Industrial Crops & Products 113 (2018) 135–141

Contents lists available at ScienceDirect

Industrial Crops & Products

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

Impact of pretreatments on the solid/liquid expression behavior of canola seeds based on the simplified computational method

Laurine Bogaert, Houcine Mhemdi*, Eugène Vorobiev

Sorbonne Universités, Université de Technologie de Compiègne, Laboratoire Transformations Intégrées de la Matière Renouvelable (UTC/ESCOM, EA 4297 TIMR), Centre de Recherche de Royallieu, CS 60319, 60203 Compiègne Cedex, France

ARTICLE INFO

Keywords:
Consolidation
Expression
Modeling
Flaking
Dehulling
Cooking

ABSTRACT

The impacts of expression parameters (pressure and temperature) and pretreatments (dehulling, flaking, cooking and their combination) on the consolidation behaviour of canola seeds were studied using a laboratory hydraulic press. It was demonstrated that the expression kinetics of treated seeds follows filtration-consolidation behaviour. For these samples, the simplified computational method used in this work allowed the determination of the filtration diffusivity (consolidation coefficient *b*). Results showed that flaking and cooking enhance the expression kinetics and increase the consolidation coefficient. However, dehulling reduces the pressing performance. Model adjustment showed that experimental data coincide reasonably well with the model for $\nu < 2.85$ demonstrating the co-existence of primary and secondary consolidation.

1. Introduction

Vegetable oil is a triglyceride extracted from plants and used since ancient times. Nowadays vegetable oils are used in foods, paints and for the production of renewable fuels.

Mechanical expression (pressing) and organic solvent extraction are the most used technologies for oil extraction. For canola seeds, the industrial process used for oil recovery is multistage (Bredeson, 1983). Seeds are first pressed using a screw press to obtain an oil of high quality and a press cake (meal) with high residual oil content (20–25%). The cake is then subjected to hexane extraction to recover the residual oil. Each technique of extraction has its benefits and drawbacks as far as operating cost, capital cost, yield and quality of the extracts are concerned.

Mechanical expression (pressing) is the oldest and the cheapest extraction technique (Khan and Hanna, 1983). It gives oil of outstanding quality but the oil yield is unsatisfying adversely affecting the economical profitability of the crushing process. Organic solvent extraction is very efficient for oil recovery. However, concerns about the solvent residues in the oleoresin products, the new regulations of volatile organic solvent emissions in the air, and the extent of further refining that is required after the extraction step restrain the use of this technology.

In order to improve the pressing efficiency, different pretreatments are usually applied before oil expression (Daun et al., 1993). In fact, oil is stored in small vesicles called oleosomes and enclosed in the intracellular medium (Lanoisellé, 1995). Cell rupture is necessary to facilitate oil expression. Oleosomes denaturation deeply facilitates oil releasing in the extracellular medium. Industrially, different pretreatments (e.g. flaking, dehulling, moisture conditioning, cooking) may be employed to damage oilseed structure and increase oil availability. These pretreatments can be applied separately or in combination (Carré et al., 2016; Savoire et al., 2013; Zheng et al., 2003). Oil expression efficiency depends on oilseeds variety, pretreatment methods and pressing conditions (pressure, temperature, duration). The impacts of these parameters on the extraction yield were intensively studied in the literature (Ward, 1984; Savoire et al., 2013). However, just a few studies have focused on the modeling of pressing behavior according to the applied pretreatment methods. Currently, most articles dealing with the simulation of mechanical expression from cellular materials adopt the filtration–consolidation theory initially developed for soils (Terzaghi, 1925; Suklje, 1969) and mineral filter cakes (Shirato et al., 1970, 1971, 1980, 1986). This theory provides a comprehensive approach for the description of liquid flow in compressible matrix of individually incompressible particles. In fact, the mechanism of solid–liquid expression from agro-food materials is very complex and the cellular materials structure is different from soils. Indeed, the biological tissues are compressible and they are often considered as triphasic systems where solid, liquid and gas phases (air) are present. The air is located between particles. The dissipation of the air and the cells damage during

* Corresponding author at: Université de Technologie de Compiègne, Département de Génie des Procédés Industriels, Laboratoire Transformations Intégrées de la Matière Renouvelable (UTC/ESCOM, EA 4297 TIMR), Centre de Recherche de Royallieu, CS 60319, 60203 Compiègne Cedex, France.
E-mail addresses: h.mhemdi@escom.fr, h.mhemdi@live.fr (H. Mhemdi).

https://doi.org/10.1016/j.indcrop.2017.12.053
Received 8 July 2017; Received in revised form 11 November 2017; Accepted 20 December 2017

pressing complicate the model and require the introduction of other assumptions and considerations to adapt existing models (Rebouillat, 1983). Lanoisellé et al. (1996) have developed an original model, called "Deformable Model in Three Volumes", which describes the mechanisms governing discontinuous pressing of cellular materials and particularly oil seeds (Lanoisellé et al., 1996). This model describes the different compression stages of the cellular particles, including extracellular and extraparticle volumes. Later on, other models were developed for the liquid expression from biological particles (see for example, Petryk and Vorobiev, 2007). Such phenomenological models are rather complex and need experimental determination of several interdepending parameters, which complicates the interpretation of experimental results. In this context, it was important to develop simplified computational models to characterize the pressing behavior on the base of filtration – expression diffusivity (Shirato et al., 1986; Rebouillat, 1983).

In this line, Grimi et al. (2010) and Mhemdi et al. (2012) have adapted the computational method of Shirato (Shirato et al., 1980, 1986) to characterize the pressing behavior of sugar beet cossettes computating consolidation coefficient b (m^2/s), which is filtration-expression analog of moisture diffusivity. It was shown that this model is applicable only if biological cells are damaged (thermally by heating and/or electrically by pulsed electric field) before pressing (Mhemdi et al., 2012). The applicability of this simple computational method for the oil seeds expression was not yet tested and should be checked. Additionally, it's important to characterize the impacts of seeds pretreatments on the expression behavior. In this line, the present work aims to investigate the effect of pretreatment methods on the expression yield and the consolidation behavior for canola seeds at the constant pressure. For this purpose, three pretreatments were studied individually and in combination: flaking, cooking and dehulling. The expression kinetics were followed and a semi-empirical model was used to predict the expression behavior and calculate the consolidation coefficient *b* under different pretreatments. The development of correlationship between the oilseed material properties and the oil recovery obtained under uniaxial compression would help researchers and designers to better evaluate the mechanical oil expression equipment and systems.

2. Materials and methods

2.1. Plant materials

Entire canola seeds, dehulled seeds and hulls were provided by the Technical center for oilseeds "TERRES INOVIA" (Pessac, France) after dehulling of canola seeds. According to the supplier, canola seeds being dehulled contain an average of 18.2 ± 1.3% hulls (w/w). Oil content was determined by hexane extraction according to international standard ISO 659:2009. It was estimated to 46.4 ± 0.34%, 58.12 ± 0.10% and 21.70 ± 1.70% in the entire seeds, the dehulled seeds and the hulls respectively. Moisture content was determined using an infrared desiccator (Scaltec, Germany) and was estimated to 10 ± 0.3% in the entire seeds, 5.34 ± 0.16% in the dehulled seeds and 14.15 ± 0.20% in the hulls.

2.2. Experimental set-up, pretreatments and pressing processes

2.2.1. Pre-treatments of canola seeds

2.2.1.1. Dehulling. Seeds dehulling was performed by OLEAD (Pessac, France) using a custom-designed impactor and sorter. Briefly, seeds are fed in the center of a rotating disk. Centrifugal force propels the seeds against the wall of the device, and the impact shatters the seeds. Dehulled seeds and hulls were then separated by air classification and sieving. The details of the dehulling process are available in Carré et al. (2016).

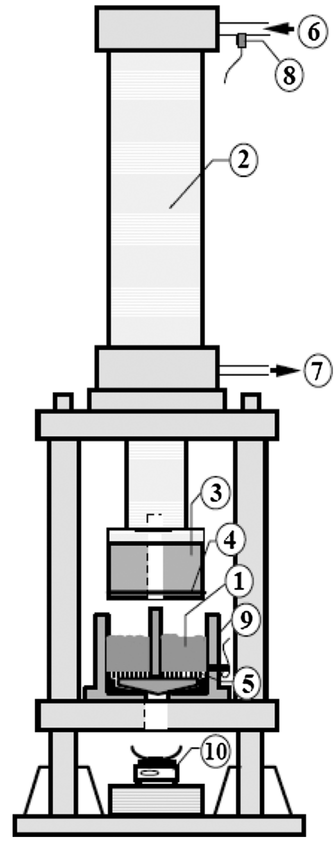

Fig. 1. Experimental set-up used for pressing. 1-pressing chamber, 2-cylinder, 3-plug, 4-ring, 5-filter, 6- hydraulic fluid in, 7- hydraulic fluid out, 8- pressure sensor, 9-temperature probe, 10-balance.

2.2.1.2. Flaking. Flaking was achieved using a rotating cylinder "Trilabo" 100 × 200 SH grinder (Grenier-Charvet, France). Flaking was applied in two consecutive steps to produce homogenous flaked seeds. Pressures of 1 bar and 15 bar were applied for the first and second step respectively.

2.2.1.3. Cooking. Cooking was performed in a hermetic container using an oven (Memmert, UK). The cooking temperature and time were varied in the range 80–100 °C and 0–60 min, respectively. Moisture content was measured before and after cooking.

2.2.2. Oil extraction by mechanical pressing

Mechanical expression was performed using a laboratory hydraulic press (Creusot-Loire, France) (Fig. 1). 300 g of untreated or pre-treated seeds were pressed under a constant pressure for 1 h. The oil mass was continuously monitored using electronic balance (Mettler Toledo, US), and the press cake thickness (*h*) was recorded during the experiment. The pressure and temperature were varied in the range 20150 bar and 20–100 °C respectively.

Oil extraction yield (Y) was determined as follows:

$$Y = \frac{\text{mass of recovered oil}}{\text{total mass of oil in seeds}} \tag{1}$$

2.3. Consolidation coefficient calculation

The consolidation performance of mechanical expression has been successfully evaluated using Eq. (2) (Leclerc and Rebouillat, 1985; Mhemdi et al., 2012; Shirato et al., 1980). This equation gives a relationship between the consolidation ratio *U* and the compression time *t*.