

Engineering Innovation for Cherry Coffee Wet Processing Using Circulation System and Agitator Grading Machine

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ABSTRACT

Coffee cherry grading technology is currently advanced, but some adjustments to the method need to be made. So far, the wet treatment process uses much water. Therefore, an innovation is needed by adding a water circulation system equipped with a filter and agitator. The filters are useful for slowing down the degradation of water quality, and the agitator functions to moisten the cherry coffee evenly. This study applies an innovation of coffee cherry grading machines with semi-wash (soaking for 12-24 hours) and full-wash (soaking for 32-36 hours) methods. The focus is on the quality of the washing water, the water used, and the quality of the coffee beans produced. The results showed that in the semi-wash process, there was a decrease in turbidity of 5.1 NTU in the main tube, from 10.42 NTU to 5.32 NTU. Meanwhile, in the full-wash process, there was a decrease of 7.95 NTU, from 15.65 NTU to 7.70 NTU. The amount of water needed to process 7 kg of cherry coffee is 306.79 liters. The quality of the coffee beans produced was 7.58 mm on average, 6.80 mm on average, while 5.68 mm was small. This is in accordance with the SNI 01-2907-2008 standard, and the visualization of coffee bean results is in accordance with the standard of semi-washed green beans, namely bluish-green and full-wash results, which appear yellowish-green.

Key words: Grading; coffee cherry; semi-wash; full-wash; turbidity.

1 INTRODUCTION

Extreme climate change has resulted in erratic rainfall, disrupting the coffee growth cycle and reducing the quality and quantity of harvests, thus affecting the income of coffee farmers. Climate uncertainty also increases adaptation costs, such as irrigation techniques and crop protection, which add to the financial burden on farmers, especially in vulnerable areas (Sujatmiko; Ihsaniyati, 2018). In addition, smallholder coffee farmers in Indonesia face challenges such as low productivity, poor infrastructure, and market uncertainty, further exacerbating economic instability and their well-being (Rico et al., 2021).

Coffee farmers in Indonesia generally sell their crops through various channels, including collectors, local markets, village unit cooperatives, and plantation companies. However, the majority of farmers prefer to sell their coffee cherry to collectors, albeit at a lower price, for a number of practical reasons (Rosiana; Feryanto 2022).

In Aceh Province, many coffee farmers choose to sell their crops to middlemen, even though the prices they receive are often well below market prices due to financial pressures and the urgent need for cash to meet high family expenses. Middlemen offer fast payments without a convoluted process, which is especially important for farmers who often do not have access to formal sources of financing or adequate financial reserves (Faradillah et al., 2019). This dependence on middlemen often worsens farmers' economic conditions, creating a cycle of poverty that is difficult to avoid, as they

are unable to maximize profits from their crops and remain trapped in unprofitable sales patterns.

Efforts to improve the quality of coffee in Indonesia include various initiatives, including improving post-harvest handling processes and implementing Good Manufacturing Practices (GMP). Better post-harvest processes, such as proper processing of coffee beans, controlled fermentation, and optimal drying, are essential for maintaining superior coffee quality and taste. Coffee farmers and producers are encouraged to adopt these practices to reduce quality loss during the processing process and ensure that the coffee beans remain in the best condition before being marketed (Prajogo et al., 2020).

The steeping time in wet processing processes, such as semi-wash and full-wash, varies depending on factors such as temperature, type of coffee, and desired quality. In general, the semi-wash process takes about 12-24 hours, while the full-wash takes up to 32 hours with running water (Ahmad; Sa'diyah; Subramaniam, 2023). Both of these processes produce premium-quality green beans that are highly valued in the market (Fitri; Tawali; Laga 2021). However, this method requires significant volumes of water, making it a challenge for small-scale coffee farmers who often face water resource limitations (Zhang et al., 2019). Nonetheless, it is important to note that the quality of coffee is not only determined by the method of processing. Competitions such as *the Colombian Cup of Excellence* show that high-quality coffee can be produced from a variety of methods, including more sustainable natural processes. Therefore, innovations in

the coffee processing process, especially those that optimize water use, remain an important need to support the economic sustainability of coffee farmers.

Current coffee grading technology utilizes artificial intelligence (AI) to separate cherry coffee fruits based on colour automatically. High-resolution cameras are used to capture images of coffee berries, which are then analyzed by machine learning algorithms to identify ripe, immature, or damaged coffee berries based on the spectrum of colour and texture (Anita; Albarda 2020; Eron et al., 2024; Han; Jiang; Zhu, 2022). This technology enables the processing of large volumes in a short period with high consistency, reducing the reliance on manual labor. The application of AI technology in coffee grading not only improves production efficiency but also provides significant opportunities for Indonesian coffee farmers to access the premium coffee market (Thai; Ko; Huh 2024; Islamy et al., 2023).

However, at the traditional farmer level, manual processes such as weight sorting are still used to separate good-quality coffee fruits using water containers. Further studies are focused on the development of coffee grading machines that integrate semi-wash and full-wash processes with water filtration technology, which allows for reduced water requirements and improved environmental quality. Parameters such as *turbidity*, water quantity, and quality of the coffee beans produced are important indicators to ensure the suitability of this tool to the needs of farmers. Better water quality management during this process can also support compliance with internationally recognized environmental standards such as the Rainforest Alliance, UTZ, and 4C,

potentially increasing the selling value of coffee products in the global market.

Improving water quality in semi-wash and full-wash processes not only supports environmental sustainability but also plays a crucial role in determining the final quality of coffee beans. The use of clean and uncontaminated water helps maintain consistent fermentation during processing. In the wet processing method, water quality significantly affects the ability of water to penetrate the pectin layer of coffee cherries. Prolonged soaking in turbid water from the mucilage of coffee cherries hinders optimal fermentation, ultimately reducing the quality of the coffee beans (Zhang et al., 2019; Sánchez-Riaño et al., 2024; Martínez et al., 2018). Therefore, wet coffee processing industries often use flowing water for soaking the cherries to ensure a more effective fermentation process and produce coffee beans with superior sensory quality.

2 MATERIAL AND METHOD

Before making the machine, design and planning are carried out using CAD software, as shown in Figure 1.

The main components of this machine are the main tube and water storage. The main tube is a place to clean cherry coffee where low-quality coffee will float and be carried over-flow to water storage. Another component is the AC motor as a drive agitator with adjustable rotation. The main tube is equipped with a water inlet and outlet, used for soaking and washing coffee cherries, and has a capacity of 7 kg. The overflow water will flow into the water storage and pass through the filter

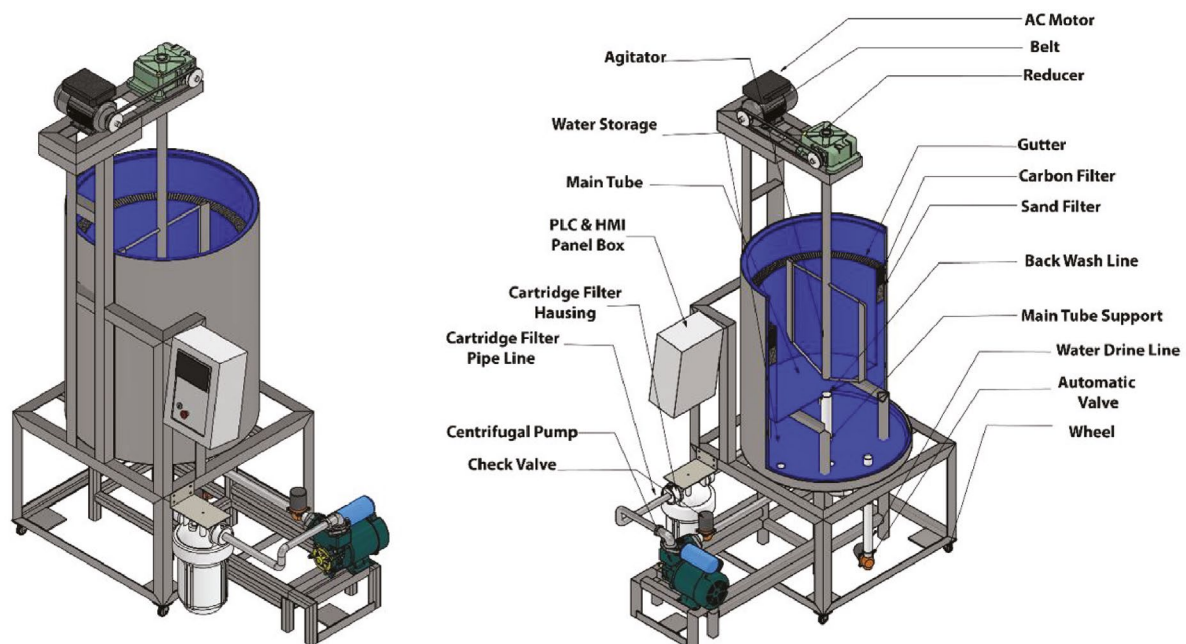


Figure 1: Design of semi-wash and full-wash coffee cherry grading machine.

housing with a 10-micron filter cartridge mesh. The backwash water is then filtered through a sand filter consisting of silica sand to separate the *Total Suspended Solid* (TSS) material and then through a carbon filter to filter out odours, tastes, and colours so that the water is still clear for reuse. The system is also equipped with a check valve to regulate the one-way water flow, as well as a *Human Machine Interface* (HMI) that allows the operator to choose between semi-wash or full-wash process options. The panel box contains a *Programmable Logic Control* (PLC) device to automate the machine. The agitator cylinder in the main tube functions to make the cherry coffee fruit of low-quality float and move to water storage. The inlet valve automatically regulates the water flow to the water storage, and a strainer is used to keep silica and carbon sand from mixing. The water enters the main tube through the inlet after filtration by discharging the water through the drain and outlet. All of these components are designed to ensure that the cherry coffee washing process runs efficiently and maintains the quality of the final result.

The manufacturing process of this machine involves high-quality materials and precise tools to ensure durability and optimal performance. Key construction materials include 304 stainless steel (SS 304) plates (6 mm thick), hollow iron (40x40 mm), and SS304 pipes and elbows, chosen for their corrosion resistance and strength. Additional essential components include bearings, bolts, check valves, cylinder axles, water filters, and filter housings, as well as silica sand and carbon materials used as filter media. For the electrical system, components such as an AC 1/4 horsepower motor, centrifugal pump, automatic valves, touch HMI screens, PLCs, and supporting accessories like relays, timers, and contactors are utilized to ensure reliable functionality.

The device functionality test was carried out by measuring the turbidity of the coffee cherry washing media in the water storage and main tube in the semi-wash and full-wash processes using a turbidity meter (see Figure 2) to ensure that the water filtration runs well.

In addition, the volume of water used is also measured both theoretically and actually on pipes and tubes. Theoretically, volume is measured using the Equation 1 and 2:

$$V_p = \pi \times r_p^2 \times l \quad (1)$$

Where: V_p = Pipe volume (cm³), π = 3.14 (Constanta), r_p = Pipe radius (cm), l = Pipe length (cm)

$$V_t = \pi \times r_t^2 \times t \quad (2)$$

Where: V_t = Pipe volume (cm³), π = 3.14 (Constanta), r_t = Tube radius (cm), t = Tube height (cm)

In addition, the coffee beans produced by this machine are measured based on the SNI 01-2907-2008 standard to

compare the physical quality of wet-processed robusta coffee bean samples. In this study, robusta cherry coffee samples were used, originating from Muntea Village, Bantaeng Regency, South Sulawesi, Indonesia (1,200-1,500 m above sea level), with an average size of 12 mm. Meanwhile, data collection was conducted as follows: Cherry coffee is placed into the main tube, and water is filled until the main tube is full. A sample of raw water turbidity is then taken. Next, the circulation system and agitator are operated by pressing the semi-wash button. Once the semi-wash process is completed, turbidity samples are collected from the main tube and storage tank. The full-wash button is then pressed to proceed with the next stage. After the full-wash process is completed, turbidity samples are again taken from the main tube and storage tank. Subsequently, the water in the grading machine is drained, the tank is emptied, and the cherry coffee is removed for further processing with the pulper. The diameter of the green beans is measured, and the visualization of the green beans is observed.



Figure 2: Turbidity Meter.

3 RESULT

The resulting innovation tool is shown in Figure 3 as follows:



Figure 3: Coffee cherry grading machine semi-wash and full-wash method.

Turbidity measurements for semi-washes are performed after 12 hours of immersion, in which the pump engine and agitator are switched off. After that, the machine activates again automatically and proceeds to the full-wash process for 32 hours. Then, the pump and agitator machine stops automatically, and the turbidity measurement is done again. The results of the measurement of turbidity of the coffee cherry washing medium for the semi-wash (12 hours) and full-wash (32 hours) processes are shown in Table 1.

Table 1: Turbidity testing of washing media using a turbidity meter with NTU units.

No.	Before the Process	Semi Wash		Full Wash	
		Main Tube	Water Storage	Main Tube	Water Storage
1	0.48	10.2	5.34	15.45	7.71
2	0.48	10.8	5.33	15.41	7.70
3	0.47	10.7	5.34	15.83	7.71
4	0.48	10	5.30	15.91	7.69
Average	0.47	10.42	5.32	15.65	7.70

From the filtration function data by measuring the turbidity of the coffee cherry washing medium in the water storage and main tube in the semi-wash and full-wash process of the coffee cherry, the average water turbidity value before the grading and washing process (raw water) was obtained of 0.47 NTU. In the semi-wash process, the turbidity value in the main tube was 10.42 NTU, and water storage was 5.32 NTU. In the full wash process, the turbidity value on the main tube is 15.65 NTU, and water storage is 7.70 NTU. The filtration performance test can be measured with the following turbidity graph in Figure 4.

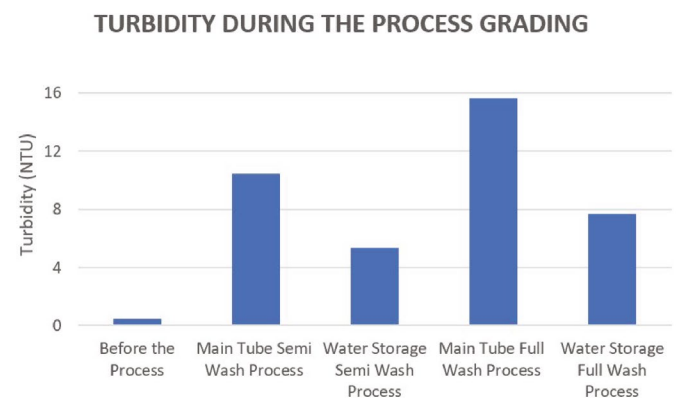


Figure 4: Turbidity testing filtration coffee cherry grading machine semi-wash and full-wash.

In Figure 4, it can be seen that the turbidity rate of the filtration test shows a normal trend, meaning that the water filtration process during the back-wash process to lift low-quality coffee beans to the surface until separated at the edge of the main tube runs well. The longer the turbidity value of the media increases, the is due to the level of filtration saturation. In this study, it is not done to the extent to which filtration can function properly.

The results of measuring the quantity of water used during the grading process can be seen from the following Table 2:

From Table 2, a comparison of the volume in the context before the entry of coffee cherries, the theoretical volume of the entire system is estimated to be around 321.69 litres, while the actual volume observed is around 316.24 litres. However, after the addition of 7 kg of the coffee cherry, the theoretical volume of the system is reduced to about 311.54 litres, while the actual measured volume is about 306.79 litres. This change in system volume reflects the effect of the addition of coffee cherry on the capacity and space available in the various components of the system. The data can be seen in figure 5 below:

After washing, peeling, and measuring, green beans are carried out. The measurement results are obtained according to the reference SNI 01-2907-2008 as quality requirements for robusta coffee, as shown in Table 3 below:

Table 2: Results of the water calculation of the quantity of immersion media.

Component	Volume Before Coffee Cherry Intake (litres)		Volume After Intake of Coffee Cherry is 7 kg (litres)	
	Theoretical	Current	Theoretical	Current
3/4" diameter pipeline 100 cm long. (Before and after the cartridge filter)	0.36	0.44	0.36	0.44
Housing Filter (diameter 13 cm x height 30 cm)	3.36	3.8	3.36	3.8
Water Storage (Diameter 60 cm, height 90 cm)	254.47	250	254.47	250
Main Tube (Diameter 45 cm, Height 40 cm)	63.5	62	53.35	52.55
TOTAL	321.69	316.24	311.54	306.79

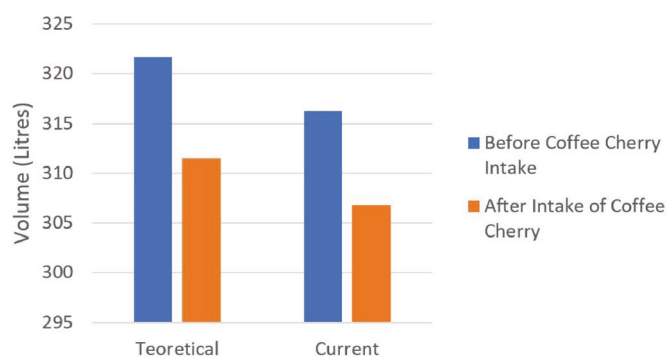


Figure 5: Comparison of the quantity of water immersion media for semi-wash and full-wash process coffee grading machines.

Table 3: Results of the physical quality test of coffee beans based on size in mm.

NO	Big	Medium	Small	Information
1	7.6	6.8	5.0	The size of small coffee beans does not meet SNI
2	7.6	6.5	5.7	Appropriate
3	7.8	6.6	6.3	Appropriate
4	7.7	6.9	5.6	Appropriate
5	7.2	7.2	5.8	The size of large coffee beans does not comply with SNI
Average	7.58 ± 0.20	6.8 ± 0.24	5.68 ± 0.42	Appropriate

Sampling was performed 5 times based on the size of robusta coffee beans selected from the largest, medium, and small based on visual observation. Produces an average of 7.58 mm large, 6.8 mm medium, and 5.68 mm small seeds. Based on the results of the tests carried out, the coffee beans obtained are obtained by the Indonesia National Standard

(SNI 01-2907-2008) regarding special requirements for wet-processed robusta coffee.

Visually, it can be seen that the green bean results produced from the grading process of the coffee cherry machine created in Figure 6 below:



Figure 6: (a) Semi-wash green bean (b) Full-wash green bean.

4 DISCUSSION

Turbidity, caused by suspended particles, is a key indicator of water quality (Keener; Sewiwat; Ratpukdi, 2017). In this study, the main factor affecting the soaking medium's turbidity is the mucilage and pectin layer of the coffee cherry. In the testing of the filtration functionality of the coffee cherry grading machine, the results of the study showed a normal trend because the graph pattern of the water turbidity value in the coffee cherry grading machine went up and down, which indicated that the filtration process of carbon, silica sand, and cartridge filters that were flowed by back-wash on this machine was successful by obtaining data on the average turbidity value of water before the grading & washing process (raw water) of 0.47 NTU. In the semi-wash process, the turbidity value in the Main Tube was 10.42 NTU, and Water Storage was 5.32 NTU. In the full wash process, the turbidity value at the Main Tube is 15.65 NTU, and Water Storage is 7.70 NTU. The longer the coffee cherry soaking process, the more the turbidity value of water increases, this is due to the reduced or saturated filtration function. This result is in line with what was done (Cervera et al., 2007; Zhang et al., 2015), which found that the integration of activated carbon with sand filtration has been found to effectively remove organic matter, turbidity, and pollutants from the water but as the continuous filtration process causes the carbon filter and sand filter to be saturated.

As for the volume comparison in the context before the input of coffee cherries, the theoretical volume of the entire system is estimated to be around 321.69 litres, while the actual volume observed is around 316.24 litres. However, after the addition of 7 kg of the coffee cherry, the theoretical volume of the system is reduced to about 311.54 litres, while the actual measured volume is about 306.79 litres. In the research conducted (Tascón, et al., 2012) found that a water flow of 5 litres /minute resulted in 95.1% mucilage removal during the coffee cherry washing process. This means that the semi-wash process requires 3600 litres of water and a full wash of 9600 litres. This indicates that the tool has been made effective in saving water for semi-wash and full-wash treatment processes.

The results of the visualization of green beans produced by this tool are in line with the results of research conducted by (Sinaga et al., 2021) Related to the visualization of green beans of Gayo coffee in semi-wash and full-wash quality. In his research, the semi-wash results appeared bluish-green and the full-wash results appeared yellowish-green.

5 CONCLUSIONS

The coffee cherry grading machine innovation with semi-wash and full-wash methods was successfully implemented. In the semi-wash process, turbidity decreased from 10.42 to 5.32 NTU, while in the full-wash process, it

changed from 5.65 to 7.70 NTU. The machine uses 306.79 liters for 7 kg of cherries, suitable for water-limited plantations. The beans met SNI 01-2907-2008 standards, with semi-washed beans bluish-green and full-washed yellowish-green. A filtration resistance test is recommended for filter durability.

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7 AUTHORS' CONTRIBUTION

Conceptual Idea: Z. Djafar; Methodology Design: Z. Djafar, W. H. Piarah; Data Collection: W. H. Piarah, Z. Djafar, M. Massaguni; Data Analysis and Interpretation: Z. Djafar, W. H. Piarah, Z. Djafar, M. Massaguni; Statistical Analysis: M. Massaguni; Writing and Editing: Z. Djafar, W. H. Piarah, Z. Djafar, M. Massaguni; Supervision: Z. Djafar, W. H. Piarah, Z. Djafar.

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