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Field Performance of a Cylinder-Type Coffee Pulper at Two Cherry Ripeness Levels

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ABSTRACT

This study describes the field performance of a commercial cylinder-type coffee pulper processing Arabica cherries of two ripeness levels and compares it with the manufacturer's specification. Cherries were sorted by color into a 90–100% ripe lot and a 40–80% ripe lot and pulped in the field, and the output was separated into whole beans, broken beans, unpulped beans, and skin fragments. Working capacity was 403.51 kg/h for the ripe lot and 228.89 kg/h for the underripe lot against a specified 528.36 kg/h, and whole beans were 95.99% and 82.62% against a specified 95.04%. Unpulped beans rose from 0.58% to 8.25% and broken beans from 0.62% to 2.61%, while skin fragments in the bean stream reached 5.7% and 23.49% against a specified 1.97%. Lower cherry ripeness therefore reduced capacity and bean integrity mainly through unpulped beans rather than breakage, but each lot was tested in three repetitions and only one value per indicator is reported, without dispersion, so the differences are descriptive.

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1. INTRODUCTION

In the wet processing of Arabica coffee, the initial step is pulping, where a machine removes the skin and part of the flesh from freshly picked cherries, exposing the beans covered in parchment (Bizimungu et al., 2023; PAES, 2011). The effectiveness of a pulper is evaluated based on its throughput and the composition of its output, which includes whole parchment beans, broken beans, unpulped cherries, and skin fragments (Bizimungu et al., 2024; PAES, 2011). Recent developments in Indonesia have focused on creating pulper designs that are both portable and affordable for small-scale farmers, such as mobile and compact models (Baroroh et al., 2023; Rinaldi et al., 2024; Sutopo and Irsad, 2025). The pulping process involves squeezing each cherry through a narrow gap, making the size, fracture force, and density of the cherries crucial for effective separation of pulp from beans (Bizimungu et al., 2023). Consequently, the machine's performance is influenced by both the characteristics of the cherries and its own settings. Reports on pulper performance are only meaningful if they specify the type of cherries processed.

Cherries on a tree do not ripen simultaneously, leading to deliveries to processors that often contain a mix of maturity levels (Ansari et al., 2025). While maturity influences cup quality, its impact is not consistent: when cherries were categorized into seven maturity stages, only the completely immature stage showed a noticeably lower score in sensory evaluation, with minimal differences among the other stages (Velásquez et al., 2019). This finding implies that processors might have a rationale for retaining partly mature cherries in the batch rather than discarding them (Velásquez et al., 2019). The decision to keep them hinges on their effect on the pulper's performance. Farmers in the coffee village where this research was conducted noted that small, unripe cherries with green skin were difficult to pulp, often leaving the skin on many beans. The practical issue is determining how much capacity and bean quality a field operator sacrifices by processing batches that are not fully ripe.

Test standards outline the criteria for assessing a pulper's performance. According to the Philippine Agricultural Engineering Standard (PAES) 253, factors such as pulping efficiency, unpulped loss, and other related metrics must be considered, and it is essential to document the type, size, variety, and origin of the cherries (PAES, 2011). Manufacturers provide data on capacity and output quality derived from factory tests, which typically use uniform cherries under controlled conditions. However, in practical settings, variations in cherry size, ripeness, and operator techniques can affect these figures. The unit under review is an Ishoku cylinder-type pulper, which is specified to have an input capacity of 528.36 kg/h, produce 95.04% whole beans, and contain 1.97% chaff mixed with beans. Conducting a field evaluation of this unit against its specifications offers buyers and cooperatives a reference point for performance expectations with a lot of mixed ripeness.

Earlier studies examined how pulper output depends on machine settings and design. Hendrawan and Ariyanto (2021) examined peeler clearance together with shaft speed, and Sidi et al. (2018) varied peeler speed in a wet Arabica pulper. Bizimungu et al. (2024) compared drum and disc pulpers on Arabica in three replicates of 3 kg at 1200 rpm and 16 mm clearance, and the drum pulper reached 98.37 ± 0.73% pulping efficiency and 872.3 ± 91.05 kg/h against 75.56 ± 7.69% and 684.4 ± 215.9 kg/h for the disc pulper, although the disc pulper damaged less parchment. A manual single-disc pulper reached 68.15% pulping efficiency with 9.7% unpulped loss and 10.19% mechanical damage (Adesokan et al., 2025), whereas a solar-powered electric pulper reached a stripping capacity of 783.176 kg/h (Iqbal et al., 2024). Studies that worked on the raw material examined the effect of storage duration of red cherries on wet pulper performance (Yuliani et al., 2025) and found that mesocarp–exocarp stiffness measured by indentation was 15.43 and 17.43 MPa in unripe and semi-ripe cherries but 6.8 MPa in ripe and 2.02 MPa in overripe ones (Tinoco et al., 2022). Compression tests on 192 ripe cherries gave a mean fracture force of 38.19 ± 19.35 N that varied significantly with variety and size (Gutiérrez Madrid et al., 2026), and indentation and compression tests across ripeness stages were proposed as inputs for pulper and sorter design (Duque-Dussán et al., 2025). Soaking before pulping eased the handling of firmer cherries, with the largest quality gain for green cherries (Ansari et al., 2025). Design studies produced mobile and compact pulper concepts, one of them reporting calculated rather than measured capacity (Baroroh et al., 2023; Rinaldi et al., 2024; Sutopo and Irsad, 2025), and a performance test of a mobile pulper–huller unit has been reported from an Indonesian field site (Akbar et al., 2020).

These studies leave a practical gap. Studies that vary settings or design treat the cherries as a uniform input, at least as far as their titles and abstracts indicate. Studies of the raw material look at storage, stiffness, or soaking, but they do not report how a commercial unit’s output changes when the cherry lot is less ripe. A Scopus search for 2016–2026 records on coffee with pulper terms returned 20 documents, which included design, power-supply, and cherry-mechanics studies but no field test across ripeness levels. A narrower search that added ripeness or maturity terms returned four records, none of which measured pulper output by ripeness. Without that comparison, a buyer cannot tell how much of the specified capacity and bean quality survives when the lot is mixed. The finding that matters to operators, namely the size of the penalty for pulping underripe cherries, is therefore missing.

This study therefore tests a commercial cylinder-type pulper in the field at two cherry ripeness levels and sets the results against the manufacturer’s specification. Cherries were sorted by color into a 90–100% ripe lot and a 40–80% ripe lot, and capacity and output composition were recorded for each lot. The purpose is to describe how working capacity, whole beans, broken beans, unpulped beans, skin fragments in the beans, and yield loss differ between the two lots and from the specification. The study is deliberately descriptive: it reports one value per indicator and lot from three repetitions, without dispersion or inferential tests, and it states which values can and cannot be interpreted. Its contribution is a field reference for how much of the specified performance is retained when cherries are not fully ripe, together with an explicit account of the measurement limits that later tests should remove.

2. MATERIALS AND METHODS

2.1. Site, machine, and cherries

The test was carried out from September to November 2025 in a coffee village in Gowa Regency, South Sulawesi, Indonesia. The machine was an Ishoku cylinder-type wet pulper driven by a Honda GX200 petrol engine (6.5 hp), with overall dimensions of 750 × 690 × 1435 mm. The manufacturer’s specification lists an input capacity of 528.36 kg/h, 95.04% whole beans, 1.97% chaff mixed with beans, and 2.52% yield loss. Arabica cherries came from farmers in Soppeng Regency at 1,000–1,500 m above sea level and were transported to the test site. The time between harvest and pulping was not recorded. The instruments were a digital scale, a tachometer, and sample containers.

Figure 1 shows the machine and its main parts. The unit has a feed hopper, a bean outlet and a skin outlet, and an engine that drives the cylinder through a pulley and V-belt.

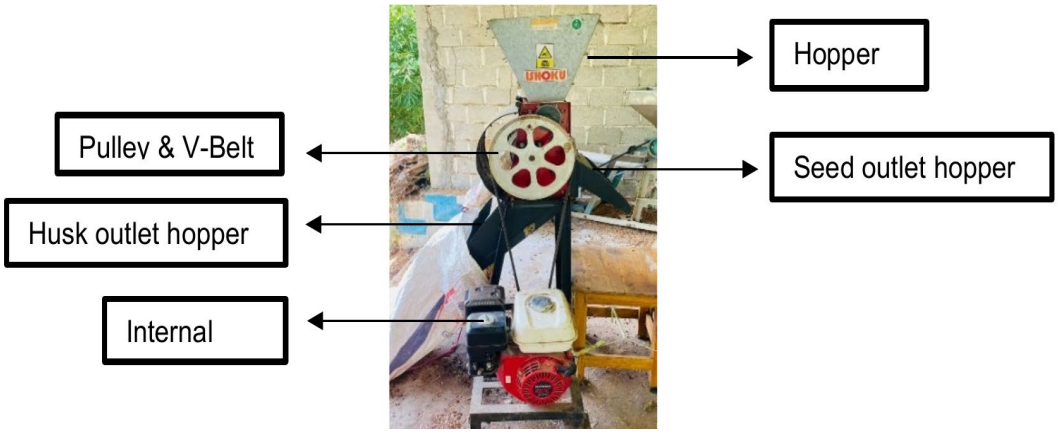


Figure 1. The Ishoku cylinder-type wet coffee pulper used in the field test

2.2. Procedure

Cherries were sorted by color into a ripe lot (maturity 90–100%) and an underripe lot (maturity 40–80%). The color scale and the thresholds that define these percentages were not documented. Each lot was pulped in three repetitions and was fed gradually into the hopper of the pulper in each one. The machine has two outlets, one for beans and one for skin, and the material from each outlet was collected separately and sorted into whole beans, broken beans, unpulped beans, and skin fragments. Figure 2 shows a cherry from each lot.



(a) (b)

Figure 2. Cherries from the two lots: (a) ripe lot, 90–100% maturity; (b) underripe lot, 40–80% maturity

2.3. Performance indicators and data treatment

Six indicators were calculated. Working capacity (C, kg/h) is the mass of cherries processed (W, kg) divided by the pulping time (t, h):

$$C = \frac{W}{t} \tag{1}$$

The other indicators are percentages. Broken beans (B) and skin fragments in the beans (S) are expressed relative to the product leaving the bean outlet:

$$B = \frac{m_{\text{broken}}}{m_{\text{out}}} \times 100 \tag{2}$$

$$S = \frac{m_{\text{skin}}}{m_{\text{out}}} \times 100 \tag{3}$$

where m_{broken} is the mass of broken beans at the bean outlet (kg), m_{skin} is the mass of skin fragments at the bean outlet (kg), and m_{out} is the mass of all product leaving the bean outlet (kg). Whole beans (WB) are expressed relative to the total beans obtained, and unpulped beans (U) relative to the cherry mass before pulping:

$$WB = \frac{m_{\text{whole}}}{m_{\text{beans}}} \times 100 \tag{4}$$

$$U = \frac{m_{\text{unpulped}}}{m_{\text{in}}} \times 100 \tag{5}$$

where m_{whole} is the mass of whole beans (kg), m_{beans} is the total mass of beans obtained from pulping (kg), m_{unpulped} is the mass of unpulped beans collected at the skin outlet (kg), and m_{in} is the mass of cherries before pulping (kg). Yield loss (L) is:

$$L = \frac{m_{\text{in}} - m_{\text{final}}}{m_{\text{in}}} \times 100 \tag{6}$$

where m_{final} is the mass of coffee recovered after pulping (kg). The field protocol defined yield loss as the initial mass minus the final mass, and Eq. (6) expresses this difference as a percentage of the initial mass.

The reference mass therefore differs between indicators. A yield value (bean output as a percentage of cherry input) was also recorded but is excluded from this paper, because its reference mass could not be reconciled with the other indicators. Each lot was tested in three repetitions, as noted in Section 2.2. Each indicator is reported as one value per lot; the value was not documented as a mean, and the values of the individual repetitions were not retained, so no standard deviation can be computed and no inferential test was applied. Differences are therefore reported as absolute differences, percentage points, and ratios, and comparisons with the specification are descriptive. Calculations were done in a spreadsheet.

3. RESULTS AND DISCUSSION

3.1. Measured performance

Table 1 lists the values for the two lots next to the manufacturer's specification, and Table 2 expresses the same values as differences and ratios. The ripe lot was pulped at 403.51 kg/h and the underripe lot at 228.89 kg/h, so the underripe lot ran at 56.7% of the ripe-lot capacity and at 43.3% of the specified 528.36 kg/h, against 76.4% for the ripe lot. Whole beans were 0.95 percentage points above the specification in the ripe lot and 12.42 percentage points below it in the underripe lot. Broken beans increased from 0.62% to 2.61% and unpulped beans from 0.58% to 8.25%, while skin fragments in the bean stream were 5.7% and 23.49% against a specified 1.97%. Yield loss was 1.3% for the ripe lot and 12% for the underripe lot against a specified 2.52%.

Table 1. Performance of the cylinder-type pulper at two cherry ripeness levels and the manufacturer's specification

Indicator	Ripe lot (90–100%)	Underripe lot (40–80%)	Specification
Working capacity (kg/h)	403.51	228.89	528.36
Whole beans (%)	95.99	82.62	95.04
Broken beans (%)	0.62	2.61	not specified
Unpulped beans (%)	0.58	8.25	not specified
Skin fragments in beans (%)	5.7	23.49	1.97
Yield loss (%)	1.3	12	2.52

Each value is one reported figure per lot (three repetitions were run; per-repetition values and standard deviations are not available).

Table 2. Differences from the specification and between lots, computed from Table 1

Indicator	Ripe lot vs specification	Underripe lot vs specification	Underripe lot vs ripe lot
Working capacity	76.4% of specification	43.3% of specification	56.7% of ripe lot (−174.62 kg/h)
Whole beans	+0.95 percentage points	−12.42 percentage points	−13.37 percentage points
Broken beans	–	–	4.2 times
Unpulped beans	–	–	14.2 times
Skin fragments in beans	2.9 times	11.9 times	4.1 times
Yield loss	0.52 times	4.8 times	9.2 times

A dash means that the specification gives no value for that indicator.

3.2. Working capacity: a large penalty with two possible origins

The 43% drop in capacity between the lots is the largest effect in the data and the one that most directly affects an operator, because it nearly halves the daily throughput. Neither lot reached the specified 528.36 kg/h, and even the ripe lot stayed at 76% of it. Two readings are open. The specification may describe a feed condition with uniform ripe cherries that field operation did not reproduce, or the operator may have throttled the feed to avoid blockage. The record does not log feed rate or engine and cylinder speed, so the two readings cannot be separated, and the shortfall of the ripe lot cannot be assigned to the machine or to the way it was used. For the gap between lots, cherry mechanics offers a consistent mechanism. Indentation tests on another cultivar put mesocarp–exocarp stiffness at 15.43 and 17.43 MPa for unripe and semi-ripe fruit against 6.8 MPa for ripe fruit, which is 2.3 to 2.6 times stiffer (Tinoco et al., 2022), and soaking was proposed to ease pulping of firmer cherries (Ansari et al., 2025). If firmer cherries need a longer residence in the cylinder gap, throughput falls, as observed. This is an inference from other studies, since firmness was not measured here.

For scale, the capacity of the disc pulper in a replicated study varied by about 32% of its mean and that of the drum pulper by about 10% (Bizimungu et al., 2024). A 43% difference is larger than both, which makes a real ripeness effect plausible, but it does not prove it for this unit. Both pulpers in that study exceeded the 403.51 kg/h of the ripe lot here (872.3 and 684.4 kg/h), and a solar-powered electric pulper reached 783.176 kg/h (Iqbal et al., 2024). Machine design, power source, clearance, and cherries differ among these units, so the comparison only brackets the order of magnitude.

3.3. Output quality: the loss is incomplete pulping, not breakage

The ripe lot matched the specification for whole beans, whereas the underripe lot fell 12.42 percentage points below it. The composition of the losses (Figure 3) shows where the difference arose. Unpulped beans increased 14-fold, from 0.58% to 8.25%, an addition of 7.67 percentage points, while broken beans increased 4.2-fold but by only 1.99 percentage points. The main failure of the underripe lot is therefore that the skin stays on the bean, and bean breakage is a secondary effect. This weakens the common explanation that firm cherries mainly damage beans through high pressure in the cylinder. Bean breakage was low in absolute terms. The 0.62% of the ripe lot is slightly below the 0.91 ± 0.27% reported for a drum pulper, and the 2.61% of the underripe lot is about 2.9 times that mean (Bizimungu et al., 2024). Both values are far below the 12.6–21.4% broken beans that older double-cylinder designs produced (Widyotomo et al., 2011), although those figures rest on a different basis and are only indicative. The 8.25% of unpulped beans in the underripe lot is close to the 9.7% unpulped loss of a manual single-disc pulper (Adesokan et al., 2025), but that machine also damaged 10.19% of its output, compared with 2.61% here. A reasonable reading is that the cylinder pulper has largely solved the breakage problem, and that its weak point is firm cherries that the cylinder gap does not strip. That reading would be tested by varying clearance and speed within each ripeness lot, which this study did not do.

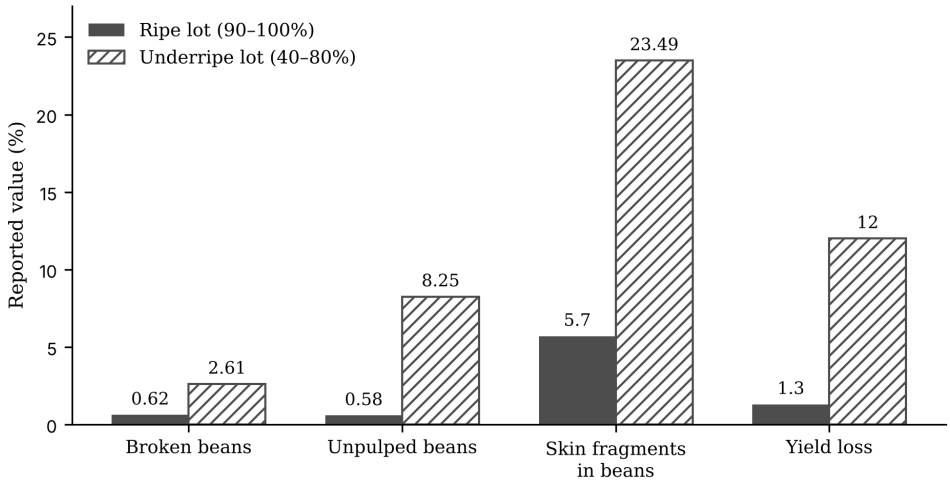


Figure 3. Loss-related indicators of the two lots (the reference mass differs between indicators; see Section 2.3)

3.4. Skin fragments and yield loss

Skin fragments in the bean stream were already 2.9 times the specified value in the ripe lot and 11.9 times in the underripe lot. The skin-separation step is therefore under strain even when the cherries are ripe, which means more cleaning work downstream. Yield loss shows the opposite pattern for the ripe lot, which lost 1.3% against a specified 2.52%, whereas the underripe lot lost 12%, 4.8 times the specification. A ripe lot that loses fewer beans than specified but carries more skin than specified suggests that the separation outlet favors bean recovery over cleanliness. This is a hypothesis, because the way the specification was measured is not known and the two figures may not be strictly comparable. The yield loss of the underripe lot is of the same order as the unpulped fraction, which fits the view that most lost beans leave with the skin because they were never freed from it.

3.5. What the percentage sums can and cannot say

The percentage indicators do not add up on a common basis. Whole, broken, and unpulped beans sum to 97.19% for the ripe lot and 93.48% for the underripe lot, which is possible if they share one denominator, but adding the skin fragments gives 102.89% and 116.97%, which is not. This matches the field protocol, in which the denominators differ between indicators (Section 2.3). The indicators can be read one by one and compared between lots, but they cannot be converted into a mass balance. This is the main reason the study makes no claim about statistical significance and treats all results as descriptive.

3.6. Implications for operators and for quality

The underripe lot spanned 40–80% maturity, a wide band that probably includes cherries that would score acceptably in the cup, since only the fully immature stage scored clearly lower in the sensory study (Velásquez et al., 2019). For a processor, the machine penalty measured here (43% less capacity and 12 percentage points fewer whole beans) must therefore be weighed against the quality gain from sorting more strictly, and the data of this study do not allow that balance to be struck. Four levers appear in the literature and were not tested here. Machine settings can be matched to cherry size, as in the replicated study that used a 16 mm clearance for Arabica and 12 mm for Robusta (Bizimungu et al., 2024). Peeler speed and clearance were the variables examined in two

Indonesian pulper studies (Hendrawan and Ariyanto, 2021; Sidi et al., 2018). The time between harvest and pulping matters as well (Yuliani et al., 2025). Cherry mechanics also differ with variety and size (Gutiérrez Madrid et al., 2026) and with ripeness stage (Duque-Dussán et al., 2025), so a ripeness-by-size test would be a logical next step. The cherries tested here traveled from another regency and the transport time is not reported, so the storage variable may have contributed to the difference between lots in an unknown direction.

3.7. Limitations

The results come from one machine and one test season. Each lot was tested in three repetitions, but only one value per indicator and lot is reported, without per-repetition data or dispersion, so differences between lots are descriptive and no claim of significance can be made. Ripeness was assigned by color, but the scale and thresholds are not described, and the 40–80% class is wide, so the share of green cherries in it is unknown. Cherry size, moisture content, and hardness were not measured, so the mechanisms proposed in this section are inferences from other studies. Sample mass per run, whether the reported value is a mean, engine and cylinder speed, feed rate, clearance, the timing device, scale resolution, water use, and fuel consumption were not recorded, although the PAES 253 standard asks for the cherry data to be recorded (PAES, 2011). The denominators of the indicators differ, and a recorded yield value was excluded because its basis could not be reconciled. The comparison with the manufacturer's specification rests on a table whose test conditions are not described. A test suited to firm conclusions would report every repetition and its standard deviation, use a fixed sample mass, record speed, clearance, and feed rate, use one reference mass for all indicators so that a mass balance closes, define ripeness classes by documented color limits, and then apply a test of differences.

4. CONCLUSION

In the field, the tested cylinder-type pulper unit processed ripe cherries (90–100%) at 403.51 kg/h with 95.99% whole beans, which matches the specified 95.04% but reaches only 76% of the specified 528.36 kg/h, and it processed underripe cherries (40–80%) at 228.89 kg/h with 82.62% whole beans, which is 43% of the specified capacity and 12.42 percentage points below the specified bean integrity. The loss in the underripe lot came mainly from unpulped beans (0.58% to 8.25%) and less from breakage (0.62% to 2.61%), and skin fragments in the bean stream exceeded the specified 1.97% in both lots (5.7% and 23.49%). For operators, pulping lots dominated by underripe cherries cost about 43% of the capacity and 12 percentage points of whole beans in this unit, a penalty to weigh against the quality gain from stricter sorting of the cherries. These findings are descriptive and apply to this unit only: each value is one reported figure without dispersion, the denominators of the indicators differ, so no statistical significance is claimed. The study offers a field reference for the penalty of pulping underripe cherries and shows what a test reporting every repetition, documented operating conditions, and a single reference mass must add before the penalty can be tested statistically.

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Author Contributions

W.C.L.: investigation, data curation, formal analysis, writing – original draft. I.: supervision, guidance on the study design and analysis, writing – review and editing.

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Conflict of Interest

The authors declare no conflict of interest.

Generative AI Use

The authors used Claude to help restructure the manuscript and edit the language. The authors reviewed and edited the output and take full responsibility for the content of this manuscript.

Ethical Clearance

Not applicable.

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