

Design and Evaluation of a Small-Scale Hydraulic Cocoa Press Machine

Perancangan dan Evaluasi Mesin Pengempa Hidrolik Kakao Skala Kecil

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ABSTRACT

Cocoa is crucial for Small and Medium Enterprises (SMEs), facilitating the production of primary and secondary cocoa-based products, including various chocolate derivatives. This study aims to design and evaluate a small-scale hydraulic cocoa press suitable for SME applications by examining the effects of temperature and material mass on extraction yield. These factors form the basis for developing an efficient press machine for small to medium-scale production. The research involved a theoretical machine design followed by experimental testing using three temperature levels (90°C, 100°C, and 110°C) and three material capacities (150 g, 200 g, and 250 g). Results indicated that temperature was the primary factor affecting extraction performance. A temperature of 110°C consistently yielded the highest extraction, reaching 25% at 150 g and staying above 17% at 250 g. Lower temperatures (90°C and 100°C) produced significantly lower yields, with minimal gains despite increased material amounts. These findings offer a strong technical foundation for designing a more efficient cocoa press with an integrated heating system to maintain optimal operating temperature. Implementing this machine in SMEs could enhance production efficiency, reduce processing losses, and increase the added value of cocoa products, thereby strengthening SME competitiveness in the agro-industrial sector.

Keywords: Cocoa; pressing machine; cocoa fat; hydraulic; agroindustry

ABSTRAK

Kakao memberikan peranan penting pada pelaku Usaha Kecil Menengah (UKM) untuk menghasilkan produk primer dan sekunder, termasuk turunan coklat. Penelitian ini bertujuan untuk merancang dan evaluasi mesin pengempa untuk menghasilkan produk sekunder di UKM dengan menggunakan mesin pengempa melalui identifikasi pengaruh suhu dan kapasitas bahan terhadap yield sebagai dasar perancangan mesin pengempa skala kecil-menengah. Metode penelitian dilakukan dengan desain teoritis rancangan, dan eksperimen pengujian dilakukan dengan variasi suhu (90°C, 100°C, dan 110°C) serta massa bahan (150g, 200g, dan 250g). Hasil penelitian menunjukkan bahwa suhu merupakan faktor dominan dalam peningkatan yield. Suhu 110°C secara konsisten menghasilkan yield tertinggi di seluruh kapasitas, yield mencapai 25% pada 150g dan tetap stabil di atas 17% pada 250g. Sebaliknya, suhu rendah (90°C dan 100°C) menghasilkan yield yang lebih rendah dan tidak menunjukkan peningkatan signifikan meskipun massa bahan ditambah. Hasil ini menjadi dasar dalam merancang mesin pengempa yang efisien, dengan sistem pemanas terintegrasi yang mampu mempertahankan suhu optimal. Penerapan mesin ini pada skala UKM berpotensi meningkatkan efisiensi produksi, mengurangi limbah, serta meningkatkan nilai tambah produk kakao, sehingga berkontribusi terhadap penguatan daya saing UKM di sektor agroindustri.

Kata kunci: Kakao; mesin pengempa; lemak kakao; hidrolik; agroindustri

INTRODUCTION

Cocoa is a plantation crop that holds significant economic value in local and global markets (Fuadi Mubaroq et al., 2023). In Indonesia, cocoa plantations are nearly entirely operated by smallholder farmers (Eko Pudjianto et al., 2024). While the downstream processing sector is dominated by Small and Medium Enterprises (SMEs). However, SMEs often face difficulties in increasing the added value of cocoa-derived products due to limited access to appropriate technology, capital, and efficient processing equipment (Caecar et al., 2024). Similar challenges have also been reported broadly across Indonesian cocoa SMEs, particularly related to technological limitations and production

inefficiencies that hinder value-added processing (Astuti et al., 2024).

One of the most significant barriers is the length and complexity of the cocoa processing chain, which involves several sequential steps including fermentation, drying, roasting, pasteurising, and pressing (Widyantari, 2023, Asyik & Ansi, 2018, Mulyandari, 2019). Recent studies highlight that modern cocoa processing focuses not only on processing volume but also on extraction efficiency, preserving bioactive components, and more sustainable use of cocoa residues (Salcedo-Puerto et al., 2025, Tušek et al., 2024). Research on cocoa butter extraction optimisation also highlights the importance of temperature control, adequate mechanical force, and process consistency, serving as a benchmark for improving press machine design at the SME

scale (Y. Palacios et al., 2024). Furthermore, global reports on the cocoa sector indicate mounting pressures on sustainability, supply stability, and processing innovation, thereby reinforcing the need for affordable, scalable technologies for SME processors (Kongor et al., 2024). This technological gap stops many SMEs from moving past selling dried cocoa beans, limiting their ability to produce higher-value products like cocoa powder and cocoa butter (BSN, 2008). Although manual hydraulic press technology has proven effective in separating cocoa butter from cocoa liquor (Susilo et al., 2019), existing models typically are not built for SME-scale operations and often lack necessary features such as adequate capacity, integrated heating, steady pressure control, and ergonomic design. The importance of this research is due to the lack of an affordable, efficient, and appropriately scaled hydraulic cocoa press designed specifically for SMES. Without such a device, SMEs are unable to compete effectively in the cocoa value chain or fully exploit the economic potential of their raw materials. This study introduces a novel hydraulic cocoa press tailored for SME production, featuring optimised mechanical design, controlled heating, enhanced fat-extraction efficiency, and easier operation and maintenance which attributes rarely present in current SME equipment. The aim is to develop and assess a cocoa hydraulic press that meets SME requirements for capacity, efficiency, and ease of use, helping them produce cocoa powder and butter with higher yields and better consistency.

METHODOLOGY

This study started with developing a small-scale hydraulic cocoa press suited to the capacity and operational requirements of small businesses (Dwicahyo et al., 2024). The machine has dimension 60 x 50 x 80 cm and can process up to 250 g of paste per cycle. It features a heating system with a temperature indicator to ensure a stable processing temperature and enhance cocoa butter extraction. Development and testing took place at ChoCoYa Premium Chocolate Jember. The vertical pressing mechanism was chosen for its stable force distribution, while capacity was optimised for ergonomics, energy efficiency, affordability, and suitability for SMEs. Technical drawings, created using Solidworks 2016, shows the frame built from UNP steel profiles, a stainless-steel paste container, and a stainless pressing anvil 2016.

Design Experiment

The pressing machine was designed to ensure sufficient production capacity. Currently, ChoCoYa Cokelat Premium Jember produces dried and ground cocoa beans into powder, but the machine is not fully effective at separating cocoa butter.

The press design was guided by theoretical hydraulic calculations to guarantee the machine could produce enough compressive force for extracting cocoa butter. The hydraulic force was determined using the equation:

$$F = P \times A \tag{1}$$

F: Force (N)
 P: Fluid pressure (pa)
 A: Cross-sectional area (m²)

Where A was determined using:

$$A = \pi \times r^2 \tag{2}$$

r: centre diameter (cm)

The cylinder's working volume was calculated as :

$$V = A \times h \tag{3}$$

V : Cylinder working volume (cm³)
 A : cross-sectional area (cm²)
 h : piston height (cm)

These theoretical evaluations confirmed that a 20-ton hydraulic jack provided adequate pressing strength (Figure 1). Extraction yield was calculated using:

$$RIK = \frac{BI(kg)}{Ba(kg)} \times 100\% \tag{4}$$

RIK : Cocoa butter yield (%)
 BI : Cocoa butter weight (kg)
 Ba : Initial weight of paste (kg)

The principles of force transfer and pressure multiplication were illustrated through standard hydraulic diagrams (Figure 2), ensuring alignment between design specifications and mechanical requirements.

Force comparison as follows:

$$F_2 = F_1 \times (A_2 / A_1) \tag{5}$$

Hydraulic frame using UNP profile steel 15 cm x 5 cm x 0.6 cm, stainless press anvil, stainless paste container. The frame is modelled in SolidWorks 2016, as shown in Figure 3. The frame and hydraulic circuit adjust the assembly and design based on the jack specifications.

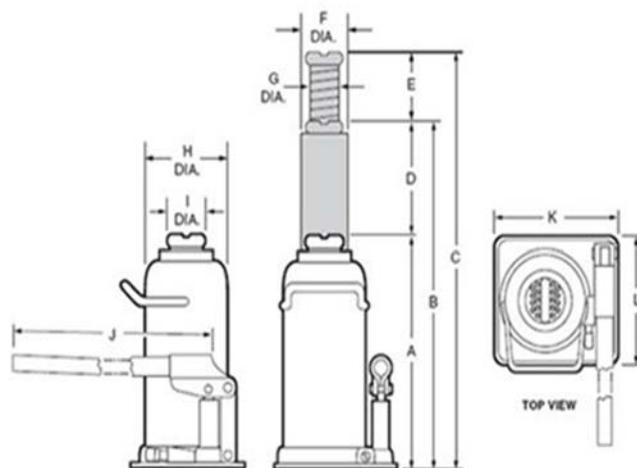


Figure 1. 2D view of hydraulic bottle jacks (SGS, n.d.)

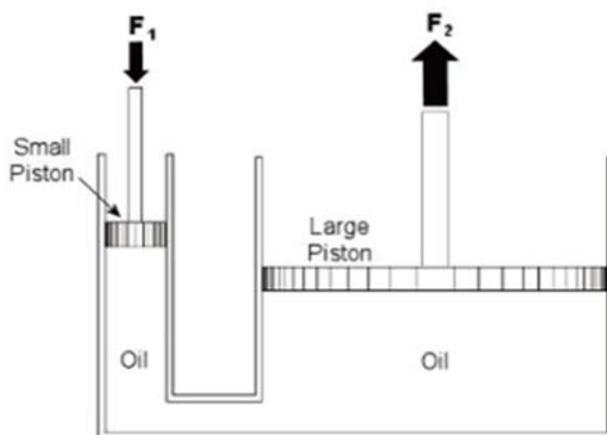


Figure 2. Principle of hydraulic press force (SGS, n.d.)

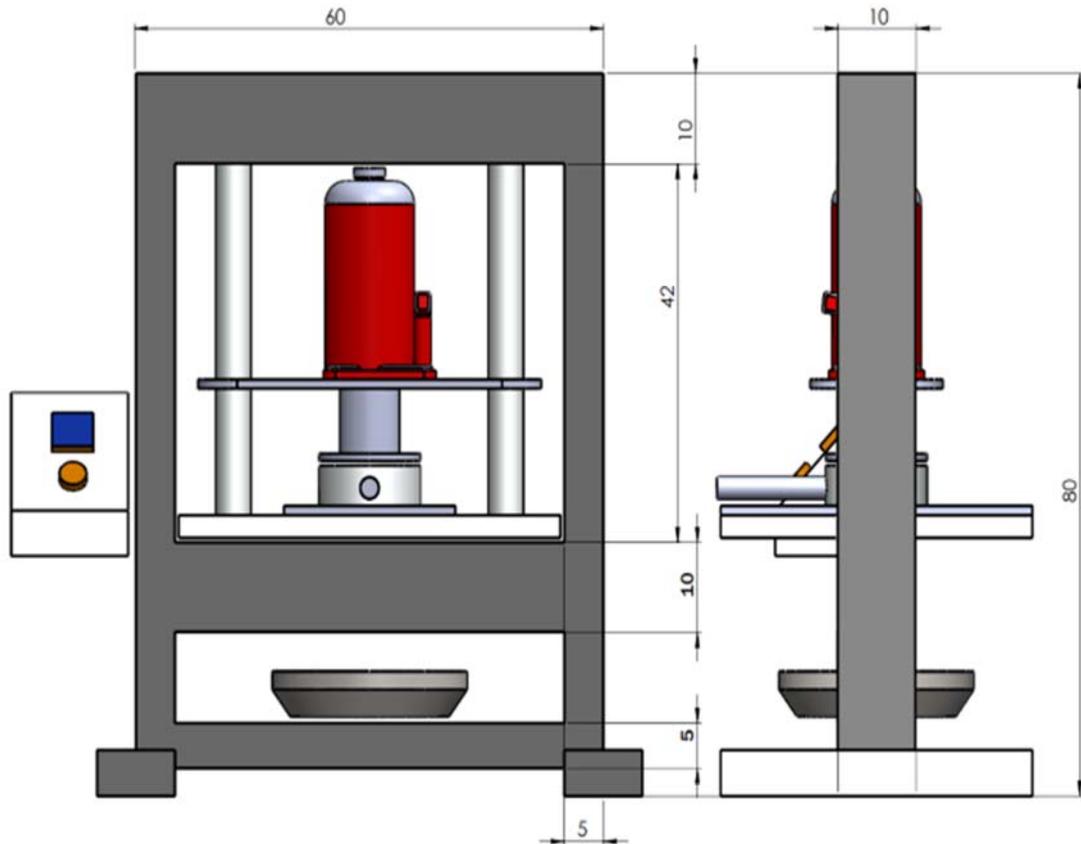


Figure 3. Cocoa press design

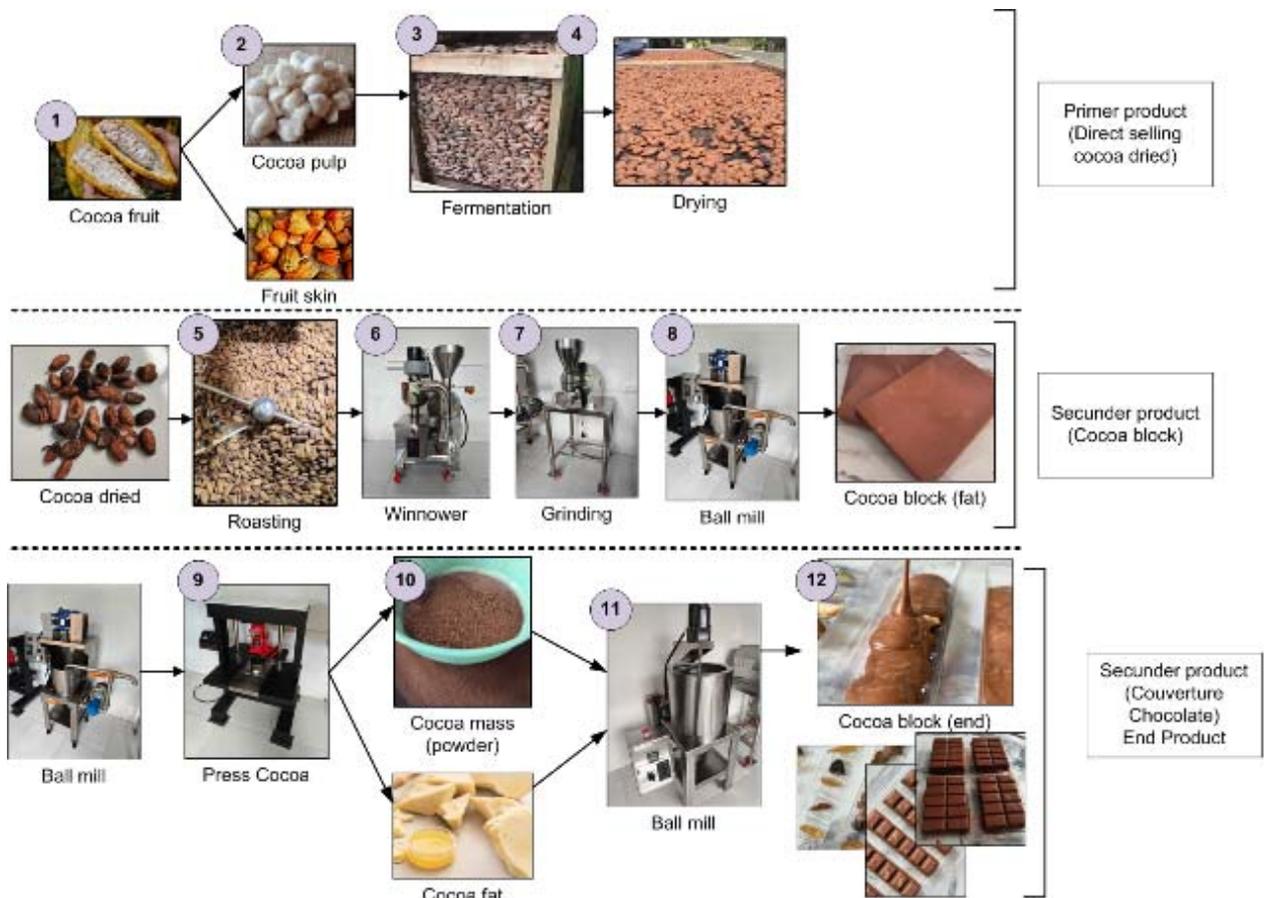


Figure 4. Cocoa bean processing flow

Experimental and material

Cocoa beans (MCC type, Jember origin) were processed from fresh pods to dried beans, then roasted at 150°C for 10–12 minutes, followed by 5 minutes of cooling. The roasted beans were shelled using the existing SME winnower and ground into cocoa paste. A factorial experimental design was employed to assess how temperature and material mass influence extraction efficiency. The pressing was carried out at three temperatures (90°C, 100°C, 110°C) and three paste weights (100 g, 200 g, 250 g). Each combination was repeated to ensure measurement accuracy. Key parameters measured included cocoa butter yield and residual fat solids. All tests were conducted between June and December 2024 under typical SME conditions to evaluate the machine’s real-world performance.

Analysis and evaluation

Performance analysis concentrated on assessing cocoa butter yield across various temperature and mass conditions to identify optimal pressing settings. The study compared the impact of temperature on fat extraction efficiency, the stability of the heating system, and the consistency of hydraulic pressure. Additional assessments focused on the frame’s mechanical stability, ease of operation, ergonomic factors, and suitability for SME production capacity. The findings from this evaluation validated the designed press machine as a practical, efficient, and cost-effective solution for cocoa-processing SMEs.

RESULT AND DISCUSSION

The cocoa pressing machine designed in this study uses a 20-ton hydraulic jack (Groz, 2025). The specifications, illustrated in Figure 1, show that the jack has an 11.4 cm body diameter, a 4 cm piston diameter, and a maximum lift of 14.5 cm. According to hydraulic principles, the small piston (F1) transmits force through hydraulic oil to the larger piston (F2), operated manually by a 59.5 cm lever. The theoretical maximum thrust of a 20-ton jack is about 196,200 N. Measurements reveal the small piston diameter is 1.8 cm with an area of 2.54 cm², and the large piston is 9 cm with an area of 63.62 cm², providing an effective force-multiplication suited for cocoa pressing. With a maximum stroke of 14.5 cm, the cylinder’s working volume is 922.45 cm³. Assuming proportional force reductions at capacities of 15 t, 10 t, and 5 t, as detailed in Table 1, even the lowest force remains suitable for cocoa fat extraction, as shown in Table 2.

Previous findings indicate that hydraulic presses can extract up to 50% of cocoa butter when used under optimal conditions (Dwicahyo et al., 2024). With a mould capacity of 250 g, the ideal separation would produce 125 g of butter. However, realistic efficiencies of 50–60% result in recoveries of 25–30%, or about 75 g of fat. This theoretical potential aligns with the mechanical capabilities of the designed machine.

Table 1. Estimated jacking capability

No	Jack, t	Force (F ₁), N	Force (F ₂), N
1	20	7.848	196.200
2	15	5.886	147.150
3	10	3.924	98.100
4	5	1.962	49.050

Table 2. Among all treatments, 110°C consistently produced the highest and most stable yields

Temperature	Observed Yield Range	Interpretation
110°C	19–26%	Optimal melting and drainage of cocoa butter; thermal softening maximised.
100°C	15–18%	Partial melting; moderate extraction efficiency.
90°C	13–16%	Limited fat mobility; incomplete melting.

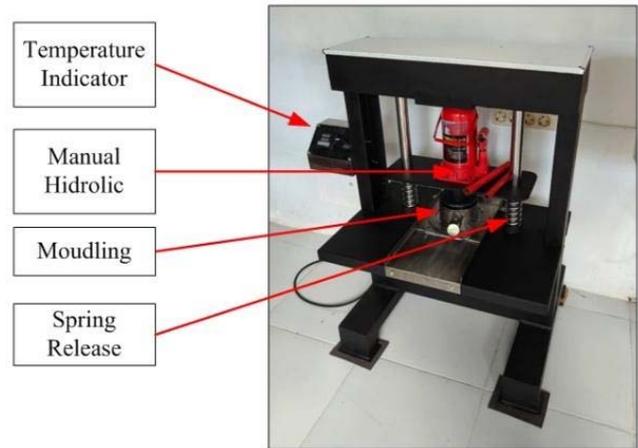


Figure 5. Cocoa butter pressing machine

The cocoa processing chain—from fresh pods to cocoa mass—impacts the properties of the paste used in pressing (Figure 4). Approximately 50 pods yield 10 kg of wet cocoa pulp, yielding 3.5 kg of dry beans after fermentation. Roasting yields around 2.8 kg of roasted beans, with about 2.1 kg of nibs obtained after winnowing. During grinding, typically 0.15–0.30 kg of cocoa butter can be separated, leaving 1.8–1.95 kg of cocoa mass. This initial profile determines the moisture content and structural characteristics that affect extraction behaviour.

This study’s pressing machine (see Figure 5) features an adjustable heating system, and a mould capacity of 250 g. Tests were carried out with three different material masses—150 g, 200 g, and 250 g— and at three temperature settings: 90°C, 100°C, and 110°C. For the 150 g samples (shown in Figure 6), yield significantly increased as temperature rose: from 22.5–25.5% at 110°C to 16.5–18% at 100°C and 15–17% at 110°C. For the 200 g samples (Figure 7), the same behaviour was observed. The 110°C treatment produced yields of 17.5–20.5%, followed by 15.5–17.5% at 100°C and 14–15.5% at 90°C. For the 250 g samples (Figure 8), 110°C again produced the highest extraction (16.5–18%), whereas 100°C yielded moderate levels (14.5–16.5%). The lowest and most variable yields occurred at 90°C (13–14.8%)

These results confirm that temperature primarily affects cocoa butter extraction. At 110°C, the cocoa butter’s viscosity decreases and the cell structure softens, enabling easier fat flow during pressing. In contrast, at 90°C, the cocoa butter stays semi-crystalline, which restricts fat movement. Increasing the mass from 150 g to 250 g does not significantly improve extraction efficiency when the temperature is adequate; however, the increased variability between samples indicates possible material inconsistencies or uneven heating, issues typical in small-scale pressing setups.

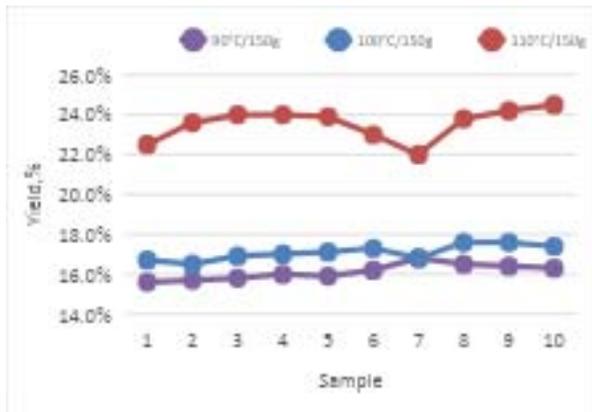


Figure 6. 150g pasta testing sample

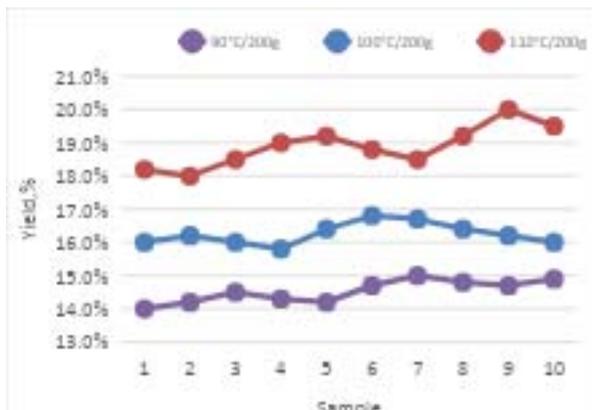


Figure 7. Test yield at 200g

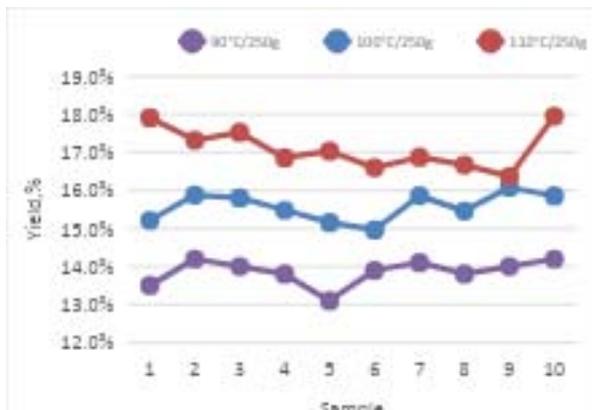


Figure 8. Test yield at 250g

Overall, 110°C was identified as the optimal pressing temperature, consistently achieving the highest extraction across all tested mass levels. This underscores the importance of thermal control over pressing force or material quantity. Future research should explore temperatures above 110°C, longer pressing times, and the long-term durability of hydraulic jacks to ensure sustainable operation in SME-scale cocoa processing.

CONCLUSION

This study shows that thermal control is the key factor affecting cocoa butter extraction efficiency in small-scale hydraulic presses. Besides confirming temperature's role, it highlights 110°C as a validated operational point that maintains consistent extraction results regardless of material load. This offers a practical guideline for SMEs and machine

designers, as earlier research largely focused on pressure capacity, with less attention to thermal optimisation in cacao pressing.

This study offers new insights into how mass loading affects heat transfer in SME-scale presses. While more material mass doesn't directly decrease yield proportionally, the variability highlights the importance of having a uniform heating system and controlled thermal distribution. This aspect has not been extensively explored in existing small hydraulic systems presses.

From a socio-economic perspective, identifying an optimal, energy-efficient temperature range provides a practical technological pathway for SMEs to enhance yield consistency without needing industrial-scale equipment. Using thermally controlled presses can enable small processors to produce higher-value cocoa butter, minimise material waste, and improve competitiveness in local and regional markets.

Overall, this study offers a scientific basis for how extraction mechanisms depend on temperature and presents a practical engineering framework to develop adaptable, cost-efficient cocoa presses designed for SMEs. Future research should focus on incorporating automated thermal control and assessing the long-term durability of these systems to enhance technology accessibility for small cocoa producers further.

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