

Mechanical Methods of Oil Extraction from Peanuts

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Peanuts, being crucial crops of global importance, have gained widespread recognition for their versatility and nutritional value. In addition to direct consumption, either with or without treatment, peanuts can be the subject of diverse applications focusing mainly on two distinct objectives: oil extraction and defatting processes. Mechanical techniques for oil extraction from peanuts are grouped into three main sections: extrusion and screw pressing, cold pressing, and hydraulic pressing.

oil extraction

mechanical methods

defatting peanuts

defatted peanuts

peanut proteins

texturization

MEPSI

1. Introduction

Peanut, or *Arachis hypogaeae* L., is currently a vital oilseed crop widely utilized in the confectionery, snack, and fat/oil manufacturing industries ^[1]. This plant belongs to the Fabaceae family and originates from South America. It is grown in areas with tropical, subtropical, and temperate climates ^[2] and has become well-known for being a high-protein source, containing between 22% and 30% protein. Additionally, it is a source of nutrients like niacin, which helps promote healthy blood flow and brain function, folate, antioxidants, vitamin E, magnesium, phosphorus, and dietary fibers ^[3]. Peanuts are commonly eaten as a snack or processed into peanut butter, while more than 70% of the harvest is used for oil extraction ^[4]. Indeed, peanuts contain between 45.9% and 55.4% of lipids that are specifically high in essential polyunsaturated fatty acids ^{[5][6][7]}. Among the unsaturated fatty acids, oleic acid and linoleic acid account for 33.3–61.3% and 18.5–47.5%, respectively. Despite being high in calories, many studies have highlighted the health-promoting properties of peanuts ^[8]. In fact, high consumption of nuts is associated with a beneficial impact on the cardiovascular system ^[9], due to their antioxidant and anti-inflammatory properties ^{[10][11]}. Research has also found that consuming peanuts and peanut butter five times per week can reduce the likelihood of developing type 2 diabetes ^{[11][12]} and chronic diseases such as cancer ^{[11][13]}. Peanuts and their by-products could potentially serve as natural chemo-preventive agents ^[14].

Removing lipids from food products is sought by health-conscious individuals who require diets that are low in fat and high in protein. While several methods are available for extracting oil from oilseeds, some of them might negatively affect the extracted oil and/or the remaining solid matrices. The mechanical methods are the most commonly used ones, including hydraulic pressing ^{[1][2][3][4][8]}, extrusion ^{[15][16]}, screw pressing ^{[16][17][18]}, and cold pressing ^{[6][19][20][21]}. Hydraulic pressing has been significantly enhanced in certain instances to preserve the

physical form of whole peanuts following defatting. This was achieved through a technique known as “Mechanical Expression Preserving Shape Integrity” (MEPSI) [8][22], combined with a reconstitution process called “Intensification of Vaporization by Decompression to the Vacuum” (IVDV) [1][8][23][24][25]. This method relies on the use of a separating agent during defatting to prevent irreversible physical damage and distortion of peanuts. In other scenarios, the reconstitution happened via soaking in water for a sufficient time and then drying to a water content of 7–10% dry basis (d.b.) before roasting [2][3]. Chemical methods are also frequently cited in the literature. They include organic solvent extraction, such as hexane [15][16][17], trichloroethylene [26], or utilizing supercritical CO₂ (SC-CO₂) adjusted through the addition of a co-solvent containing ethanol [19][20][21], as well as aqueous extraction processing (AEP) employing water [6][17]. Another technique is Soxhlet extraction, which uses various solvents such as ethanol [23]. Advanced, environmentally friendly technologies have been implemented, involving a synergistic combination of multiple treatments and extraction methods. This strategic approach aims to enhance oil yield while reducing expenses and energy consumption. Several methods of AEP are discussed, including enzyme-assisted aqueous extraction (EAEE) [27][28][29], aqueous and mechanical extraction by treatment with NaCl [30], and aqueous extraction combined with membrane separation by applying two-stage microfiltration and ultrafiltration (MF/UF) [31]. Additionally, aqueous enzymatic extraction was coupled to an ultrasonic pre-treatment [32][33], infrared radiation (IR) [34], or microwave radiation by treatment with CaCl₂ [35], which usually relies on heat transfer and varies depending on the type of product and the oven’s chamber design and operation [36].

2. Mechanical Methods of Oil Extraction from Peanuts

Mechanical techniques for oil extraction from peanuts are grouped into three main sections: extrusion and screw pressing, cold pressing, and hydraulic pressing. **Table 1** showcases all these mechanical methods employed, along with their experimental conditions, including pre-and post-treatments, evaluation of the nutritional value of the final products, and oil yield.

Table 1. Mechanical methods of oil extraction from peanuts.

Methods/Year/Reference	Target Product(s)	Product(s) Description	Nutritional Value	Oil Recovery (%)	Pre-Treatment	Post-Treatment	Parameters
MEPSI (2014) [1]	Partially defatted peanuts and Peanut oil.	Expansion, preserving structural integrity, and organoleptic properties	High protein content in the defatted peanut	50 (Optimal conditions) up to 80%	- Air roasting: 140 °C, 15 min. - Rehydration: different water content (W).	IVDV texturization: P = 0.9 MPa, 10 s	Pressing optimal conditions: - 5% d.b. water content. - Homogenization: 2 days, 4 °C. - P = 9.7 MPa. - T = 20 °C.

Methods/Year/Reference	Target Product(s)	Product(s) Description	Nutritional Value	Oil Recovery (%)	Pre-Treatment	Post-Treatment	Parameters
							<ul style="list-style-type: none"> - t = 4 min. - compression speed: 8 mm/s.
MEPSI optimized by RSM (2016) ^[1]	Partially defatted peanuts and Peanut oil.	Expansion, recovering original shape, and organoleptic properties	High-protein, crunchy snacks with reduced fat	70–80%	<ul style="list-style-type: none"> - Air roasting: 140 °C, 15 min. - Rehydration: 5, 7, 10, 13, 15% d.b. water content. 	Reconstitution and roasting: <ul style="list-style-type: none"> - Soaking: 30 min. - Drying: 50 °C. - Roasting with salt: 170–180 °C, 210 s. - Rapid cooling. 	Pressing optimal conditions: <ul style="list-style-type: none"> - W = 13.17% d.b. - P = 12 MPa. - t = 19.19 min. - Response optimum: Expansion Ratio = 1.2, Grain Appearance = 6.2, Grain Hardness = 4.5 N, Work Done = 15.7 mJ, Quantity of Fractures = 17, Consumer Textural Evaluation = 8.5.
MEPSI optimized by RSM (2016) ^[2]	Partially defatted peanuts and Peanut oil.	Expansion, recovering original shape, and organoleptic properties	High protein, low fat, and high fiber content in the defatted peanut	70.6%	<ul style="list-style-type: none"> - Air roasting: 140 °C, 15 min. - Rehydration: W < 8% d.b. 	Reconstitution and roasting: <ul style="list-style-type: none"> - Soaking: 30 min. - Drying: 50 °C. 	Pressing optimal conditions: <ul style="list-style-type: none"> - W = 5% d.b. - P = 9.7 MPa. - t = 4 min.

Methods/Year/Reference	Target Product(s)	Product(s) Description	Nutritional Value	Oil Recovery (%)	Pre-Treatment	Post-Treatment	Parameters
						Roasting with salt: 170–180 °C, 210 s.	
						- Rapid cooling.	
MEPSI optimized by RSM (2017) ^[8]	Partially defatted peanuts and Peanut oil.	Full shape recovery of peanuts, assuring better morphological, organoleptic, and rheological properties	High protein, low fat, and high fiber content in the defatted peanut	56.26%	- Air roasting: 140 °C, 15 min. - Rehydration: W = 5% d.b.	- Rehydration: 7.1, 11.5, 18, 24.5, 29% d.b. of water content. - IVDV texturization. - Dehydration: 50 °C. - Roasting with salt: 180 °C, 210 s.	IVDV optimal conditions: - W = 17.3% d.b. - P = 12 × 10 ⁵ Pa. - t = 18.6 s. - RSM: Expansion Ratio = 1.54, Grain Appearance = 7.11, Defatting Ratio = 56.26%, Overall Appreciation (/10) = 7.71
MEPSI optimized by RSM (2018) ^[4]	Partially defatted peanuts and Peanut oil.	Full shape recovery of peanuts, assuring better morphological, organoleptic, and rheological properties	High protein, low fat, and high fiber content in the defatted peanut	45.02 ± 0.4%	- Air roasting: 140 °C, 15 min. - Rehydration: W = 5% d.b.	- Rehydration: 7.1, 11.5, 18, 24.5, 29% d.b. of water content. - IVDV texturization. - Dehydration: 50 °C.	IVDV optimal conditions: - W = 19.9% d.b. - P = 9.1 × 10 ⁵ Pa. - t = 17.1 s. - RSM: Grain Hardness = 5.94 N, Work Done =

Methods/Year/Reference	Target Product(s)	Product(s) Description	Nutritional Value	Oil Recovery (%)	Pre-Treatment	Post-Treatment	Parameters
						<ul style="list-style-type: none"> - Roasting with salt: 180 °C, 210 s. 	5.76 mJ, Texture Sensory Analysis (/10) = 8.14, Consumer Colour Evaluation (/10) = 7.66.
MEPSI optimized by RSM (2021) [22]	Partially defatted peanuts and Peanut oil.	Full shape recovery of peanuts, assuring better morphological, organoleptic, and rheological properties	High protein, low fat, and high fiber content in the defatted peanut	70.62%	<ul style="list-style-type: none"> - Air roasting: 140 °C, 15 min. - Rehydration: 5, 7, 10, 13, 15% d.b. 	<ul style="list-style-type: none"> - Dehydration: 50 °C. - Roasting with salt: 180 °C, 210 s → 2% d.b. - Coating and rapid cooling. 	IVDV optimal conditions: <ul style="list-style-type: none"> - W = 12.2 ± 0.6% d.b. - P = 6 ± 0.3 MPa. - t = 18.2 ± 0.6 min. - RSM: Free Fatty Acid = 0.13%, Total Oxidation = 19.68 meqO₂/Kg, Taste (/10) = 9, Aroma (/10) = 7.57.
Hot and cold press (2020) [6]	Peanut Oil	Formation of PDPM	Low fat, High protein, and high fiber content in the PDPM	N/A	Roasting: 180 °C, 20 min (With or without removing the red skin).	N/A	Pressing optimal conditions: <ul style="list-style-type: none"> - P = 100–110 MPa. - T = 180 °C. - t = 20 min.
Hydraulic press (pre-treated with IR irradiation) (2020) [37]	Partially defatted peanuts	Full shape recovery of peanuts,	Rich in fiber and more than 30 essential	45%	<ul style="list-style-type: none"> - Placing the peanuts in a 	IVDV texturization.	Process optimal conditions:

Methods/Year/Reference	Target Product(s)	Product(s) Description	Nutritional Value	Oil Recovery (%)	Pre-Treatment	Post-Treatment	Parameters
	and Peanut oil.	assuring better morphological, organoleptic, and rheological properties	nutrients. High concentrations of polyphenols and antioxidants in the defatted peanut		round bottom flask: distance = 1 cm from the ceramic IR emitter. - Irradiation: Different exposure times and temperatures.		- IR irradiation: 88.5 °C, 56 min. - Hydraulic pressing: 80 bar, 1 min.
Extrusion optimized by RSM (2009) [15]	PDPF and Peanut oil.	PDPF was used to develop peanut-based Textured Meat Analogue	High protein content and cholesterol-free in the peanut-based TMA	N/A	N/A	N/A	Extrusion Optimal conditions: - 60–65% protein. - 160–165 °C. - 80–90 rpm screw speed.
Screw pressing (2019) [17]	Peanut oil	The peanuts exhibit compromised integrity characteristics of oil were investigated.	Peanut oil is a rich source of bioactive components	-Roasted peanuts: 41.18–46.28%. -Non-roasted peanuts: 41.17%	- Dry air roasting: 140, 160, and 180 °C, 5 and 10 min. - Cooling: Room temperature.	Centrifugation of peanut oil: 12,000 rpm, 10 min.	- Pressing optimal conditions: T < 50 °C. - Roasting optimal conditions: 180 °C, 10 min.
MEPSI optimized by RSM (2016) [38]	Partially defatted peanuts and Peanut oil.	Full shape recovery of peanuts, assuring better morphological,	High protein, low fat, and high fiber content in the defatted peanut	70%	- Air roasting: 140 °C, 15 min. -	- Soaking. - Drying: 50 °C.	Pressing optimal conditions: - W = 5% d.b. - P = 9.7 MPa.

2.1. Extrusion and Screw Pressing

Methods/Year/Reference	Target Product(s)	Product(s) Description	Nutritional Value	Oil Recovery (%)	Pre-Treatment	Post-Treatment	Parameters	
[43] [39]		organoleptic, and rheological properties [42]			Rehydration: 5, 7, 10, 13, and 15% d.b. water content.	Roasting with salt: 180 °C, 210 s.	t = 4 min. RSM: Colour consumer evaluation = 8.03/10, Total colour change = 74.9, Fracturability = 7.12 N; First fracture percentage of deformation = 8.2%; Rupture force = 22.93 N; Percentage of deformation at rupture = 4.8%.	
	[16]	PDPF and Peanut oil.	Formation of PDPM	High protein, low fat, and high fiber content in the PDPM	65.6% extruder only vs. 90.6% extrusion and screw pressing	Dehulling and separating of skins.	N/A	Extrusion optimal conditions: 136–138 °C, 30 s, feed rate = 142 kg/h. Pressing optimal conditions: T = 90 °C, 1 min discharge opening in the screw press: 4.49 mm.
	[19]	PDPF and Peanut oil.	Formation of PDPM	High-quality oil [15] obtained suitable for direct consumption	65%	Peeling. Drying.	N/A	Pressing experimental conditions: T = 50, 100, 150, and 200 °C. Cold Rotation speeds = 17, 49, 96 rpm

A study carried out in 2019 by Sun et al. examined how peanut oil quality characteristics were affected by a combination of dry air roasting and mechanical extraction using screw pressing [17]. The researchers found that optimal conditions for air roasting were 180 °C for 10 min, followed by cooling at room temperature. Oil extraction using screw pressing at a temperature below 50 °C resulted in a yield of 41.18–46.28%, followed by centrifugation of the oil at 12,000 rpm for 10 min to remove impurities. The study demonstrated that this method led to a lower PV and a higher oxidative stability index (OSI) [17]. Mridula et al. conducted a study in 2020 that involved subjecting peanuts to hot air treatment at 105 °C and then mixing them with distilled water to increase moisture levels [39]. They achieved an extraction of 75.89% of the oil in peanuts by using a screw speed of 20 rpm and pressing the samples at a temperature of 70 ± 2 °C with a sample moisture content of 8%. RSM response parameters showed a desirability of 81.8%. It was observed that maintaining a lower pre-treatment temperature of 105 °C and a moisture content of 8% w.b. yielded a higher quantity and quality of oil, thus ensuring a relatively high level of desirability for consumers. However, it is important to note that the experimental conditions and methods employed in the two studies may have varied, leading to differences in the results. For instance, the optimal air roasting temperature

Methods/Year/Reference	Target Product(s)	Product(s) Description	Nutritional Value	Oil Recovery (%)	Pre-Treatment	Post-Treatment	Parameters
							- T(oil) ≤ 84 °C.
Cold pressing (2020) [21] [19]	PDPM and Peanut oil.	Formation of PDPM	Low fat, High protein (>25%), and high fiber content in the PDPM	30%	- Mechanical shelling. - Dehydration: W = 4–8% d.b. - Skin coat removed.	N/A	Pressing experimental conditions: - Twinscrew press: T < 60 °C. - Frame filter (press and filter three times): T < 30 °C.
Cold pressing (2017) [20]	PDPM and Peanut oil.	Formation of PDPM	High protein, with reduced fat in the PDPM. Oil is in line with national standards.	39.8%	- Shelling. - Crushing. - Regulation of moisture content. - Frying.	Filtering: Peanut oil.	Pressing optimal conditions: - T(oil) < 65 °C. - W (peanuts) = 7% d.b.
Screw Pressing (2020) [39]	PDPM and Peanut oil.	Formation of PDPM [20]	Peanut oil contains oleic and linoleic acids (38–56%) and (16–38%), respectively, and is low in free fatty acids	75.89%	- Nude peanut [26] hot air exposure: 105 °C. - Rehydration: 8, 11, and 14% w.b.	N/A	Pressing optimal conditions: - Screw speed: 20 rpm. - T = 66.5 °C. - W = 8% d.b.
Hydraulic Pressing (2007) [40]	Peanut oil	Formation of PDPM	High protein, with reduced fat in the PDPM.	33.36%	N/A	N/A	Pressing optimal conditions: - P = 25 MPa. [45] - t = 7 min.

to extract the oil, which was then subjected to malaxation and centrifugation processes at 25 °C for 30 min and at 5000 rpm, respectively. Peanuts were found to have the highest free fatty acid content at 1.36%, which can result in poor-quality oils with significant losses during the refining process. Additionally, peanut oil had a high initial PV of 8.39 meq O₂/kg, indicating a short shelf life and limited suitability for human consumption [45]. On another note, a study performed by Ji et al. in 2020 aimed to investigate the presence of cancer-causing compounds in extracted peanut oil [6]. The amount of AF in oil extracted through hot pressing was much higher than that in oil extracted through cold pressing. This increase in concentration at high temperatures could be due to the breakdown of other food components and the release of bound AF. It is crucial to implement preventative measures against AF contamination from the outset because of its adverse health impacts [46]. This includes sound agricultural practices and effective chemical and bio-control strategies targeting AF-producing *Aspergillus* spp. [47]. It is worth noting that the cold press extraction method has a relatively low oil yield (<40%), which is considered mediocre. These findings suggest that appropriate pre-treatment/extraction methods can improve the quality and yield of cold-

Methods/Year/Reference	Target Product(s)	Product(s) Description	Nutritional Value	Oil Recovery (%)	Pre-Treatment	Post-Treatment	Parameters	needed to properties
							- W = 1.76% d.b.	
Hydraulic Pressing (2014) [41]	Peanut oil	Formation of PDPM	High protein, with reduced fat in the PDPM.	32.36%	Drying: 130 °C, 6 h	N/A	Pressing optimal conditions: - P = 15.77 MPa. - t = 6.69 min. - W = 8.13% d.b.	s before after the

In 2007, Olajide et al. assessed the predictive precision of a recently devised neural network concerning oil yield. The extraction process involved hydraulic pressing, and the researchers identified the optimal operating conditions as follows: pressure of 25 MPa, pressing time of 7 min, and moisture content of 1.76% d.b. Under these specified conditions, the maximum oil yield was 33.36% [40]. Another related study explored the influence of operating parameters on the mechanical extraction of oil from groundnut kernels through the utilization of a hydraulic press [41]. The oil yield recorded was 32.36% under a pressure of 15.77 MPa for 6.69 min, and with a moisture content set at 8.13% d.b. The low oil yield raises concerns about the efficiency of the extraction process, knowing that higher oil yields are often desired in industrial applications to maximize the utilization of raw materials and increase overall production efficiency. Additionally, the obtained results can be compared with alternative extraction methods to ascertain the competitiveness and practicality of the hydraulic press approach.

A recent improvement has led to a more efficient and economical defatting process for whole peanuts, resulting in less waste of misshapen seeds, a reduced risk of grain breakage under high pressure, and streamlined oil extraction for diverse applications. The unique aspect of this defatting method is the use of a special separation material placed between the grains within the press chamber [3][39], which helps to retain the structural and sensory qualities of the final product [2]. Consequently, the objective of this technique is to maximize oil extraction while generating defatted whole peanuts with high levels of protein and fiber and reduced oil content. The details are clearly explained in the patents LB-10,492 [48] and LB-10,493 [49], in which MEPSI involved air-roasting peanuts as a pre-treatment. The purpose of this step was to improve the taste and appearance of the nuts, enhance the oil extraction, reduce the deformation of the kernels, and decrease the moisture content to 2–3% d.b. The peanuts were then rehydrated and pressed at room temperature to achieve different water content levels ranging from 5% to 15%. This was necessary to improve the compressibility of the grains and their resistance to disintegration, which in turn reduced the occurrence of permanent deformation during the pressing process [1][4][8][39][50]. A supplementary post-treatment using IVDV was applied to improve the properties of the final product. It involved subjecting the distorted seeds to a steam pressure of up to 1.5 MPa, reached within one second, and treating them under such high pressure and temperature for a certain period of time. The pressure is then suddenly released into the vacuum, causing some of the water content to auto-vaporize, thus leading to an expanded structure. The resulting products were subsequently dried in a ventilated oven at 50 °C until the relative humidity reached 7–10% w.b. This thermo-mechanical process was aimed at texturizing the product by regaining its original shape and size, as well as enhancing its textural, physiochemical, and sensorial properties [4].

A coupling between MEPSI and IVDV was achieved by Nader et al., reaching around 56% of the oil extraction rate from whole peanuts when the optimal conditions were applied [1][8]. When lower pressure and processing times were used, a slight decrease in the oil yield was noted [4]. The physical characteristics of peanuts were examined after oil extraction. The consumer color evaluation and the textural sensory analysis demonstrated a significant advantage over previously produced partially defatted whole peanuts [2][3]. Further enhancements were introduced by the same team, and a significantly higher defatting ratio of 70.62% was reached upon applying greater pressure [22]. An evaluation of the response factors was performed, providing insights into the impact of the treatment on the textural qualities of the peanuts. The treated whole peanuts exhibited reduced malleability, lighter coloration, and enhanced crunchiness, indicating desirable textural characteristics [38]. Following an RSM optimization, the desirability of the defatted peanuts increased by up to 80%. The physical constraint induced by pressing caused a greater exposure of the remaining oil to oxygen during defatting and final roasting, resulting in a reduction in the oxidative stability of peanuts. Furthermore, the optimal conditions obtained through multiple optimizations using RSM resulted in a significant reduction of lipid oxidation. The texture of partially defatted whole peanuts appears to be preserved better when MEPSI is combined with IVDV, owing to the lower risk of damaging the product. With that being stated, the integration of MEPSI-IVDV enables manufacturers to provide a variety of product lines to cater to diverse consumer demands with varying levels of fat and protein content. Processing conditions can therefore be optimized to maximize oil extraction while keeping desirable partially defatted whole peanuts. It is also pertinent to note that in a product that underwent expansion, an increase in porosity leads to heightened product aeration, decreased hardness, an elevated occurrence of mechanical fractures, and a greater number of acoustical events [51].

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