

Effect of hydraulic pneumatic pressing pressure on the physical quality and production performance of gambier

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ABSTRACT

Gambier (Uncaria gambir Roxb.) is an important Indonesian plantation commodity whose physical quality and processing productivity are strongly influenced by the pressing stage. This study evaluated the effect of hydraulic–pneumatic operating pressure on gambier pressing performance and physical characteristics. We conducted experiments at five pressure levels (1, 3, 5, 7, and 8 bar), using an initial material mass of 5 kg for each test. We calculated the following parameters: pressing force, product density, estimated production capacity, wet-basis moisture content after pressing, and water removal during pressing. Pressures of 1 and 3 bar were insufficient to form a compact product. Within the effective range of 5–8 bar, increasing pressure increased product density from 1162.67 to 1270.40 kg/m³ and estimated production capacity from 14.88 to 23.42 kg/h. The calculated pressing force increased from 491.07 N at 5 bar to 785.71 N at 8 bar. Water removal based on the initial mass increased from approximately 0.60% at 5 bar to 5.00% at 8 bar. Among the tested conditions, 8 bar provided the best overall performance. However, because we did not evaluate pressures above 8 bar or energy consumption, this condition should be regarded as the best tested pressure rather than a globally optimised operating point.

Keywords: Gambier; hydraulic–pneumatic press; pressing pressure; density; production capacity

INTRODUCTION

Gambier (*Uncaria gambir* Roxb.) is one of Indonesia's important plantation commodities and is used in pharmaceutical, food, leather-tanning, textile, cosmetic, and natural-dye applications. The

economic value of gambier depends not only on its chemical constituents but also on the consistency and physical quality of the processed product. Therefore, improving post-harvest processing technology is important to increase product

uniformity, reduce manual labour, and improve production efficiency.

Pressing is a critical stage in gambier processing because it compacts the material and removes part of the retained liquid. Conventional pressing commonly relies on manual or simple mechanical systems, which may produce inconsistent force and variable product quality. Hydraulic systems can generate high, stable forces, whereas pneumatic systems provide rapid actuation and simple control. A combined hydraulic–pneumatic system is therefore attractive for small- and medium-scale agricultural processing, provided that the relationship between operating pressure and product response is properly characterised.

Previous studies have reported the development of hydraulic, screw, and pneumatic pressing systems for gambier and other agricultural materials. Nevertheless, information remains limited on the simultaneous effects of hydraulic–pneumatic operating pressure on calculated pressing force, product densification, processing throughput, and liquid removal in gambier. In addition, a distinction is required between moisture content measured after drying and the amount of liquid physically removed during the pressing stage.

Accordingly, this study evaluates hydraulic–pneumatic pressing at 1, 3, 5, 7, and 8 bar using a constant initial gambier mass. The novelty of the work lies in the combined evaluation of pressure-dependent densification, estimated production capacity, wet-basis moisture content, and water

removal during pressing. The objective is to identify the best-performing pressure among the tested conditions and to provide experimental information for further development and scale-up of hydraulic–pneumatic gambier pressing systems.

MATERIALS AND METHODS

Research Design

This experimental study investigated five hydraulic–pneumatic operating pressures: 1, 3, 5, 7, and 8 bar. We used an initial mass of 5 kg of fresh gambier for each condition. We calculated the response variables as pressing force, compacted product density, estimated production capacity, wet-basis moisture content, and water removal during pressing. We kept all other controllable operating conditions as consistent as possible.

Materials and Equipment

The hydraulic–pneumatic system used compressed air to actuate the pressing mechanism. Because the pressing-force values reported in this study were obtained from $F = PA$ rather than a load-cell measurement, they are referred to as calculated theoretical pressing forces. The pressure-to-force calculation is valid only when P represents the actual pressure acting on the stated piston area; this assumption must be verified against the machine configuration.

Experimental Procedure

Before each test, the hydraulic and pneumatic components were inspected for leakage and proper operation. The pressure regulator was adjusted to the required test pressure.

Five kilograms of gambier were loaded into the pressing chamber and subjected to 1, 3, 5, 7, or 8 bars. After pressing, we recorded the final mass, compacted dimensions, and processing time. We then dried a subsample to determine wet-basis moisture content.

We used the collected data to evaluate pressure-dependent changes in compaction, throughput, and liquid removal. We treated the 1- and 3-bar tests as unsuccessful compaction conditions rather than as products with zero density or zero moisture content.

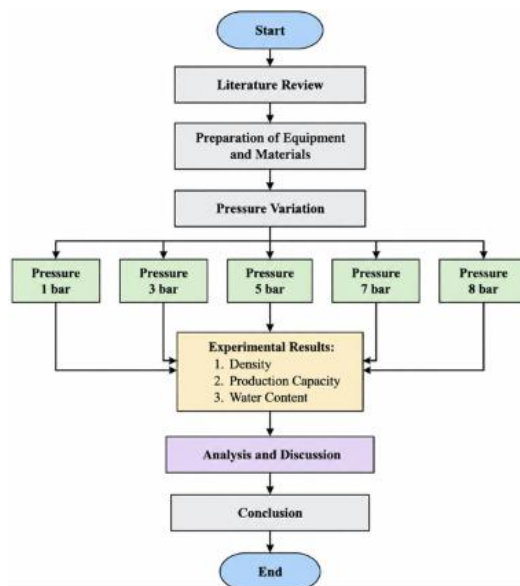


Figure 1. Research flowchart

Data Analysis

The experimental data were analyzed quantitatively to evaluate the performance of the hydraulic–pneumatic pressing system. The calculated parameters included pressing force, density, production capacity, and moisture content.

Pressing Force

$$F = P \times A$$

where:

- F = pressing force (N)
- P = applied pressure (Pa)
- A = piston cross-sectional area (m²)

Density

$$\rho = \frac{m}{V}$$

where:

- ρ = density (kg/m³)
- m = mass of pressed gambier (kg)
- V = volume of pressed gambier (m³)

Production Capacity

$$Q = \frac{m}{t}$$

where:

- Q = production capacity (kg/h)
- m = mass of pressed gambier (kg)
- t = processing time (h)

Wet-Basis Moisture Content

$$MC = \frac{m_w - m_d}{m_w} \times 100\%$$

where:

- MC = moisture content (%)
- m_w = initial mass before drying (kg)
- m_d = final mass after drying (kg)

Water removal during pressing was calculated as $WR = (m_i - m_p)/m_i \times 100\%$, where

m_i is the initial mass before pressing, and m_p is the mass immediately after pressing. This quantity must not be interpreted as moisture content.

RESULT AND DISCUSSION

Effect of Hydraulic-Pneumatic Pressure on Pressing Force

The calculated pressing force increased linearly with the applied pressure because it was derived from $F = PA$ using a constant piston area. The values increased from 98.21 N at 1 bar to 785.71 N at 8 bar. This linearity therefore follows directly from the governing equation and should not be interpreted as an independently measured experimental relationship.

Table 1. Effect of Pressure on Pressing Force

Pressure (bar)	Pressure (Pa)	Pressing Force (N)
1	100000	98,21
3	300000	294,64
5	500000	491,07
7	700000	687,49
8	800000	785,71

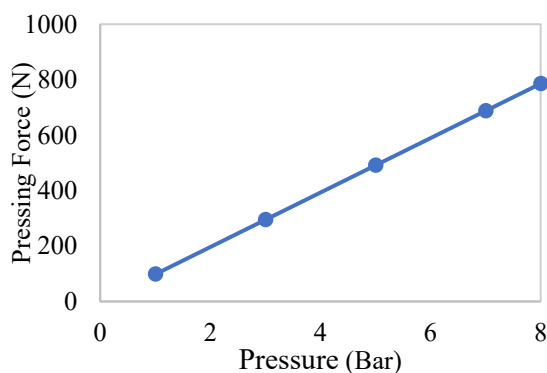


Figure 2. Relationship Between Pressure and Pressing Force

The calculation is consistent with Pascal's law only if the reported pressure is the actual pressure acting on the piston area used in the calculation.

Effect of Pressure on Gambier Density

For successful compaction conditions, density increased from 1162.67 kg/m³ at 5 bar to 1202.56 kg/m³ at 7 bar and 1270.40 kg/m³ at 8 bar. The 1- and 3-bar conditions should be reported as unsuccessful compaction (N/A), not as zero density, because no compact product was obtained.

Table 2. Effect of Pressure on Gambier Density

Pressure (bar)	Initial Mass (Kg)	Final Mass (Kg)	Volume (m ³)	Density (Kg/m ³)
1	5	N/A	N/A	N/A
3	5	N/A	N/A	N/A
5	5	4,97	0,004275	1162,674
7	5	4,82	0,004008	1202,555
8	5	4,75	0,003739	1270,404

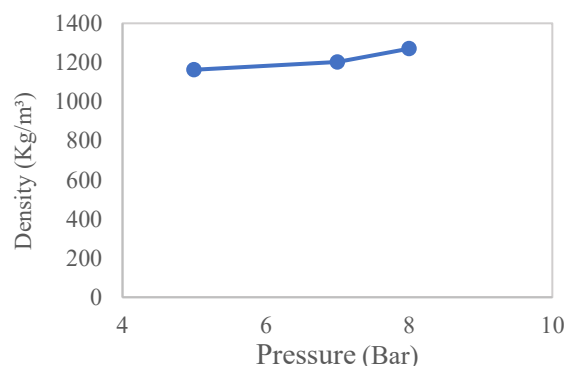


Figure 3. Effect of Pressure on Gambier Density

At 5 bars, the pressing process successfully produced compacted gambier with a density of 1162.67 kg/m³. Increasing the pressure to 7 bar increased the density to 1202.56 kg/m³, while the highest density of 1270.40 kg/m³ was obtained at 8 bar. These results demonstrate a positive relationship between operating pressure and the density of the pressed gambier.

The density increase is attributed to the combined reduction in compacted volume and removal of liquid during pressing. Although product mass decreased slightly as pressure increased, the volume reduction was proportionally greater, resulting in a higher mass-to-volume ratio. This trend indicates enhanced consolidation at higher pressure.

Among the tested conditions, 8 bar produced the highest measured density. This result indicates the greatest degree of compaction within the investigated pressure range; however, it does not establish a global optimum because pressures above 8 bar were not evaluated.

Effect of Pressure on Production Capacity

Estimated production capacity increased from 14.88 kg/h at 5 bar to 16.83 kg/h at 7 bar and 23.42 kg/h at 8 bar. The increase primarily reflects the reduction in recorded processing time at higher pressure. The term 'estimated production capacity' is used because the calculation is based on the recorded pressing cycle; actual plant throughput also depends on loading, unloading, reset, and compressor-recovery times.

Table 3. Effect of Pressure on Production Capacity

Pressure (bar)	Initial Mass (Kg)	Final Mass (Kg)	Processing Time (jam)	Production Capacity (kg/jam)
1	5	N/A	N/A	N/A
3	5	N/A	N/A	N/A
5	5	4,97	0,334	14,88
7	5	4,82	0,286	16,83
8	5	4,75	0,203	23,42

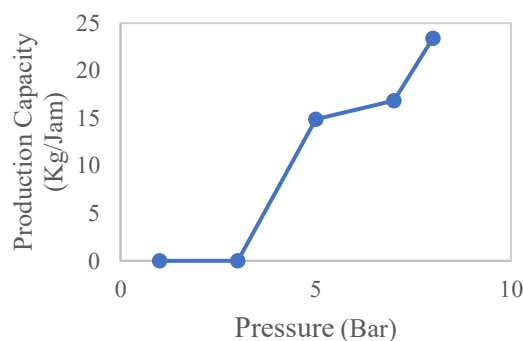


Figure 4. Effect of Pressure on Production Capacity

At 5 bar, the machine produced pressed gambier at 14.88 kg/h. Increasing the pressure to 7 bar improved the production capacity to 16.83 kg/h, while the highest production capacity of 23.42 kg/h was achieved at 8 bar. This improvement shows that higher operating pressure completes the pressing process faster, increasing product output per hour.

Higher pressure accelerated compaction and liquid expulsion, thereby shortening the recorded pressing time. If the reported time excludes auxiliary cycle operations, do not interpret the calculated kg/h value as continuous industrial production capacity. Additional

cycle-time and energy-consumption measurements are required to assess scale-up.

The highest estimated production capacity occurred at 8 bar among the tested conditions. These data provide a basis for further scale-up development, but they do not by themselves demonstrate suitability for large-scale processing.

Effect of Pressure on Moisture Content and Water Removal

Moisture content and liquid removal during pressing must be distinguished. Based on the reported post-pressing and dry masses, wet-basis moisture content changed only slightly: 25.35% at 5 bar, 25.31% at 7 bar, and 25.26% at 8 bar. In contrast, the mass physically removed during pressing increased substantially with pressure.

Table 4. Effect of Pressure on Moisture Content

Pressure (bar)	Initial Mass (Kg)	Final Mass (kg)	Mass After Drying (kg)	Moisture Loss (%)
1	5	N/A	N/A	N/A
3	5	N/A	N/A	N/A
5	5	4,97	3,71	25,35
7	5	4,82	3,60	25,31
8	5	4,75	3,55	25,26

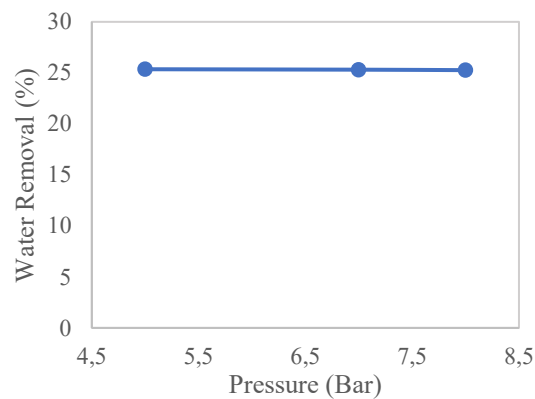


Figure 5. Effect of Pressure on Moisture Content

At 1 and 3 bars, no compacted product was obtained; therefore, report the moisture content as N/A rather than zero. For successful tests, water removed during pressing, calculated from the difference between the initial 5.00 kg mass and the mass immediately after pressing, was approximately 0.03 kg (0.60%) at 5 bar, 0.18 kg (3.60%) at 7 bar, and 0.25 kg (5.00%) at 8 bar.

These results show that increasing pressure enhanced dewatering during the pressing stage even though the subsequent wet-basis moisture-content values were similar. The water-removal ratio is therefore a more direct indicator of pressing-induced dewatering than the previously labelled ‘moisture loss’ parameter.

The higher water-removal ratio is consistent with the observed increase in product density because stronger compaction reduces void space and expels more liquid. Further work should quantify the energy required per kilogram of pressed product to determine whether the gain in dewatering and throughput offsets the additional compressor/hydraulic energy required at higher pressure.

Overall, operating pressure strongly influenced the performance of the hydraulic–pneumatic gambier press within the investigated range. Effective compaction began at 5 bar. From 5 to 8 bar, density, water removal, and estimated production capacity increased, while recorded processing time decreased. Because replicate statistics were not reported, these trends should not be described as statistically significant until appropriate analysis is provided.

Overall Discussion

The experimental results show that hydraulic–pneumatic pressure significantly influences the performance of the gambier pressing machine. Increasing the operating pressure consistently improved all measured parameters, including pressing force, density, production capacity, and moisture reduction.

At low pressures (1 bar and 3 bar), the generated pressing force was insufficient to compress the gambier material, resulting in unsuccessful pressing and no measurable product characteristics. Effective pressing began at 5 bars, where the machine could produce compacted gambier with acceptable density and production capacity.

These results show that increasing pressure enhanced dewatering during pressing, even though the subsequent wet-basis moisture-content values were similar. The water-removal ratio is therefore a more direct indicator of pressing-induced dewatering than the previously labelled ‘moisture loss’ parameter.

Table 5. Water Removal During Pressing

Pressure (bar)	Initial Mass (kg)	Mass After Pressing (kg)	Water Removal (%)
5	5.00	4.97	0.60
7	5.00	4.82	3.60
8	5.00	4.75	5.00

Among the tested pressure levels, 8 bar provided the best overall measured performance, with a calculated pressing force of 785.71 N, density of 1270.40 kg/m³, estimated production capacity of 23.42 kg/h, and a water-removal ratio of approximately 5.00%. Because the study did not investigate pressures above 8 bar or energy consumption, 8 bar should be regarded as the best tested condition rather than a globally optimised operating pressure.

CONCLUSIONS

This study evaluated the effect of hydraulic–pneumatic operating pressure on gambier compaction over 1–8 bar. Pressures of 1 and 3 bar were insufficient to produce a compacted product, whereas effective pressing began at 5 bar.

Within the successful operating range, increasing pressure from 5 to 8 bar increased density from 1162.67 to 1270.40 kg/m³ and estimated production capacity from 14.88 to 23.42 kg/h. The calculated theoretical pressing force reached 785.71 N at 8 bar. Water removal during pressing increased from approximately 0.60% at 5 bar to 5.00% at 8 bar, while the wet-basis moisture content after pressing changed only slightly.

Among the tested pressure levels, 8 bar provided the best overall performance. Nevertheless, this pressure should not be interpreted as a global optimum because we did not evaluate pressures above 8 bar, energy consumption, or long-term machine performance. Future work should include repeated trials with statistical analysis, direct force measurement, energy-specific performance, and a wider pressure range to establish an engineering optimum for scale-up.

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