m_a}{m_b} \times 100\% \tag{2}$$

where m_b and m_a are the mass of palm before and after drying in the oven, respectively.

2.7. Measurement of deterioration of bleachability index (DOBI)

The DOBI was measured using a method described by Lin (2004). About 0.1 g of oil was weighed and dissolved in up to 25 ml iso-octane. The diluted oil solution was placed in a 1 cm quartz cuvette and absorbance readings were taken at 446 nm and 269 nm using a UV Spectrophotometer (Shimadzu, UV-1800, Japan). The DOBI value was defined as the ratio of the absorbance at 446 nm–269 nm (Eq. (3)):

$$DOBI = \frac{Abs_{446}}{Abs_{269}} \tag{3}$$

2.8. Determination of energy cost

The amount of energy consumed by ohmic heating (kW-h/kg$_{palm}$) was calculated by comparing the total energy supplied to the system (Q_{in}; kJ) to the total mass of oil palm fruits in one batch (m_p; kg) as shown in Eqs. (4.1) and (4.2):