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Peanut oil pressing extraction: Effects of process conditions and peanut kernel characteristics on oil yield and quality parameters

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SUMMARY: This study explored the effects of raw material condition (whole peanuts with tegument, WP, and blanched peanuts, BP) and processing parameters on oil yield and quality. Different seed moisture contents (SMC) and pressing temperatures (PT) were tested for both materials to optimize extraction. For WP, the best results were at 6% SMC and 90 °C PT, while for BP, it was 9% SMC and 150 °C PT. Oil yield from WP was 5% higher than BP under these conditions. Both WP and BP oils met chemical quality standards for virgin oils, but WP oil had higher concentrations of tocopherols and phenolic compounds. The study suggests that using whole peanuts with tegument could eliminate the need for roasting or blanching, reducing labor and energy costs while still achieving high-quality oil.

KEY-WORDS: *Blanched peanuts; Oil composition; Peanut oil extraction; Peanuts with tegument; Processing conditions; Quality parameters.*

RESUMEN: ***Extracción de aceite de maní mediante prensado: Efectos de las condiciones del proceso y las características del grano de maní sobre el rendimiento del aceite y los parámetros de calidad.*** Este estudio evaluó los efectos de la condición del material crudo (maní entero con tegumento, WP, y maní blanqueado, BP) y los parámetros de procesamiento en el rendimiento y la calidad del aceite. Se evaluaron diferentes contenidos de humedad (SMC) y temperaturas de prensado (PT) para ambos materiales. Para WP, los mejores resultados se lograron con un 6% de SMC y 90°C de PT, mientras que para BP fueron 9% de SMC y 150°C de PT. El rendimiento en aceite de WP fue un 5% mayor que el de BP. Ambos aceites cumplieron con los estándares de calidad para aceites vírgenes, pero el aceite de WP presentó mayores concentraciones de tocoferoles y compuestos fenólicos. El estudio sugiere que utilizar maní entero con tegumento podría eliminar la necesidad de tostado o blanqueado, reduciendo costos laborales y energéticos sin comprometer la calidad del aceite.

PALABRAS CLAVE: *Composición del aceite; Condiciones de procesamiento; Extracción de aceite de maní; Maní blanqueado; Maní con tegumento; Parámetros de calidad.*

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1. INTRODUCTION

The groundnut, or peanut, is the second most important cultivated oil-bearing legume crop in the world (https://www.statista.com/statistics/267271/worldwide-oilseed-production-since-2008/). It is a major source of oil, ranking as the fourth largest edible oilseed crop. Peanuts commonly contain 45–50% oil. This is composed of high proportions of unsaturated fatty acids (FA), in particular oleic and linoleic acids, which together make up 80–85% of the total FA content. Normal peanut oils usually contain 45% oleic and 35% linoleic acids, but breeding lines containing 80% of the former and 2% of the latter have been incorporated into commercial peanut varieties (Maestri, 2023). Peanut oil is considered premium cooking and frying oil due to its higher smoke point (about 230 ºC) and better oxidative stability compared to many other cooking oils. Besides these applications, the peanut oil is used in the manufacture of margarines, mayonnaise and other dressings.

The extraction of peanut oil is commonly carried out from roasted and blanched (i.e. without seed coat) peanut kernels by using mechanical processes (expeller or screw pressing). Roasting and blanching pre-treatments may have favorable effects on oil extraction yield because they may lessen oil viscosity. which allows the oil to flow more readily. and enhance oil release during pressing. The oil obtained, which is known as aromatic roasted peanut oil, is well accepted in bulk oil markets from some Asian countries such as China and India but, on the contrary, in countries from America and the European Union slightly fragrant peanut oils are preferred (Cai *et al.*, 2021). Regardless of preference or acceptance criteria, the aforementioned pre-treatments are labor-intensive and energy-consuming processes. In addition, they could adversely affect the chemical quality of the oils by causing increments in both peroxide and free fatty acid contents (Makeri *et al.*, 2011), and significant changes in the fatty acid profile (Rodrigues *et al.*, 2011). All these facts could imply spoilage reactions which affect the nutritional quality of both the extracted oil and the residual cake.

Findings obtained from diverse oilseeds indicate that moisture content and pressing temperature are two key factors for obtaining sustainable oil yields with acceptable quality standards (Savoire *et al.*, 2013; Martínez *et al.*, 2013; Martínez *et al.*, 2017; Rabadán *et al.*, 2018). Moistening improves seed material plasticity which often increases the oil extraction rate. The application of a thermal treatment may also improve oil recovery (Martínez *et al.*, 2013; Savoire *et al.*, 2013). This can be explained by the breakdown of cell structures, which favors the release of oil, but by a decrease in oil viscosity, which is favorable to its flowing. Similar to what is observed with seed material wetting, the positive effect of heating on the oil extraction rate is observed within a certain range of pressing temperatures.

On the basis of the evidence discussed above, it could be assumed that the oil yields during pressing, as well as the chemical quality of the oils extracted, depend not only on the characteristics of the starting material but also on the methods (pre-treatments and process parameters) of how the oils are produced.

Regarding peanut oil, an un-explored alternative is oil extraction using whole kernels, i.e. with their seed coat or tegument. On the one hand, this is an advantage from the processing point of view, as it avoids the blanching treatment; and on the other hand, it offers the possibility of obtaining oils with an endogenous load of natural antioxidants. In this regard, it should be stressed that the peanut tegument is an abundant source of phenolic substances (mainly monomeric and condensed flavonoids) with notable antioxidant properties (Bodoira *et al.*, 2022). Moreover, identifying the optimal screw-press extraction conditions (those that maximize oil recovery while preserving oil quality) requires a rigorous and comprehensive experimental design. This design must consider the complex interactions among material properties (moisture content), processing parameters (temperature), and press-configuration variables (screw speed and restriction-die–induced compressive stress). For peanut oil extraction, these fundamental processes–material interactions remain insufficiently studied. In this context, multifactorial experimental designs that integrate the various unit operations involved in mechanical oil extraction have demonstrated their effectiveness in enhancing oil yield and chemical quality, as well as in imparting desirable functional attributes to the final product (Martínez *et al.,* 2013; Martínez *et al.*, 2017).

Therefore, by using a factorial design, the present study was primarily aimed to evaluate the impact of selected processing conditions on the oil yield and quality parameters of screw-press extracted peanut oils.

Another objective focused on the effect of the raw material (i.e. peanuts with or without tegument) and its relationship with the chemical properties and stability of the oils. The research was conducted on the hypothesis that a combination of skin-coated peanuts and appropriate extraction conditions can provide suitable oil yields and better oil quality than those obtained using skinned peanuts.

2. MATERIALS AND METHODS

2.1. Materials

Runner-type peanuts donated by Lorenzati Ruetsch y Cia S.A. (Córdoba, Argentina) were used for all oil extraction experiments. These included two types of materials: unprocessed whole peanuts (WP, raw peanuts with tegument), and blanched peanuts (BP, without tegument) which were obtained by means of a typical industrial blanching process (90 ºC, 10 min). Both starting materials contained about 50% oil (dry basis, d.b.), which was determined using Soxhlet devices with n-hexane as solvent (AOCS, 2009). All chemicals and solvents used were either analytical or HPLC grade.

2.2. Screw-press extraction

Peanuts, WP and BP, were ground to obtain particle sizes suitable for press feeding prior to pressing operations for oil extraction. Particles between 3–5 mm were selected using an automatic sieve (EJR 2000 Zonytest, Argentina). The extraction experiments were planned following a factorial experimental design with four factors (independent variables) at different levels: moisture content (6, 9 and 12%, w/w), pressing temperature (50, 90, 120 and 150 ºC), screw rotation speed (20 and 40 rpm) and compressive stress (restriction dies of 5 and 6 mm) (Table 1).

The different moisture levels were achieved following methodologies described previously (Martínez *et al.,* 2013). Briefly, ground seed materials were sprinkled with fresh water, packed in air-tight containers, and stored 48 h for equilibration. The containers were shaken at regular intervals to distribute moisture uniformly throughout the sample. Finally, seed samples were kept in a vacuum oven at 25 °C until the desired moisture level was reached. Seed materials from each moisture level were subdivided into four portions which were pressed separately at 50, 90, 120 and 150 ºC. Oil extraction was carried out using a Komet screw press (Model CA 59 G, IBG Monforts, Mönchengladbach, Germany) and a press barrel with internal diameter, effective and total length equal to 5.6 cm, 6.7 cm and 14.7 cm, respectively. The amount of sample pressed in each run was 1 kg. The screw press was first run for 15 min without seed material but with heating, via an electrical heating ring attached around the press barrel to raise the screw-press barrel temperature to the desired one. The running temperature was constantly monitored with a digital thermometer inserted into the restriction die. After each run, all press devices were cleaned and dried (Figure 1).

TABLE 1. Factorial experimental design for blanched peanuts (BP) and whole peanut kernels (WP) oil extraction

Process parameters	Low	High	Levels
PT (°C)	*50*	*150*	*4*
SMC (%)	*6*	*12*	*3*
CS (mm)	*5*	*6*	*2*
SRS (rpm)	*20*	*40*	*2*

PT, pressing temperature; SMC, seed moisture content; CS, compressive stress; SRS, screw-rotation speed.

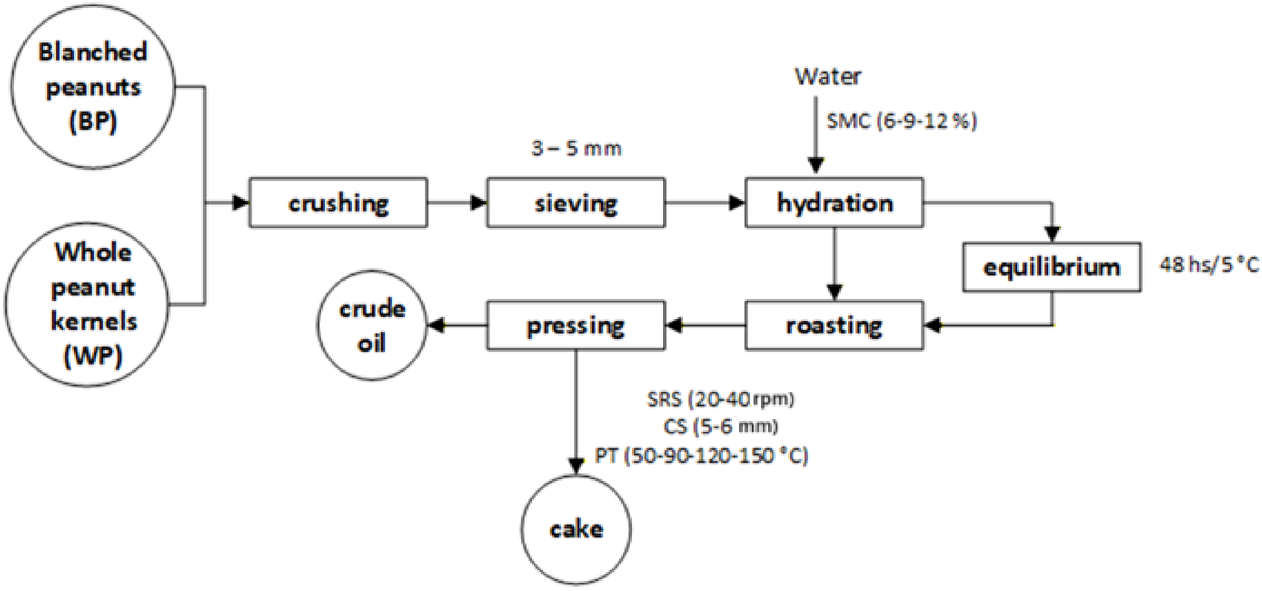

FIGURE 1. Peanut oil pressing extraction process.

2.2.1. Oil recovery and fine solid content in oil

For each experimental run, the oil recovery (OR, %) was calculated considering the initial oil content in the incoming material (TO, total oil (g)) and the residual oil content in the pressed cake (CO, cake oil (g)) obtained by Soxhlet extraction as indicated previously according to the following equation:

OR = [(TO – CO)/TO] × 100

Oils from each experimental run were centrifuged at 11.000 g for 30 min. The precipitated solids were recovered, washed with n-hexane, dried and weighed. Solid content in oil was expressed as g solids/100 g extract (oil + fine solids) (Martínez *et al.,* 2013).

2.3. Oil analyses

Centrifuged and filtrated oil samples were used for all analytical determinations. Acid, peroxide and K232, and specific extinction coefficient values were analyzed according to the standard methods of AOCS (2009). The concentration of total phenolic compounds in the extracted oils was determined by means of the Folin-Ciocalteau reagent following a method used previously (Torres *et al.,* 2009). The oxidative stability index (OSI) was evaluated under accelerated oxidation conditions using the Rancimat (Metrohm, Herisau, Switzerland) apparatus. The airflow rate was set at 20 L/h and the temperature of the heating block was maintained at 110 ºC. The results corresponded to the break points in the plotted curves and were expressed as induction time (hours).

Fatty acid (FA) and tocopherol compositions were analyzed by gas chromatography (Clarus 500, Perkin-Elmer, Shelton, USA) and high-performance liquid chromatography (HPLC Series 200, Perkin-Elmer), respectively, according to the protocols for oil sample preparation and chromatographic conditions as reported previously (Maestri *et al.,* 2015).

For FA composition, the oil samples (0.5 g) were subjected to alkaline saponification (5 min reflux using 10 mL 0.5 N KOH in methanol) followed by esterification (5 min reflux, 10 mL 0.5 N H_2SO_4 in methanol). The FA methyl esters (FAMEs) were separated on a fused silica capillary column CP Wax 52 CB (Varian, Walnut Creek, CA, USA) with carrier gas N_2 at 1 mL/min, split ratio 100:1, column temperature programmed from 180 ºC (5 min) to 220 ºC at 2 ºC/min, injector and detector temperatures at 250 ºC, FID. The identification of FAMEs was made by comparison of their retention times with those of reference compounds (Sigma-Aldrich, St. Louis, MO, USA), and their concentrations were expressed as percentages of the total FA contents.

For tocopherol analysis, accurately-weighed oil samples (1 g each) were diluted with n-hexane to 10 mL. The solutions were filtered through 0.45 µm pore filters. Aliquots of 20 µL of the filtrated solutions were injected into a Supelcosil LC-NH_2-NP column (25 cm x 4.6 mm, Supelco, Bellefonte, USA). The mobile phase was n-hexane/ethyl acetate (70/30, v/v) at a flow rate of 1 mL/min. UV detection at 295 nm was performed. Individual tocopherols were identified by comparing their retention times with those of authentic standards (ICN Biomedicals, Costa Mesa, USA), and were quantified by the external standard method. The linearity of the response was verified by fitting to line the results of each tocopherol individual (six standard solutions with known concentrations), covering the concentration range from 2 to 800 ppm, with a linearity regression coefficient $R^2 = 0.99$.

2.4. Statistical analysis

The different extraction treatments were carried out in triplicate. All parameters were evaluated for statistical differences using one-way analysis of variance (ANOVA) at a significance level of $p \leq 0.05$. Whenever the ANOVA test indicated a significant difference, Fisher's Least Significant Difference (LSD) test was performed for pair-wise comparison of means, also at a 5% significance level. Statistical analysis was performed using the InfoStat program (National University of Córdoba, Córdoba, Argentina).

3. RESULTS AND DISCUSSION

The oil extraction operations performed with WP yielded a maximum OR percentage (82.10% with respect to the total available oil) when using seed material with moisture content of 6%, pressed at 90 °C (Table 2). This recovery percentage represents approximately 450 g of oil per kg of ground and hydrated material. Considering the levels of all factors evaluated, the adjustment of the oil yield data (OR %) resulted in the following equation:

$$OR\ \% = 40.60 - 0.40\ SRS + 14.48\ SMC - 0.003\ PT^2 - 0.044\ PT \times SMC - 0.811\ SMC^2$$

where SRS is the screw-rotation speed, SMC is the seed moisture content, and PT is the pressing temperature.

TABLE 2. Percentages of oil recovery and fine solid contents in oils obtained from blanched peanuts (BP) and whole peanut kernels (WP) under the process conditions for maximum extraction yield.

Process parameters	Optimal condition for maximum OR			
	BP		WP	
PT (°C)	150		90	
SMC (%)	9		6	
CS (mm)		5		
SRS (rpm)		20		
Response variable	**Experimental**	**Model**	**Experimental**	**Model**
OR (%)	77.56^a ± 1.10	76.90	82.10^b ± 1.64	81.49
FSCO (%)	4.56^a ± 0.28	4.60	8.65^b ± 2.22	6.07

PT, pressing temperature; SMC, seed moisture content; CS, compressive stress; SRS, screw-rotation speed; OR, oil recovery; FSCO, fine solid content in oils. Mean values (n = 3) ± standard deviation. Mean values follow by different superscript letters in the same row represent significant differences ($p \leq 0.05$) between the two tested treatments.

The coefficient of determination of the model (R^2) was able to explain 96.0% of the data variability in OR. The predicted value (81.49%) and the experimental value (82.10 ± 1.64%) showed an error of 0.74%, thus suggesting a good prediction level of the model.

Regarding the individual effects of the examined factors, it should be noted the negative quadratic effects of both PT and SMC, as well as a negative cross effect between both factors (Figure 2) at 90 °C, the OR % decreased when using materials containing the highest SMC. A graphic representation of the combined effect of those two factors is shown in Figure 3.

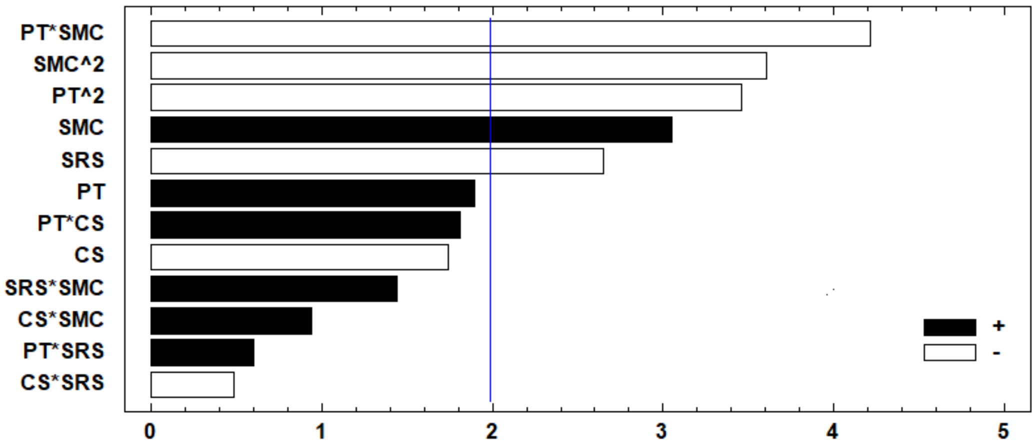

FIGURE 2. Pareto chart showing significant effects of process conditions on oil recovery from whole peanut kernels. Abbreviations: PT, pressing temperature; SMC, seed moisture content; CS, compressive stress; SRS, screw-rotation speed. Each experimental condition was applied in triplicate.

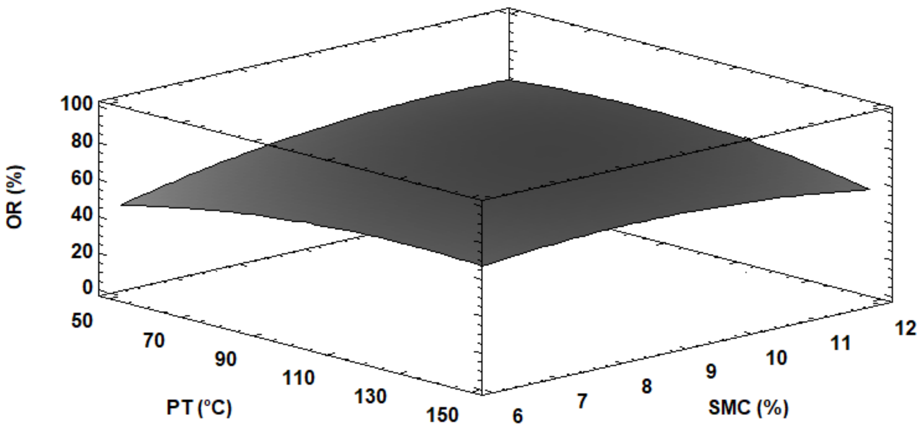

FIGURE 3. Effects of pressing temperature (PT) and seed moisture content (SMC) on oil recovery (OR) from whole peanut kernels. Each experimental condition was applied in triplicate.

Considering all the extraction treatments tested, the quality parameters of the oils obtained showed values within the following ranges: acid value (AV), 0.54–1.97 mg KOH/g oil; peroxide value (PV), not detected - 1.99 meq O_2/kg oil; specific extinction coefficient (K232), 1.22–2.36; oxidative stability, 41.4–50.6 h. At the optimal extraction condition (6% SMC, 90 °C PT), AV and PV (0.69 mg KOH/g oil and 0.10 meq O_2/kg oil, respectively, Table 3) were well below the maximum values allowed by Codex Alimentarius (up to 4.0 mg KOH/g oil and up to 15 meq O_2/kg oil, respectively) for virgin, cold-pressed oils (CODEX, 1999). Moreover, the fatty acid composition of the oil extracted at that condition was similar to that of "high oleic" Runner peanut oils obtained from cold-pressed raw kernels (Martín *et al.,* 2018). Likewise, the concentrations of total tocopherols (442.2 mg/kg oil), and their individual components were in agreement with the average values from "high oleic" Runner peanuts of Argentine origin (https://alimentosargentinos.magyp.gob.ar/). Therefore, it can be deduced that the process conditions used for maximum OR did not alter the characteristic fatty acid and tocopherol profiles of the starting material. The oil from the above mentioned treatment contained approximately 3 mg of total phenolic compounds/kg. Although this represents a low concentration, taking into account the proportion of these compounds present in the peanut tegument (Bodoira *et al.,* 2022), the result achieved is a matter of interest considering the contribution they can make to the oxidative stability of the oil.

The oil extraction operations using BP yielded a maximum OR percentage (77.56%) with seed material containing 9% moisture, pressed at 150 °C (Table 2). The fitted model equation was as follows:

$$OR\ \% = -123.46 + 0.59\ PT - 0.39\ SRS + 37.40\ SMC - 0.06\ PT \times SMC - 1.77\ SMC^2$$

The coefficient of determination of the model (R^2) was able to explain 95.8% of the data variability in OR. The predicted value (76.90%) and the experimental value (77.56 ± 1.10%) showed an error of 0,85%, thus suggesting a good prediction level of the model.

Regarding the individual effects of the examined factors, the positive linear effects of both PT and SMC, a negative cross effect between both factors, and a negative quadratic effect of the SMC (Figure 4) should be noted. The combined effect of PT and SMC on OR % is shown in Figure 5. Under the extraction conditions for maximum OR, the oil obtained showed chemical quality and compositional parameters similar to those found in WP-extracted oils (Table 3).

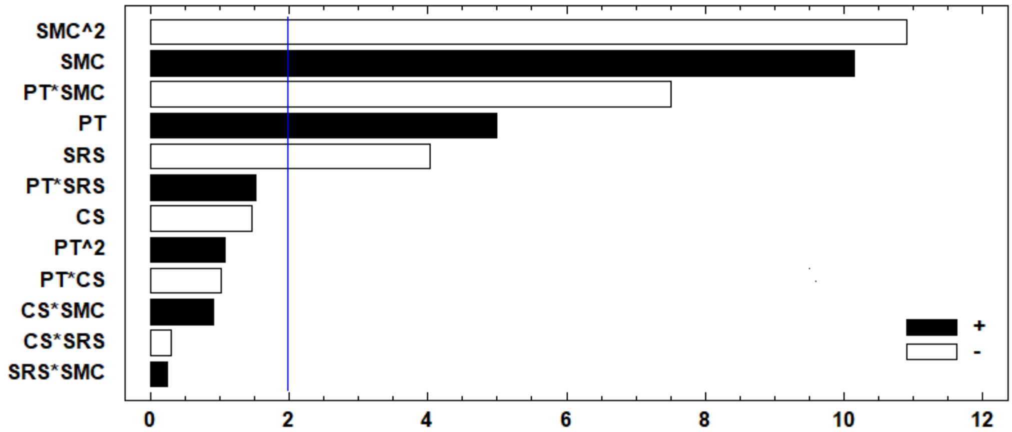

FIGURE 4. Pareto chart showing significant effects of process conditions on oil recovery from blanched peanut kernels. Abbreviations: PT, pressing temperature; SMC, seed moisture content; CS, compressive stress; SRS, screw-rotation speed. Each experimental condition was applied in triplicate.

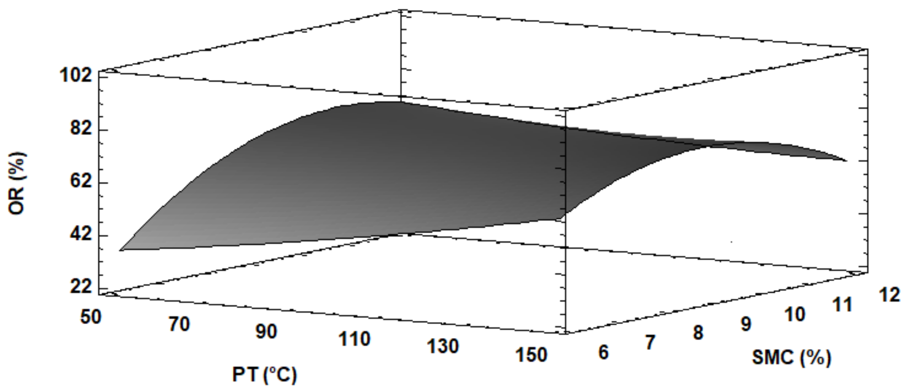

FIGURE 5. Effects of pressing temperature (PT) and seed moisture content (SMC) on oil recovery (OR) from blanched peanut kernels. Each experimental condition was applied in triplicate.

Comparison of the oil yields obtained from the two types of materials used emphasizes the significantly higher oil recovery when skin-coated peanuts are used ($p \leq 0.05$). The results demonstrate that pressing whole peanuts under optimal conditions—6% moisture content, a temperature of 90 °C, and a compressive stress of 5 mm—produces a maximum oil recovery (OR) of 82.10%. In contrast, blanched peanuts under similar stress conditions yield a significantly lower OR of 77.56%, requiring a higher temperature (150 °C) and moisture content (9%). These results strongly suggest that the presence of the fibrous tegument (skin) plays a crucial role in enhancing the extraction process. Although it is not possible to give a conclusive response on this fact, a possible explanation is that the presence of tegument, which is rich in fiber, may increase frictional forces inside the press barrel, thus leading to enhanced oil release during the pressing process. In support of this hypothesis, it has been observed that the presence of hull in whole sunflower seeds increases the frictional resistance in the barrel and enhances oil recovery (Mridula *et al.,* 2020a). Likewise, the oil recovery from pressing whole flaxseed was reported to be higher as compared to that reached from dehulled flaxseed (Zheng *et al.,* 2005). Other research has also demonstrated the desirability of using whole flaxseed in order to increase oil extraction efficiency (Mridula *et al.,* 2015). These authors reported high oil recovery percentages (up to 83% of the total available oil) by pressing samples of mixed whole and dehulled flaxseeds with 6.4% moisture content and pressed at 80 °C. These conditions are also similar to those indicated for obtaining the highest oil recovery from whole peanut kernels.

TABLE 3. Composition and quality parameters of oils obtained from blanched peanuts (BP) and whole peanut kernels (WP) under the process conditions for maximum extraction yield.

Parameter	BP	WP
Fatty acid (%)		
Palmitic	$5.53^a \pm 0.12$	$5.29^a \pm 0.32$
Palmitoleic	$0.68^a \pm 0.15$	$0.13^a \pm 0.01$
Stearic	$1.81^a \pm 0.04$	$2.64^a \pm 1.10$
Oleic	$83.94^a \pm 0.71$	$81.52^a \pm 0.77$
Linoleic	$4.60^a \pm 0.11$	$4.40^a \pm 0.39$
Linolenic	Tr	Tr
Arachidic	$0.98^a \pm 0.01$	$1.05^a \pm 0.01$
Eicosenoic	$2.49^a \pm 0.01$	$2.50^a \pm 0.32$
Total tocopherols (mg/kg oil)	$414.6^a \pm 8.32$	$442.2^b \pm 10.7$
α-Tocopherol	$257.4^a \pm 3.27$	$254.0^a \pm 1.81$
β-Tocopherol	ND	13.2 ± 1.69
γ-Tocopherol	$157.2^a \pm 5.74$	$175.0^b \pm 2.15$
Total phenols (mg/kg oil)	ND	2.87 ± 0.20
AV (mg KOH/g oil)	$0.82^a \pm 0.09$	$0.69^a \pm 0.03$
PV (meq O_2/kg oil)	$0.21^a \pm 0.10$	$0.10^a \pm 0.01$
K_{232}	$1.68^b \pm 0.06$	$0.49^a \pm 0.01$
OSI (h)	$43.30^a \pm 0.62$	$43.99^a \pm 0.37$

Abbreviations: AV, acid value; PV, peroxide value; OSI, oxidative stability index; Tr, trace (< 0.1 %); ND, not detected. Mean values (n = 3) ± standard deviation. Mean values follow by different superscript letters in the same row represent significant differences ($p \leq 0.05$) between the two tested treatments.

Our findings indicate a higher extraction efficiency compared to previous studies on peanut oil. For instance, Mridula *et al.* (2020b) reported an oil recovery (OR) of 75.89% from blanched peanut kernels pressed at 66.5 °C, 8% moisture content, and 8 mm compressive stress. These values are slightly lower than those observed in the present research for blanched peanuts. Conversely, the oil yields obtained in this study significantly exceed the 41.17% OR reported by Suri *et al.* (2019), who utilized cold pressing at temperatures below 50 °C. In summary, this study revealed that optimizing process variables is essential for maximizing oil recovery, primarily by modifying viscosity, friction, and compression. Specifically, applying thermal treatment significantly improves extraction by decreasing the viscosity of the fluid phase, thereby facilitating oil flow (Suri *et al*., 2019). Furthermore, the moisture content of the material plays a crucial, dual role as it enhances extraction not only by increasing material plasticity but also by acting as a lubricant to reduce friction. Process configuration parameters control the mechanical efficiency, smaller nozzle diameters maximize yield by increasing the degree of compression, while lower pressing speeds enhance recovery by prolonging the material's residence time under pressure (Mridula *et al*., 2020b).

Nevertheless, while high temperature and moisture are beneficial for yield, it must be considered that these conditions theoretically risk chemical degradation (i.e. glyceride hydrolysis); however, this adverse effect was not observed in this study. In fact, the comparison of the oils extracted from WP and BP indicated minor differences in their quality/stability parameters and FA composition (Table 3). The oils extracted from WP showed higher total tocopherol content and phenolic compounds as compared to BP-extracted oils. These findings suggest exploring other levels of process parameters in order to obtain oils enriched with such bioactive compounds. In this regard, studies on the metabolomics and functional properties of peanut oils obtained by means of different conditions have been published (Wang *et al.,* 2019; Jiang *et al.,* 2020). By using extraction temperatures close to 130 °C, these authors succeeded in obtaining peanut oils enriched in phenolic substances, which in turn showed beneficial effects on lipid metabolism in *in vivo* experimental trials (Jiang *et al.,* 2020).

4. CONCLUSIONS

Factorial designs were used to maximize peanut oil extraction by means of screw-pressing operations. The experimental designs included two types of materials (blanched peanuts, BP, i.e. kernels without tegument, and whole peanut kernels, WP, i.e. with tegument), and seed moisture content (SMC) and pressing temperature (PT) as the main process parameters. Fitted models for oil recovery (OR) showed maximum predicted values similar to the highest experimental values, which were reached under the following conditions: 6% SMC, 90 ºC PT (WP), 9% SMC, 150 ºC PT (BP). The extractions carried out with the two types of materials showed significant differences in oil recovery (about 82 and 77% of the total seed oil content, for WP and BP, respectively), in both cases with chemical quality indicators within the ranges of values stated in Codex (FAO/WHO) standards for virgin, non-refined oils. As a distinctive feature, the oils extracted from WP contained higher concentrations of both tocopherols and phenolic compounds as compared to oils extracted from BP. As a whole, the results suggest the possibility of using whole peanut kernels (with tegument) as raw material to obtain the oil. This could preclude the necessity of roasting and/or blanching steps thus allowing to save on labor-intensive and energy-consuming processes.

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DECLARATION OF COMPETING INTEREST

The authors of this article declare that they have no financial, professional or personal conflicts of interest that could have inappropriately influenced this work.

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AUTHORSHIP CONTRIBUTION STATEMENT

M.L. Martínez: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing; R.M. Bodoira: Formal analysis, Investigation, Methodology, Writing – review & editing; F.V. Grasso: Formal analysis, Investigation, Methodology; M.C. Penci: Formal analysis, Funding acquisition, Investigation, Methodology; M.C. Cittadini: Formal analysis, Investigation, Methodology; D.M. Maestri: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing.

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