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A novel process for preparing low-fat peanuts: Optimization of the oil extraction yield with limited structural and organoleptic damage

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ABSTRACT

The main purpose of this study was to extract the maximum amount of oil from peanuts without causing major damage and preserving their organoleptic quality after defatting. Accordingly, a successful, healthy, eco-friendly and economic defatting process for peanuts was implemented using mechanical oil expression, which was optimized by means of Response Surface Methodology. The results demonstrated that maximum extraction yields were obtained at a low initial moisture content (5–7% d.b.). Defatting and deformation ratios were mostly affected by the pressure and water content with high correlation coefficients (98.4% and 97.5%, respectively), and overall acceptability decreased following higher oil extraction yields. It was concluded that the optimum values for the product moisture content, pressure, and pressing duration were 5% d.b., 9.7 MPa and 4 min, respectively, with a defatting ratio of 70.6%. This resulted in an insignificant irreversible deformation ratio (<1%) and an overall acceptability of 7.6 over 10.

1. Introduction

The peanut is a plant from the Fabaceae family that is native to South America and is cultivated in tropical, subtropical, and temperate climate regions (Hammons, 1973). Approximately 29 million metric tons of peanuts are produced annually worldwide, mostly in China, India, and the USA (American Peanut Council, 2014). These oleaginous seeds are concentrated sources of essential unsaturated fatty acids, with a number of other nutrients and bioactive components (Kris-Etherton et al., 1999). Several studies have related the regular consumption of nuts and seeds with various health benefits, such as lower cholesterol and a decreased risk of cardiovascular disease and type 2 diabetes (Fraser, 1999). Peanuts are also an excellent source of protein with a reasonable amount of carbohydrates, vitamins, and minerals.

Over the past 20 years, peanut processing technologies have witnessed an outstanding growth in the food industry, notably in the manufacturing of vegetable oil, peanut butter, and snack products, such as roasted peanuts. Consumers have become increasingly aware of their health, and because the caloric density of fat is double that of protein and carbohydrates (Holloway & Wilkins, 1982), an efficient defatting process would produce a lower calorie product while maintaining the organoleptic qualities of the product.

Generally, the extraction of oil from oilseeds can be achieved using a variety of methods that tend to damage the raw materials and the extracted oil. One of the methods most commonly reported in the literature is extraction with an organic solvent, such as hexane (Melgarejo Navarro Cerutti, Ulson de Souza, & de Arruda Guelli Ulson de Souza, 2012; Mani, Jaya, & Vadivambal, 2007). Other methods include using water for an aqueous extraction (Campbell & Glatz, 2009) with pressurized gaseous solvents (Venter, Willems, Kuipers, & de Haan, 2006) or with compressed solvents, such as propane and ethanol (Jesus et al., 2013). Lately, supercritical 'green' solvents (Salgın & Salgın, 2013) have also been used. The main drawbacks of solvent extraction are that hexane (the most used solvent) is expensive and that chronic exposure to this type of solvent causes neurologic and other disorders (NIOSH/OSHA/DOE Health Guidelines, 1996), as cited by Russin, Boye, Arcand, and Rajamohamed (2011).

The second method that is commonly used is mechanical expression, which leads to a relatively low extraction yield (40–52%) compared with the solvent extraction method (80–90%) (Holloway, Finley, & Wheeler, 1991). To increase oil extractability, several destructive pretreatments need to be performed, such as

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grinding (Mrema & Mc Nulty, 1985), extrusion (Evangelista, 2009; Kartika, Pontalier, & Rigal, 2010), enzymatic (Gaur, Sharma, Khare, & Gupta, 2007; Jiang, Hua, Wang, & Xu, 2010), ultrasonication (Abdullah & Koc, 2013), or thermal and microwave pretreatments (Jiao et al., 2014; Qu et al., 2013).

In addition to solvent extraction and mechanical expression, the most widely used method in the literature is extraction by supercritical carbon dioxide or by the combination of enzymatic treatment with any other means of extraction.

The purpose of using enzymes in the enzymatic extraction method is to damage and/or degrade cell walls, thereby increasing the permeability of oil in oilseeds (Domínguez, Núnēz, & Lema, 1995). Although this method has the advantage of a high extraction rate, it causes the degradation of grains, which is not recommended in the defatting process for snack industries.

On the other hand, the advantages of oil extraction by supercritical carbon dioxide are its easy removal from food samples without contamination, the fact that it is environmentally and nutritionally non-toxic and that the extraction conditions are relatively mild, thereby leading to a high oxidative stability and low protein denaturation. Nevertheless, this extraction operation is very expensive (Passey & Patil, 1994). Therefore, an alternative method of oil removal would be more efficient and beneficial to manufacturers.

Consequently, after performing a comparative study of these various defatting methods, the defatted grains, extracted oil quality, oil yield and cost effectiveness were the most important factors, and mechanical expression was adopted to extract oil from groundnut seeds. This method was chosen because it is the cheapest method in the industry and is the healthiest way to remove oil without polluting the grain samples. Therefore, the highest possible oil recovery from groundnuts is possible at an economical rate. After pressing, the seeds are flattened and soaked in water for a specific time to recover their initial shape and size (Wilkins & Gannis, 1984; Passey & Patil, 1994).

Several patents have been released with the purpose of attempting to produce low-fat nuts, but as shown in Table 1, the inventors were unable to achieve high extraction yields without damaging or deforming the seeds. Additionally, their processes consumed high amounts of energy (for heating, long pressing durations and very high pressures), with relatively low percentages of extracted oil. As a result, none of these methods have been retained by the industry because of their inefficiency and low return on investment. Mechanical pressing, which eliminates oil, is usually performed at pressures between 6.9 and 10.3 MPa for 15–120 min. At higher pressures (>10.3 MPa), there is a significant loss of flavor. At lower pressures (<6.9 MPa), the pressing time to extract a certain percentage of oil has to be extended (Holloway et al., 1991).

Therefore, studies have been developed to research the most cost effective methods for defatting. These methods would be useful for industries that produce popular snacks and products from defatted nuts. The main objective of this study was to optimize the defatting process parameters of peanuts by means of the Response Surface Methodology. The aim is to obtain a maximum oil extraction yield with minimum damage and breakage of the seeds during pressing, while preserving their organoleptic qualities. The obtained defatted nuts would satisfy consumers because they would retain their original shape and taste but have a lower amount of calories.

2. Material and methods

A novel defatting process called MEPPI (Mechanical Extraction Preserving Product Integrity) was designed, implemented and optimized to prepare low-fat, high fiber, high protein peanuts, thereby preserving the structural and organoleptic properties of the finished product.

2.1. Sample preparation

Unshelled peanuts of "Arachis Hypogaea" botanical origin and of Virginia type were imported from China (Laixi city shunxiang peanuts product's Co. LTD) and shipped to "El Kazzi", which is a local nut roasting facility in Beirut, Lebanon. The peanuts were manually cleaned and sieved twice using 8.5- and 7.5-mm square mesh sieves to select those that had approximately the same shape and dimensions.

2.2. Pretreatments

2.2.1. Light initial roasting and peeling

An initial roasting is often performed to produce the flavor and color that characterize peanuts. This process also reduces the water content and denatures proteins to facilitate the subsequent extraction of oil (Holloway & Wilkins, 1982). Preliminary optimization of the initial roasting was performed. The optimal conditions obtained from this study were: roasting at 140 °C for 15 min with a cake thickness of 3.3 cm. Then, the peanuts were manually peeled.

2.2.2. Hydration

Hydration before pressing is important to increase the compressibility of the seed and its resistance to disintegration. However, this process leads to a loss of many important soluble materials by dissolution in water. Therefore, according to the literature, the water content before pressing should not exceed 8% d.b.,

Table 1
Process parameters and extraction yields previously obtained by researchers.

Grain type	Pressure (MPa)	Pressing duration (min)	Temperature (°C)	Water content (weight per cent)	Oil extraction yield (%)
Peanuts (Ammann, 1935)	34.3	45–60	80–90	1–4	60–70
Peanuts (Holloway & Wilkins, 1982)	6.9–10.3 8.3[a]	15–120	–	4–8 5[a]	20–55 35–45[a]
Peanuts (cold pressing) (Vix et al., 1966)	13.8	30–120	0–40	3–8	20–90
Peanuts (hot pressing) (Vix et al., 1966)	13.8	60	82.2–104.4	3–8	20–90
Peanuts (Wilkins & Gannis, 1984)	8.3–10.3	15–120	20–50	4–6	20–60 35–55[a]
Peanuts (Simelunas, Wilkins, & Gannis, 1985)	17.2	10–20	20–50	5–7	35–55
Peanuts (Wong & Sackenheim, 1992)	10.3–51.7 35.9[a]	5–30 10[a]	15	<6 3–5[a]	25–80 80[a]
Peanuts (Holloway et al., 1991)	7.6–9	15–20	–	–	40–52
Melon seeds (Ajibola, Eniyemo, Fasina, & Adeeko, 1990)	25	10	130	9.2	41.6

[a] Optimum values.