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Effects of roasting temperatures and grinding type on the yields of oil and protein obtained by aqueous extraction processing

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ABSTRACT

A three cylindrical roll crusher was used in this study to solve the comminution problem and to improve oil and protein yields in aqueous extraction processing (AEP) of peanuts. We combined confocal laser scanning microscopy (CLSM) and particle size distribution analysis to investigate the effect of different peanut processing material on oil and protein extraction. A proper roasting treatment (150 °C) is beneficial to oil extraction yield. However, the protein yield has been declining from 84.33% to 51.40% with the increase of roasting temperature from (130 °C–210 °C). The optimal average particle size of peanut paste in AEP was 15.2 μm which could hardly find intact oil bodies by CLMS. Nevertheless, the remained intact of protein body still could be found in insoluble fraction. In AEP, highest free oil yield (92.2%) was achieved with roasted peanut (150 °C, 20 min) using 1: 5 solid to liquid ratio (twice ground peanut pastes/water), pH 9, 60 °C for 2 h and demusification by adding 0.5% (w/w) Protex 50FP at pH 4.5 and incubating at 50 °C for 2 h. Without roasting treatment, the oil contents of insoluble and residual cream fractions from AEP were highly correlated with their protein contents (R^2 = 0.8724, 0.9178, respectively). Additionally, the exposure of interior hydrophobic groups of peanut protein adhere more oil to the protein body surface, which may have led to increment in the oil content of insoluble fraction.

1. Introduction

Peanuts are a major oilseed in the world, grown for vegetable oil and protein. In China, the production of peanuts has exceeded 17 million metric tons per year. Meanwhile, the peanut oil consumption reached 2.76 million metric tons during 2013–2014 crop season, according to the USDA report (USDA, 2014). Currently, peanut oil is mainly produced by solvent extraction, continuous screw pressing, a combination of the two patterns and the rest of defatted peanut flour which contains 47–55% of the proteins was ground and sieved (Ji et al., 2014; Zheng et al., 2015). All of these processes may denature protein and destroy its functional properties which are key indicators for food use (Yu et al., 2007). Furthermore, the most prevalent solvent used in oil extraction is n-hexane. Although n-hexane achieves high crude oil yield (>95%) (de Moura et al., 2009), acute inhalation exposure of humans to large amounts of hexane causes mild central nervous system (CNS) effects, including dizziness, giddiness, slight nausea, and headache (EPA, 1999) and its high flammable and explosive nature may jeopardize the safety of plants and humans (Hanmoungjai et al., 2002; Sharma et al., 2002). Therefore, alternative methods for edible oil extraction are needed.

The use of water as an extraction medium, namely, aqueous extraction processing (AEP) is feasible alternative to screw pressing and organic solvent extraction technologies. Compared with traditional processing methods, AEP may extract oil and protein simultaneously and have little impact on the environment. In AEP, oil was extracted due to its insolubility in water and floated in hot water (Lamsal et al., 2006; Rosenthal et al., 1996). In contrast, proteins dissolved in water and can be recovered by acid precipitation or membrane separation processes (Lawhon et al., 1981; Zheng et al., 2015). The major obstacle to commercial adoption of AEP was the low oil yields. The inefficient extraction was caused by difficulties in rupturing cell walls and releasing oil directly into

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water in the form of stable cream (Rosenthal et al., 1996; Lamsal and Johnson, 2007).

The comminution of oilseeds which have high oil and high protein contents have always been a huge problem when using AEP. The commonly used methods can be divided into wet grinding and dry grinding. A large amount of stable emulsion was formed during wet grinding. In general, dry grinding could avoid the generation of stable emulsion as well as obtaining higher oil yields than wet grinding. Cater et al. (1974) reported that pre-grinding of peanut kernels into a peanut butter consistency or flaking to a thickness of 0.1 mm prior to extraction is necessary to insure maximum recovery, particularly of the oil. Rosenthal et al. (1996) reported that oil yield was inversely proportional with particle size and increased by 31% of total oil when flour particles were changed from 400 μm to 100 μm. However, fine ground peanuts form sticky paste which was hard to shift and may block the grinder and sieves, resulting in uneven grain particle sizes. In addition, blade type crushers or hammer mills were difficult to meet the requirements of pilot scale test due to their low processing capacity and poor production continuity. Meanwhile, roll crusher was used to oilseeds pretreatment process (Gros et al., 2003; de Moura et al., 2009). After crushed by a roll crusher, the deformed and disrupted cell walls and the thinning of plasticized cotyledons were suitable for conventional solvent extraction processing of edible oil (Lamsal et al., 2006), but the flaked materials were not acceptable for AEP due to have not completely disrupted cotyledon cells (mainly for soybean). So far, there are few reports about the application of roll crusher in aqueous extraction of peanut oil. Lamsal et al. (2006) investigated the combination of flaking and extrusion prior to AEP and the soybean oil yield was significantly improved from 60% to 75%. However, they chose a high extrusion temperature (100 °C) to improve the oil yield. This may seriously destroy the cytoplasmic networks, but also denatured the proteins. Meanwhile, extrusion is known to cause the formation of new network and lipid–protein complexes as well as with starch (Camire et al., 1990), both the new network and complexes may entrap oil. Consequently, a feasible mechanical treatment prior to AEP was necessary.

In addition, aromatic roasted peanut oil (ARPO), especially in China, has been widely accepted by customers. It was produced by a screw press which was typically composed of a pressing cage, gearbox, screw shaft, machine stand and a feeder. The roasting treatments (around 200 °C) of crushed peanut seeds prior to pass through a screw press may form the typical aroma of nutty and roasty which could be preserved due to the absence of refining processes (Liu et al., 2011). Most researchers agreed that pyrazine compounds contribute significantly to the nutty and roasty aroma in roasting treatment food (Magaletta and Ho, 1996; Ku et al., 1998; Baker et al., 2003; Misnawi et al., 2004). The amounts of aroma compounds in peanut oil increased with the increase of heating time (Liu et al., 2011). However, the flavor of raw peanut oil which was extracted from EAEP has a lower aroma score than roasted peanut (Zhang et al., 2011). Therefore, we attempted to select roasted peanut for AEP to improve the oil flavor in this study.

Peanut microstructure has been well studied (Young and Schadel, 1991a, b). Young et al. (2004) used scanning electron microscope (SEM) and transmission electron microscope (TEM) observed the microstructure of peanut seed cotyledons during development and maturation to better understand the difference of cell size and type of storage substances synthesized. Idrus and Yang (2012) compared the peanut microstructure from different roasted methods. Although, many studies have been conducted, there is little data on the microstructure of peanut nutritive component such as oil and protein in the starting material and insoluble fraction from AEP. It is conducive to achieve greater oil and protein extraction yields when scientists gain better understanding of these microstructures. TEM, SEM and fluorescence microscope were used to deduce the microstructure of peanuts, but these process can be affected by limiting factors such as laborious sample preparation (TEM and SEM) and poor resolution (fluorescence microscope). Therefore, methodological and instrumental advancements are required. Confocal laser scanning microscopy (CLSM) is a technique for obtaining sensitivity and spatial resolution high-resolution optical images with depth selectivity (Vukojevic et al., 2008). The major advantage of the CLSM was able to capture in a detail digital image of fluorescently labeled tissue specimens which formerly could be observed only by eye in a conventional fluorescence microscope (Paddock, 1999). Based on our limit knowledge that few studies mentioned the observation of microstructure of raw, roasted and ground peanut by using CLSM.

The objectives of this study were: (i) to evaluate the effect of particle size distribution on the oil and protein extraction yields when using AEP; (ii) to study the effect of roasting temperature on oil and protein extraction yields when using AEP; (iii) and to show the location of oil and protein in the raw and roasted peanut starting materials which were obtained from high speed universal grinder and three cylindrical roll crusher (Fig. 1), as well as the location of oil and protein in the insoluble fractions from AEP by using CLSM.

2. Materials and methods

2.1. Materials

Blanched peanuts were prepared from variety Haihua No.1 peanuts (Shandong Province, China) harvested in 2014. Protex 50FP (acid fungal endopeptidase–exopeptidase complex , optimal pH 4.5 , optimal temperature 50 °C) was purchased from Genencor Division of Danisco (Rochester, NY, USA). Fluorescein isothiocyanate isomer I and Nile red for CLSM were purchased from Sigma (USA), Pure standards of tocopherols (DL-α-tocopherol, δ-tocopherol, γ-tocopherol) were obtained from Supelco (Supelco, Bellefonte, PA, USA) , all the other reagents used were of analytical grade.

2.2. Roll crusher

A three cylindrical roll crusher (Model; Changzhou Zili Chemical Machinery Co. Ltd., China) was used to crush the peanuts into paste. The rolls have different rotational speeds and the adjacent rollers rotate in opposite directions. The distances between adjacent rolls could be modified to change the crushing particle sizes with four screws. The equipment was design as a vertical type instead of horizontal. The advantage is that low viscosity materials or oil

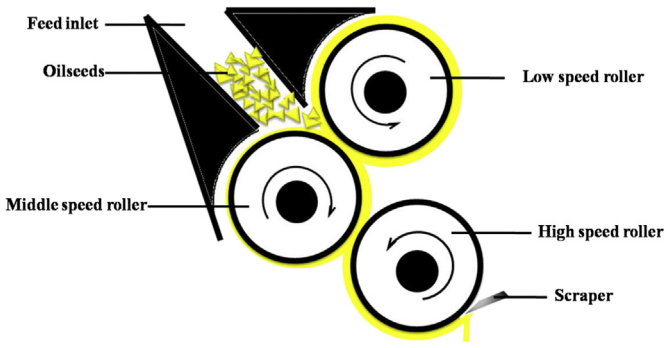

Fig. 1. Sketch of operational principle of three cylindrical roll crusher. Arrows represent the direction of rotation.