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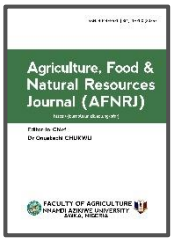

Original Article

Performance evaluation of a screw press expeller for oil extraction from white Melon (*Cucumeropsis mannii*) seeds

OPEN ACCESS

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A B S T R A C T

This study investigated the effects of varying the speed, pressure, time, and temperature across multiple levels on the performance of a screw press expeller for extracting oil from white melon (Cucumeropsis mannii) seeds. A factorial design was implemented, consisting of three factors and three levels each, resulting in a total of 27 experimental runs. The data from the experiments were analysed using ANOVA and modelled with the Response Surface Methodology (RSM). The findings revealed that speed, pressure, and extraction time influenced oil yield significantly (p value < 0.005). The results obtained for throughput were also similar. In both cases, speed has the greatest effects. The conditions for optimal oil yield, determined statistically were 550 rpm speed, screw pressure of 6 turns, and time of 9 minutes, giving an oil yield of 29% at a throughput of 13 kg/min. Thus, while maintaining low pressure settings may reduce operational complexity and costs, speed adjustments are vital for optimizing the screw press's performance. These findings provide practical guidelines for the industrial application of screw presses, offering insights into achieving higher efficiency in oilseed processing.

K E Y W O R D S : *Oil yield, Optimisation, Pressure, Response surface methodology, Speed.*

INTRODUCTION

The global demand for vegetable oil is increasing, driven by population growth and urbanization (FAO, 2020; Mannucci et al., 2023). In Africa, the demand for vegetable oils rose by 3.5% annually from 2020 to 2025 (OECD/FAO, 2020). White melon (*Cucumeropsis mannii*) is an indigenous West African crop packed with nutrients and oil, making it a valuable food source, oil for cosmetics, and biofuel (Oluwole et al., 2022). Nigeria is a significant melon producer, with an annual production of over 1.4 million tonnes (Oyediran *et al*., 2018). The seeds contain above 40% oil, which is a staggering amount compared to many other oilseeds (Khalid, *et al.,* 2021). The primary challenge in extracting the oil from white melon seeds is the lack of appropriate, efficient, and mechanized processing technologies for small-scale production, coupled with the laborious nature of traditional manual methods (Giwa & Akanbi, 2020).

The extraction of oil from oil seeds is a complex process with various methods employed to achieve optimal results. Mechanical and chemical techniques, often in combination, have been employed to efficiently separate the oil from the solid meal (Shahidi *et al,* 1996). In Nigeria, traditional methods typically require minimal equipment and rely on human

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labour, making them accessible for small-scale producers or communities with limited resources (Bankole & Hameed, 2024). However, a low percentage of oil from the seeds is recovered, compared to mechanical expellers or solvent extraction. Vegetable oil expellers enable the efficient extraction of oil from various oil seed sources (soybean, peanuts, etc.), making them an essential tool for industries worldwide (Kuma *et al*., 2020). Among these expellers, screw press expellers stand out for simplicity, ease of operation, and cost-effectiveness (Belay *et al*., 2020). Efficiency, oil yield, and quality are critical parameters in assessing the performance of screw press expellers.

Ajibola *et al*. (1990) investigated the mechanical extraction of oil from melon seeds (*Cucumeropsis mannii*) using a continuous screw press. The research identified optimal conditions for extraction, as seed moisture content of 5 - 8% and finely milled particle sizes. Pérez *et al.* (2020) reported that moisture content of seeds before pressing is a critical factor enhancing oil yield - overly dry seeds result in lower extraction efficiency. Olaoye *et al*. (2020) presented an oil expeller capable of extracting oil from various seeds. The results showed that increasing moisture content improved oil yield and efficiency, but reduced the volumetric flow rate, while increasing worm shaft speed improved oil recovery, oil yield, throughput capacity, and efficiency. Efficiency, ranging from 39.4 - 52.1% for palm kernel, 82.1% for soybean, and 53.1 - 72% for groundnut, were reported. The key findings of Mousa *et al*., (2022) included that lower screw speeds (20 rpm) and smaller nozzle diameters (8 mm) resulted in the highest oil yield. It is to be noted that the type of seed is a foundational factor because it determines the oil content, while the other factors can be considered as the pre-treatment conditions and specific operating parameters, which can be optimized for a given seed type (Fantino *et al*., 2020; Midun *et al*., 2023).

While many previous studies have evaluated the performance of screw press expellers for various oil seeds, there is a significant knowledge gap regarding white melon (*Cucumeropsis mannii*) seeds. More investigations are required to establish the factors for establishing machine and operating parameters for extracting oil from white melon seed. Understanding how these parameters affect oil extraction, can help to optimize the process and unlock the full potential of white melon seeds. This study examines the performance evaluation of a screw press developed at the Obafemi Awolowo University, Ile Ife, Nigeria in extracting oil from white melon seeds.

MATERIALS AND METHOD

The Screw Press Expeller

The screw press (Plate 1) used in this work is a prototype multipurpose expeller designed and fabricated in the Department of Agricultural and Environmental Engineering Obafemi Awolowo Ile Ife. It features a 2-horsepower electric motor that drives the screw press via a pulley and belt system, ensuring smooth, continuous operation. The expeller is equipped with a heating element (220V, 75W) and a control unit used for setting the temperature, making it suitable for oil extraction. The screw press inside the barrel, having a tapered shaft diameter design that gradually increased from the inlet to the outlet, effectively crushed and pressed the oilseed against the wall of the barrel, facilitating the extraction of the oil content.



Plate 1: The screw press

White Melon Samples

54kg of white melon was purchased from Akinola market in Ile-Ife and was transported to the Agricultural and Environmental Engineering Department Workshop, where the evaluation was carried out. The seeds were cleaned in batches by winnowing, to remove dirt and foreign materials. This crucial step ensured that only clean oil seed was loaded into the expeller, preventing machinery damage and ensuring the extracted oil's purity.

The white melon seeds used in the study had an initial moisture content of 6.40%, determined according to ASABE D245.7 Standards (ASABE, 2021), which falls within an optimal range for oil extraction, ensuring smooth processing during the expeller's operation. By controlling moisture content, it was possible to maintain consistency across experimental runs, allowing for more accurate evaluation of the screw press expeller's performance.

Roasting

Pre-heating white melon seeds through roasting is a vital step that substantially improves oil extraction efficiency (Zahang *et al*., 2024). By subjecting the oil seed to a controlled thermal process, the extraction process is optimized, resulting in enhanced oil yield and improved overall quality. The white melons were roasted in an oven dryer for 30 minutes at a temperature of 150°C to achieve crispy but not burnt effects before loading it into the expeller. This helps soften the seeds and loosens the oil with the cells for easier oil extraction. The roasted white melons were cooled before loading into the expeller.

Oil Extraction

A no-load test was conducted on the screw press machine to access its operational performance and address potential faults. With the speed, pressure, and temperature set, the screw press began the extraction process. The extracted oil passed through the perforated sections of the barrel and was collected in a container,

while the residual cake was gathered at the front end of the expeller. After collection, the oil was allowed to cool and was subsequently filtered to remove any residual white melon seed particles mixed with the oil. This procedure was systematically repeated for each experimental run, with all operational parameters closely monitored and controlled. Data from each run were meticulously recorded and analysed for later evaluation and calculations, ensuring the integrity and accuracy of the results.

Experimental Design

A factorial design was implemented, consisting of three factors and three levels each, resulting in a total of 27 experimental runs. This design was chosen to examine the effects of each factor independently, investigate potential interactions between factors and provide a comprehensive understanding of the expeller's performance across a range of operating conditions. The three factors investigated in this study were:

i Temperature: the level combinations used are 80°C, 100°C, and 120°C.

ii Pressure: The screw press expeller was operated at three distinct pressure levels, achieved through adjustments of the screw, which has a pitch size of 0.35 cm per turn. The pressure settings corresponded to the number of screw-turns: 2 turns, 4 turns, and 6 turns. The resulting displacements of 0.70 cm, 1.40 cm, and 2.10 cm.

iii Speed: The level combinations used are 350 rpm, 470 rpm, and 710 rpm.

The levels were selected based on preliminary tests. For each experimental run, the response variables measured were oil yield (% oil extracted of the total oil available) and throughput (weight of oil seed processed per time). These metrics are critical in assessing both the efficiency and productivity of oil extraction processes by the expeller.

Data analysis

The data collected were analysed using Analysis of Variance (ANOVA) to determine the statistical significance of the effects of the factors on oil yield and throughput. Both main effects and interactions were assessed to understand how each factor, individually and in combination, influenced expeller performance. The Response Surface Methodology (RSM), available in the Minitab Software (Minitab, 2024), was used to model the relationship between factors and responses, facilitating the identification of optimal conditions. The ANOVA was implemented using IBM SPSS Statistical software (Version 27.1) - (IBM Corp, 2020).

RESULTS AND DISCUSSION

Table 1 shows the response surface regression of oil yield (%) against speed, pressure, temperature and time. The three factors having p value < 0.005 are speed, pressure and time (process time). The temperature effect was found to be insignificant and could not be estimated by the software. As also shown in the Table 1 (and also revealed in Figure 1a: Normalized plot of standardized effects), the factors having significant effects on oil yield (%) are speed, pressure and extraction time. Figure 1b: (Pareto chart of standardized effects) illustrates the relative importance of each of the factors. Thus, operating speed is the most critical adjustable factor for extracting oil for this screw press.

Effects of speed on oil yield.: Generally, oil yield increases with speed up to a certain level, after which increase in speed no longer encourages higher oil yield. As observed by Obi & Akpan (2020) , speeds above 600 rpm may reduce oil quality due to excessive shear forces. This indicates that while faster operation enhances oil extraction to a degree, other factors like seed properties or screw geometry also contribute to yield efficiency.

Effects of pressure and time on oil yield: The effect of pressure, though significant, is less pronounced. Higher pressures paired with longer pressing duration maximizes the amount of oil extracted. Reducing the screw speed increases the residence time of the material in the press, leading to higher oil extraction efficiency. Adesina & Bankole (2023) also found that that oil yield increased with increase in applied pressure and pressing time. Olawale *et al*. (2020) reported that moderate pressure settings provide the best balance between oil yield and cake quality. Pressure settings in a screw press are critical, acting as a balancing act between maximizing oil extraction efficiency and minimizing mechanical wear. Researchers, including Fakayode & Ajav (2019) and Sri *et al.,* **(**2004**)** reported that the higher-pressure settings increase oil recovery (lower residual oil in the cake) but also significantly increase wear and tear on components like the worm screw, screen, and cage. These findings suggest that adjusting speed should be a primary focus for optimizing the expeller's efficiency, while variations in pressure and temperature may have limited effects within the range tested. Figure 2b shows the interaction of the various factors on oil yield.

Table 1 : Response Surface Regression: Oil Yield (%) Versus Speed , Pressure and Time

Term	Coefficient	SE Coef	T-Value	P-Value	VIF
Speed	-16.83	2.14	-7.87	0.000	198.33
Pressure	-1.333	0.382	-3.49	0.003	6.12
Time	-18.67	2.62	-7.11	0.000	196.50
Speed*Speed	5.56	5.16	1.08	0.296	293.57
Pressure*Pressure	-0.528	0.312	-1.69	0.109	1.35
Time*Time	-5.33	6.94	-0.77	0.453	364.35
Speed*Pressure	-0.75	1.58	-0.48	0.640	73.14
Speed*Time	-6.0	11.1	-0.54	0.595	1288.19
Pressure*Time	-1.33	1.97	-0.68	0.508	73.42

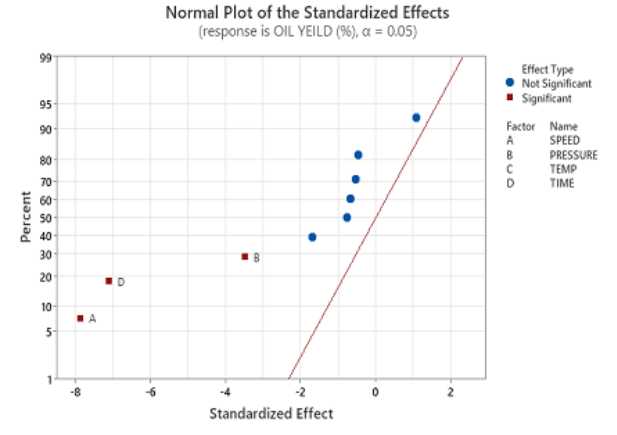

Figure 1a: Normalized plot of standardized effects,

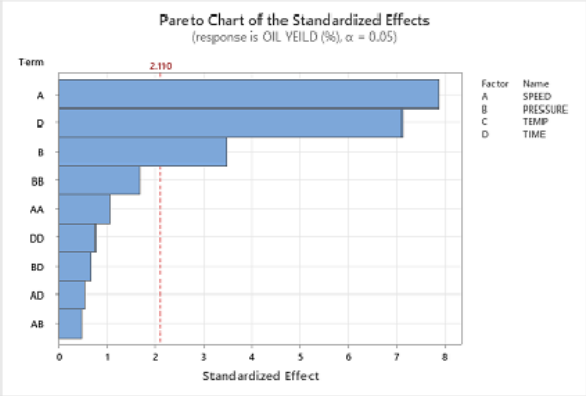

Figure 1b: Pareto chart of standardized effects

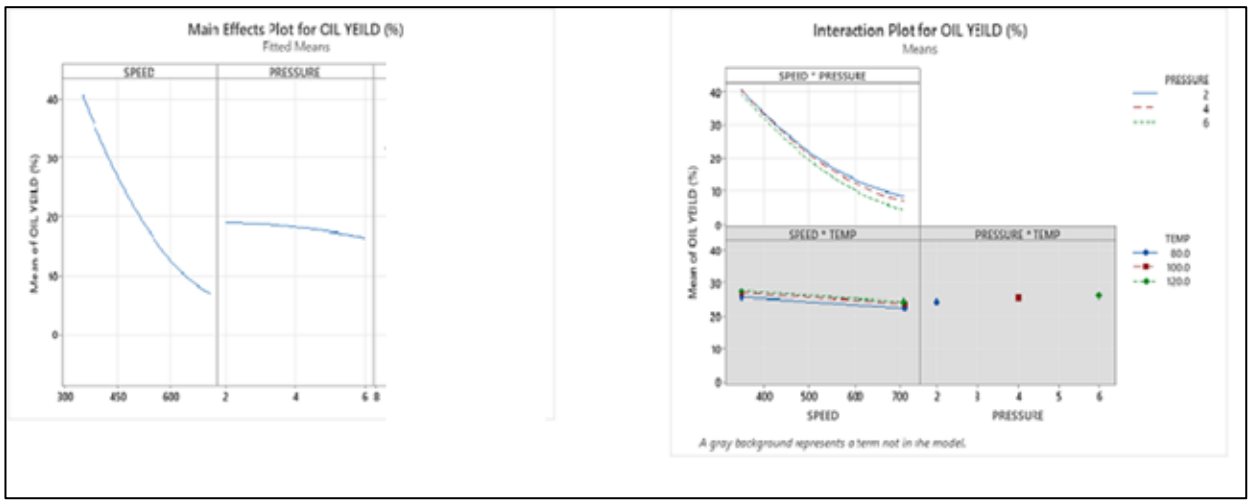

Figure 3: Main effects and interaction plots for oil yield (%)

Table 2. shows the response surface regression of throughput against speed, pressure, temperature and time. In the case of throughput, pressure is shown not to be significant (p value > 0.05) . The other factors having p value < 0.05 are speed and time (process time). The temperature was also insignificant could not be estimated be estimated by the software.

Throughput Capacity vs. Yield: A slower speed (longer press time or residence time) increases the oil yield but lowers the overall throughput or capacity of the machine.

Table 2 : Response Surface Regression: Throughput Versus speed , pressure, temperature and time

Term	Coef	SE Coef	T-Value	P-Value	VIF
Speed	-1.10333	0.24172	-4.56	0.000	198.33
Pressure	0.00261	0.04323	0.06	0.953	6.12
Time	-5.30667	0.29662	-17.89	0.000	196.50
Speed*speed	-2.17609	0.58355	-3.73	0.002	293.57
Pressure*pressure	0.04073	0.03524	1.16	0.264	1.35
Time*time	-0.97333	0.78479	-1.24	0.232	364.35
Speed*pressure	-0.12872	0.17819	-0.72	0.480	73.14
Speed*time	-5.15500	1.25353	-4.11	0.001	1288.19
Pressure*time	-0.18248	0.22291	-0.82	0.424	73.42

These relationships are better represented on the surface plots (Figures 3 and 4). The plots indicated that the oil yield falls with increasing speed and increasing pressure, as stated earlier.

Optimal operating conditions

A response surface optimisation of the factors was carried out using the RSM (Minitab software). The goal was to determine the maximum oil yield, throughput and cake residue. Table 3 presents the response surface optimisation of the factors.

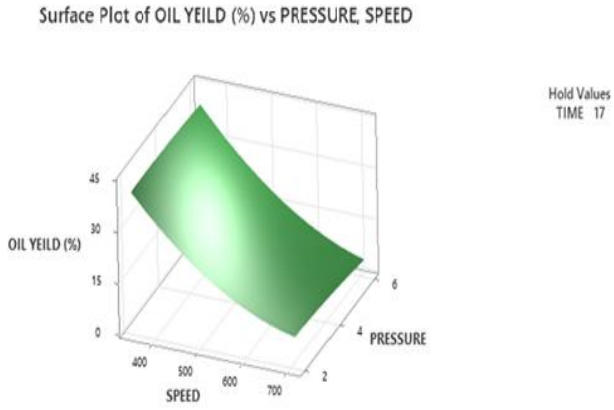

Figure 3: Surface plot of the oil yield vs speed and pressure

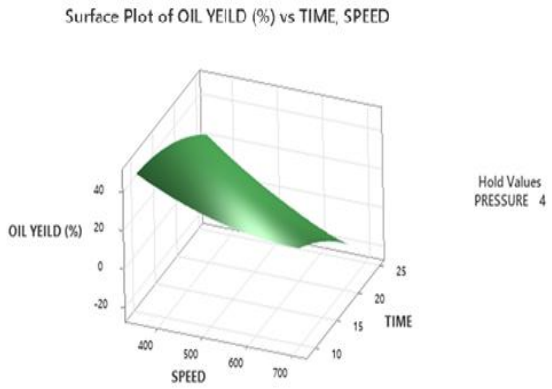

Figure 4 : Surface plot of the oil yield vs speed and time

Table 3 : Response Optimization: Oil Yield (%), Throughput, Cake Res, Oil Extracted

Response	Goal	Lower	Target	Upper	Weight	Importance
Oil yield (%)	Maximum	21.00	29.50		1	1
Throughput	Maximum	4.80	13.33		1	1
Cake Res	Maximum	1.34	1.51		1	1
Oil Extracted	Maximum	0.42	0.59		1	1

The obtained data showed that the oil yield varied from 21.0% to 29.5%, with the highest yield of 29.5% observed at a speed of 350 rpm, pressure of 6 turns, and a temperature of 120°C. The throughput values ranged from 4.80 kg/h to 13.33 kg/h, with the highest throughput recorded at 710 rpm, 6 turns of pressure, and 120°C temperature. The throughput initially increased with speed, and after some time has a more pronounced decrease with increasing speed. In both cases, the p-values confirm that the observed effects are statistically significant, meaning that speed is a key factor affecting both throughput and oil yield. Temperature affects both throughput and oil yield in the range considered were statistically insignificant. This could be because the seeds have been previously roasted. The recommended (optimal) settings for the machine were speed (660 rpm), pressure (2 turns of the screw) and extraction time (9 minutes).

CONCLUSION AND RECOMMENDATIONS

This study provides an evaluation of the performance of a screw press expeller for extracting oil from white melon (*Cucumeropsis mannii*) seeds, focusing on the operational parameters of speed, pressure, time and temperature. The analysis identified speed as the most significant ($\alpha < 0.05$) factor influencing both oil yield and throughput. In contrast, temperature was not found to have statistically significant effect on either throughput or oil yield, with p-values well above common significance thresholds. The results offer valuable insights into how these variables affect key performance metrics: oil yield and throughput. As a result, operators can maintain consistent pressure and temperature settings, reducing the complexity of the operation without sacrificing performance. The findings are particularly relevant for industrial settings, where maximizing output and minimizing operational complexity are key to achieving cost-effective and productive oil extraction processes.

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Authors' Contributions

LAS, RRD and ASA conceived the idea presented in this work. ASA under the supervision of LAS carried out the experiments. RRD with the help of ASA carried out the data analysis. RRD with support from LAS & ASA wrote the manuscript. All authors provided the critical feedback and contributed to the final version of the manuscript

Ethical Statement

Not applicable.

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