

Harvesting and Soaking Effects on Yield and Phytochemicals of Liberica Coffee from West Java, Indonesia

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ABSTRACT

The yield and phytochemical compounds show the quality of Liberica coffee (*Coffea liberica*). The observed variables will be impacted by the maturity stage of the coffee cherries at harvest time and post-harvest treatment. The objective was to investigate the yield and phytochemical compounds of Liberica coffee beans from various harvest stages and soaking durations. The experiment was conducted using a completely randomized design. Eight treatments were tested, including soaking time (without soaking = S0, 12 hours soaking = S1, 24 hours soaking = S2, 36 hours soaking = S3) and harvesting stage (H1 = ripe stage, H2 = strip-picking stage) with four replications. The main observations were the yield components before and after drying (size, weight, color, bean yield, and moisture content) and the phytochemical compounds (TPC/total phenolic content, AA/antioxidant activity, and CC/caffeine content). Weight, moisture content, bean yield, and unit colors (a^* and b^*) are the only yield traits that reveal significant datas. The highest weight before drying was shown by H1S0, and weight after drying by H2S0 and H2S1. H1S2 has the highest moisture content before drying, whereas H1S1 has the greatest moisture content after drying. In addition, H1S2 and H1S3 produced the highest bean yield. The a^* and b^* values reflect the color unit that has been most affected by the treatments. H1S0 has the highest TPC and AA. However, H1S1 had the highest CC. Using appropriate harvesting stages and soaking times will increase the quality of Liberica coffee beans.

Key words: *Coffea liberica*; harvest phase; post-harvest processing; phytochemical compounds.

1 INTRODUCTION

Liberica coffee (*Coffea liberica*) is a lesser-known species cultivated in Indonesia alongside Arabica and Robusta coffee (Hafif et al., 2014). Liberica coffee has general compounds found in coffee, such as volatile compounds, caffeine, antioxidants, phenolics, and flavonoids (Tarigan et al., 2024). In Indonesia, Liberica coffee is found in several regions, including West Java, where its cultivation has been reported (Rahadi et al., 2021). Liberica coffee has more advantages than other commonly cultivated coffee species. This species is more resistant to leaf rust diseases and is more adaptable to suboptimal soils (Hafif et al., 2014; Wahibah et al., 2023). Unlike Arabica or Robusta types, Liberica coffee has a larger coffee bean but tastes more bitter (Lambot et al., 2017; Insanu et al., 2021; Maxiselly et al., 2023a). Furthermore, the high-quality coffee beans are a key factor in farmers' decisions to cultivate this species.

The quality of Liberica coffee is evaluated through yield component and phytochemical compounds, which are influenced by agricultural procedure, post-harvest, and distribution handling (Velásquez & Banchón, 2023). The yield components and phytochemical compounds will be impacted by the maturity stage of the coffee cherries at harvest and post-

harvest treatment (Maxiselly et al., 2023b). Two common methods for harvesting coffee are selective (collects only red-colored cherries) and strip-picking (harvesting all coffee cherries at once regardless of maturity). Picking ripe coffee cherries produces more uniform and higher-quality beans, but this needs labor-intensive and costly (Velloso et al., 2020). On the other hand, the strip-picking is faster and less expensive but often results in mixed quality beans because of the inclusion of unripe and overripe cherries (Haile & Kang, 2019; Bastian et al., 2021).

Improper post-harvest processing poses a threat to the poor quality of Liberica coffee. The type of coffee processing method used to acquire green beans determines the phytochemical profile and creates the difference in distinctive quality. The post-harvest treatment commonly used by coffee farmers in Indonesia is the dry harvesting process. This is done because that process is a relatively low-cost, rapid, and convenient method (Srikandi, Widia & Sutamihardja, 2019). However, the previous research found that post-harvest handling of Robusta coffee beans with the wet method can enhance bean quality and flavor characteristics compared to dry processing (Maxiselly et al., 2023b). A key step in wet processing is soaking. The soaking duration of coffee beans can influence the yield component of coffee beans and the

content of phytochemical components (Maxiselly et al., 2023b; Aryadi, Febrina & Harahap, 2020).

Biochemical fermentation occurs naturally by microorganisms present in the mucilage coffee beans during the soaking (Shah et al., 2025). The harvesting stage of coffee cherries and soaking time have an influence on biochemical fermentation (Osorio et al., 2023; Shah et al., 2025). Variations in these parameters can influence the accumulation of phytochemical compounds. Based on these consideration, this research aimed to evaluate the yield components and phytochemical compounds of Liberica coffee beans under different soaking durations and harvesting stages using various analytical approaches. This research not only fills a knowledge gap but also provides practical insights that can be applied to improve the quality of Liberica coffee.

2 MATERIAL AND METHODS

2.1 Research preparation

This study was conducted at Faculty of Agriculture Laboratory, Universitas Padjadjaran's. For the experiment, a completely randomized design (CRD) was applied. Eight treatments were examined, including soaking time (S0 = 0 hour, S1 = 12 hours, S2 = 24 hours, and S3 = 36 hours) and harvesting stages (H1 = only red cherries/ripe stage, H2 = green, yellow, and red cherries/strip-picking stage). Each treatment was replicated four times, as detailed in Table 1.

Table 1: The treatment combinations between harvesting stages and soaking durations on Liberica coffee beans.

No	Code	Treatment
1	H1S0	Ripe stage and no soaking duration
2	H2S0	Strip-picking stage and no soaking duration
3	H1S1	Ripe stage and 12 hours of soaking duration
4	H2S1	Strip-picking stage and 12 hours of soaking duration
5	H1S2	Ripe stage and 24 hours of soaking duration
6	H2S2	Strip-picking stage and 24 hours of soaking durations
7	H1S3	Ripe stage and 36 hours of soaking duration
8	H2S3	Strip-picking stage and 36 hours of soaking duration

The Liberica coffee cherries were harvested using two techniques at different harvest stages from the Banjaran area, West Java, by local farmers at 7°5.8190'S 107°36.0020'E. There is ripe stage (Red cherries only) and in the strip-picking stage (mixed maturity cherries). For a total of 12 kg of coffee cherries, six kilograms were generated for each harvesting stage. The coffee cherries were harvested and then soaked in water for two hours. During the harvesting procedure, the cherries were sorted and separated from dirt, pests, and hollow

cherries. Subsequently, a pulper machine (VKT-200, VOS Machinery Equipment Co., Ltd., Zhengzhou, China) was used. This procedure produced coffee beans that were removed from their skins. The next stage to achieve fermentation, the coffee beans went through the final soaking process. Coffee beans were simultaneously soaked in distilled water in a plastic bucket according to treatment durations of 0, 12, 24, and 36 hours. After soaking, the mucilage was removed by washing them. The mechanical drying procedure was the last step in this study, and involved 48 hours in an oven set at 50 °C (Maxiselly et al., 2023b).

The coffee bean's yield components and phytochemical compositions, both before and after the drying process are the main findings. Bean size, weight, moisture content, bean yield, and color are all variables in yield components. Meanwhile, the phytochemical composition comprises total phenolic content, antioxidant activity, and caffeine content.

2.2 Procedure

2.2.1 Yield components

The approach of Kusolwa et al. (2019), which used digital calipers to calculate seed size (0 to 150 mm), was used to observe yield components. Bean yield was calculated by dividing the final bean weight by the initial bean weight and then multiplying by 100%. The seed size components (length, width, and thickness) were measured both before and after drying. The characters of seed color were analyzed using a Minolta Chroma Meter type CR 400. The color units selected were L*, a*, b*, or CIELAB. L* denotes the lightness variable, and a* and b* indicate the color trend, while +a* indicates redness, -a* greenness, +b* yellowness, and -b* blueness trends. The seed color characteristics were examined using a Minolta Chroma Meter type CR 400. The color units used were L*, a*, b*, and CIELAB. L* represents the lightness variable, and a* and b* represent the color trend, with +a* indicating redness, -a* greenness, +b* yellowness, and -b* blueness trends.

2.2.2 Phytochemical Composition

2.2.2.1 Sample Preparation

First, the dried coffee bean was milled using a coffee grinder (SF 3526, Sonifer, Yiwu, China). Then, the sample extracted for the determination was obtained by extracting the sample using distilled water for 24 h (25 mg/mL). The solution was filtered using Whatman filter paper No. 1, placed in an amber bottle, and preserved in the refrigerator at 4 °C until further usage (Renaldi et al., 2022). The use of distilled water was designed to serve more natural solvent system (Wellinger, Smrke, & Yretzian, 2017). The flow of this research is presented in Figure 1.

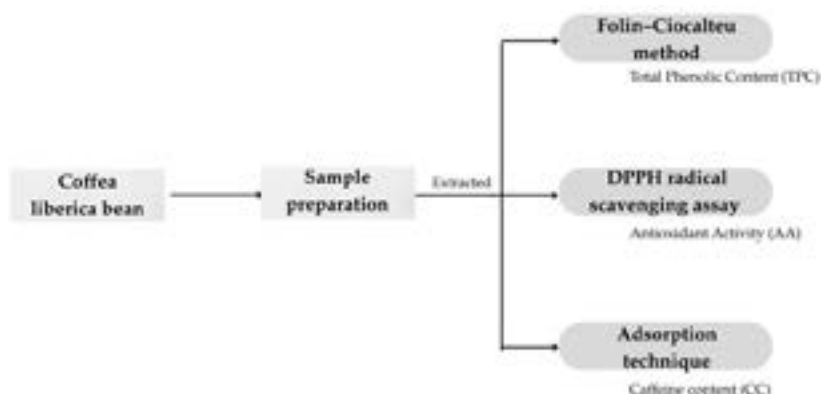


Figure 1: Procedure schematic of phytochemical composition analysis.

2.2.2.2 Total Phenolic Composition (TPC)

The technique developed by Folin was used for calculating the TPC (Renaldi et al., 2022). The extract (0.4 mL) was combined with the Folin-Ciocalteu reagent (2 mL) and 7.5% (w/v) of sodium carbonate (1.6 mL). The combination was allowed to settle in the dark for 45 minutes prior to being measured at 765 nm with a spectrophotometer (Cary 60, Agilent, Santa Clara, California, USA). The TPC was estimated using the measured calibration curve, with gallic acid as the standard. The results were expressed in milligrams of the equivalent of gallic acid (GAE) per gram of dry substance.

2.2.2.3 Antioxidant Activity (AA)

To conduct the DPPH radical scavenging test (Renaldi et al., 2022), a solution of AA (2.4 ± 0.02 mg) in methanol (100 mL) was mixed with 3.850 μ L of methanolic DPPH. The mixture was vigorously shaken for 30 minutes in the dark at room temperature. DPPH and methanol were utilized as negative controls, and ascorbic acid was used as a positive control. The absorbance of the reaction mixture was assessed at 517 nm.

2.2.2.4 Caffeine Content (CC)

The caffeine separation using the adsorption approach was done using the method issued with a few adjustments (Renaldi et al., 2022). The sample (15 mL) was placed into a 250 mL Erlenmeyer flask. After that, 0.15 g of activated carbon was added. The liquid was delicately mixed, then allowed to stand for 5 minutes before being filtered for 10 minutes using Whatman filter paper No. 1. In a volumetric flask of 100 mL, distilled water was used to dilute the filtrate to the desired level. A spectrophotometer with a 400 nm wavelength was used to measure the solution's absorbance.

2.3 Statistical analysis

The whole data is described as mean values (averages), their standard deviations (STDEV), and correlation values.

ANOVA analysis was used to identify the variance in yield components and phytochemical composition of coffee beans for different harvesting stages and soaking durations. The p-values of ≤ 0.05 were regarded as significant data, followed by Duncan's new multiple range test (DMRT). Additionally, the data variables correlation analysis examined the influence between characters using Pearson's matrix. The results of the data analysis are shown in the tables. Meanwhile, correlation data is visualized by a correlation heatmap using the R program version 4.5.1 with the ggcorrplot package (Kassambara, 2016).

3 RESULTS

3.1 Liberica coffee beans' yield component at different stages of harvest and soaking durations.

The weight, moisture content, and bean yield variables related to Liberica coffee beans at different harvesting stages and soaking durations are presented in Table 2, which shows both before and after drying. All of the characteristics were significantly influenced by the harvesting stages and soaking durations. The mature beans from the ripe phases approach produced the highest BD weight output (H1S0), whereas H2S0 and H2S1 provided the highest AD weight results, respectively. The 3 treatments with the greatest value for moisture content before drying were H2S2 (62.616%), H2S1 (59.785%), and H1S0 (58.801%). H1S1 also obtained the highest value regarding the bean yield, whereas H1S0 acquired the lowest amount of bean yield.

Table 3 shows the variation in the size of Liberica beans with variation in the methods of harvesting and soaking durations. The bean size variables include length, width, and thickness before and after drying treatment. The table reveals that neither all treatments had a significant impact on each general size bean characteristic.

Table 2: Liberica coffee bean: weight, moisture content, and yield properties at different harvesting stages and soaking times (both before and after the drying process).

Treatment	Weight BD (g)	Weight AD (g)	Bean Yield (%)	Moisture BD (%)	Moisture AD (%)
H1S0	58.687 e	21.135 a	36.018 a	58.801 bc	5.565 a
H2S0	52.599 d	22.893 d	43.52 b	57.811 b	5.459 a
H1S1	49.411 c	21.990 b	44.53 bc	55.583 ab	10.506 c
H2S1	49.232 c	22.968 d	46.665 d	59.785 bc	8.537 bc
H1S2	40.968 a	21.105 a	51.528 f	52.720 a	7.648 b
H2S2	49.954 c	22.810 cd	45.68 cd	62.616 c	7.633 b
H1S3	42.250 a	21.795 b	51.585 f	53.057 a	6.742 b
H2S3	45.754 b	22.190 bc	48.503 e	56.35 ab	7.591 b
CV (%)	2.03	1.98	2.40	5.10	21.02
p-value (Pr > F)	0.000	0.000	0.000	0.001	0.003

Note: CV (Coefficient of variation), BD (Before Drying), AD (After Drying), the harvesting stage treatments include H1 (the phase of ripe cherry) and H2 (the phase of strip picking). Meanwhile, the soaking duration treatments consist of S0 (no soaking duration), S1 (12 hours of soaking duration), S2 (24 hours of soaking period), and S3 (36 hours of soaking duration). At 95% DMRT, there is no significant difference between means in the same column followed by the same letter ($p < 0.05$).

Table 3: Size of beans of *Coffea liberica* at various harvesting stages and soaking durations.

Treatments	Before Drying			After Drying		
	L ^a	W ^a	T ^a	L ^a	W ^a	T ^a
H1S0	12.9	8.383	5.215	13.125	7.985	4.922
H2S0	13.265	8.483	5.585	12.843	8.393	5.093
H1S1	13.078	8.693	5.460	12.160	7.850	5.065
H2S1	12.418	8.310	5.858	12.825	7.968	5.200
H1S2	12.765	8.525	5.393	12.178	7.958	4.678
H2S2	13.120	8.360	5.023	12.840	8.208	5.450
H1S3	13.415	8.168	5.340	12.340	7.800	4.950
H2S3	13.575	8.435	5.508	12.218	7.700	5.158
CV (%)	4.33%	3.39%	13.19%	4.04%	5.56%	6.74%
p-value (Pr > F)	0.152	0.344	0.835	0.064	0.446	0.142

Note: ^aLength (L), Width (W), and Thickness (T) are in SI units of millimeters (mm). CV (Coefficient of variation). The harvesting stage treatments include H1 (the phase of ripe cherry) and H2 (the phase of strip picking). Meanwhile, the soaking duration treatments consist of S0 (no soaking duration), S1 (12 hours of soaking duration), S2 (24 hours of soaking period), and S3 (36 hours of soaking duration).

Liberica coffee bean color changes before and after drying are shown in Table 4. In addition, the L*, a*, and b* color units in this table represent the beans' lightness, redness, and yellowness color content, respectively. The range of lightness from white to black is represented by the L* unit, the range of red to green by the a* unit, and the range of blue to yellow by the b* unit. The a* and b* value traits were significantly different. The a* before drying shows that H1S0, H1S1, and H1S2 insignificantly differed among them. On the other hand, the b* before drying, control selective picking groups have insignificant data on the variations of soaking duration (H1S0, H1S1, H1S2, and H1S3) and indicate yellowness characteristic. The CIELAB units in the bean after drying indicate only the b*

values that indicate significant treatments, while L* and a* had insignificant data. The lowest score was H1S2 for the b* unit.

3.2 Liberica coffee bean phytochemical compositions at different stages of harvest and soaking times.

Table 5 visualized the representative phytochemical composition, such as total phenolic composition, antioxidant activity, and caffeine content (TPC, AA, and CC, respectively), as the quality variables of *Coffea liberica*. The phytochemical quantity of Liberica coffee was significantly influenced by the harvesting phases and soaking durations. The beans from the

Table 4: Color characteristics (L*, a*, and b*) before and after the drying process of *Coffea liberica* at various harvesting stages and soaking durations.

Treatments	Before drying			After Drying		
	L*	a*	b*	L*	a*	b*
H1S0	57.94	0.385 c	22.84 c	67.260	1.765	25.6 d
H2S0	57.63	-0.75 b	15.66 b	65.250	2.750	25.44 d
H1S1	56.165	0.665 cd	23.35 c	68.020	0.230	21.82 abcd
H2S1	61.77	-1.62 ab	9.655 a	64.440	2.530	24.57 cd
H1S2	52.125	0.465 c	25.585 c	68.860	-0.080	18.92 a
H2S2	61.3	-2.038 a	10.775 a	68.415	0.915	22.97 bcd
H1S3	56.485	1.665 d	23.535 c	69.360	0.600	21.44 abc
H2S3	61.185	-1.84 ab	10.38 a	69.610	0.655	20.19 ab
p-values (Pr > F)	0.094	0.000	0.000	0.156	0.055	0.020

Note: The harvesting stage treatments include H1 (the phase of ripe cherry) and H2 (the phase of strip picking). Meanwhile, the soaking duration treatments consist of S0 (no soaking duration), S1 (12 hours of soaking duration), S2 (24 hours of soaking period), and S3 (36 hours of soaking duration). At 95% DMRT, there is no significant difference between means in the same column followed by the same letter ($p < 0.05$).

Table 5: Liberica coffee beans at different stages of harvest and soaking durations in terms of their phytochemical composition.

Treatments	TPC (mg GAE per g Dry Sample)	CC (mg per 100 g Dry Weight)	AA (mg TE per g dry sample)
H1S0	15.187 g	47.643 c	20.44 g
H2S0	14.087 f	30.927 a	19.71 f
H1S1	14.08 f	48.347 d	17.59 b
H2S1	12.797 e	65.9 g	19.74 f
H1S2	10.01 c	56.25 f	17.26 a
H2S2	11.18 d	55.1 e	17.88 d
H1S3	5.6 a	41.723 b	18.33 e
H2S3	8.783 b	48.020 d	17.66 c
p-values (Pr > F)	0.000	0.000	0.000

Note: Total phenolic composition, caffeine content, and antioxidant activity are abbreviated to TPC, CC, and AA, respectively. The harvesting stage treatments include H1 (the phase of ripe cherry) and H2 (the phase of strip picking). Meanwhile, the soaking duration treatments consist of S0 (no soaking duration), S1 (12 hours of soaking duration), S2 (24 hours of soaking period), and S3 (36 hours of soaking duration). At 95% DMRT, there is no significant difference between means in the same column followed by the same letter ($p < 0.05$).

ripe stage without soaking (H1S0) had the best TPC result, whereas the treatment of ripe with 36 hours of soaking (H1S3) had the lowest TPC result. Apart from that, the mature beans harvested by strip picking and soaked for 12 hours (H2S1) had the highest CC value, and H2S0 had the smallest value. Other result, the highest value of antioxidant activity was found in the treatment of ripe beans without soaking (H1S0).

3.3 The Correlation Between Yield Component and Phytochemical Composition of Liberica Coffee Beans

Figure 2 is the correlation matrix visualization between the yield component and the phytochemical composition of Liberica coffee beans. A correlation coefficient (r) close to +1 indicates a strong positive correlation, while a coefficient close to -1 indicates a strong negative correlation. A strong positive

correlation was found between a* and b* color units before and after drying ($r=0.94$ and 0.88 , respectively). The color unit of a* and b* after drying have values that are positively correlates with antioxidant activity ($r=0.88$ and 0.91 , respectively). Therefore, the highest negative correlation was identified between a bean yield and the bean weight before drying ($r=-0.98$).

4 DISCUSSION

4.1 Liberica Coffee Yield Component, Bean Size, Moisture Content, and Color Units at Different Harvesting Stages and Soaking Durations

Yield analysis is used to test the weight loss of coffee at the initial weight and the weight after soaking treatment.

strip picking stages with 12 hours of soaking duration, which is the highest among other treatments. Alam, Warkoyo and Siskawardani (2023) describe the phases of the beans that can influence the chemical components, such as phytochemicals. The previous studies of Arabica and Robusta beans also have similar findings that the optimum maturity stages would form better phytochemical composition than coffee cherries harvested at a mixed maturity phase (Maxiselly et al., 2023b; Maxiselly et al., 2024a). The soaking time is based on the breakdown of the mucilage on the coffee beans. Liberica coffee beans have a thick mucilage, which it requires a longer soaking time. According to earlier research, mucilage Liberica beans breakdown took place throughout the 10 hours fermentation period and the TPC still elevated (Shah et al., 2025). The long fermentation process reduces phytochemical compound because it shrinks the natural sugars in coffee beans (Nizori et al., 2021).

The study additionally demonstrated that the effect of soaking on caffeine content appears to depend on the harvesting stages state. Sa'diyah et al. (2019) reported that the soaking process in coffee has significantly influenced the quality of coffee beans. The breakdown of liquids and acids results in an increase in non-liquid components like caffeine, fat, and minerals, providing it a unique flavor that leads to the differences in caffeine content (Widodo et al., 2023). This proves the proper soaking duration at different maturity stages will increase caffeine contents. These results suggest that the phytochemical compounds seen in Liberica coffee beans as a quality improvement is influenced by the harvest stage and soaking time.

4.3 The Correlation Between Yield Component and Phytochemical compounds of Liberica coffee beans

The correlation indices describe the dependent factors between the observed variables (Maxiselly et al., 2024b). Hue scaling in the matrix represents the relationship between variables, where darker tones suggesting a stronger correlation. This study investigated the correlation between all variables in Liberica coffee beans. Some of our findings were between the variables of color unit after drying (L^*AD , a^*AD , and b^*AD) showed a high positive correlation with antioxidant activity (AA). The phytochemical compounds are indicated by the colors (Suborna et al., 2024). The relationship between color changes and the DPPH process occurs due to the reduction reaction of antioxidant compounds (Ezra et al., 2023). The existence of this correlation indicates that color observation can be used as a non-destructive approach to assess the functional quality of coffee beans after the drying process as a visual indicator of AA. On the other hand, caffeine content did not exhibit a significant correlation with

color variables. According to previous research, there is no leverage between caffeine and CIELAB units in roasted coffee (Tsai & Jioe, 2021).

The correlation matrix also interprets the relationship between variables TPC and AA. A fairly positive correlation was only found in phytochemical composition between AA and TPC ($r = 0.55$). The relatively low correlation between AA and TPC might be because of TPC's inability to measure all active substances on the DPPH method and the interference from non-phenolic declining substances (Kulapichitr et al., 2022). The correlation also indicate that TPC measurement alone is insufficient to describe the overall antioxidant activity of the DPPH method. To assess antioxidant activity, at least three distinct in vitro antioxidant techniques must be used in tandem (Gulcin & Alwaseel, 2023). A combination of antioxidant activity analysis methods is necessary to obtain a comprehensive profile of the antioxidant capacity of Liberica coffee beans.

Additionally, several strong negative correlations were identified. The highest negative correlation was found between bean yield and weight before drying. The weight before drying acts as the denominator in the yield computation, which is obtained by dividing the weight of the last bean by the weight of the initial bean and then multiplying the result by 100% (Maxiselly et al., 2023b). Based on that formula, the higher the weight before drying, the lower the yield percentage.

5 CONCLUSIONS

The combination treatment of harvesting stages and soaking durations influenced the yield components and phytochemical composition. Based on bean yield values, the best treatments are ripe-picking cherries only with 24-hour or 36-hour soaking durations, H1S2 and H1S3, respectively. Ripe-picking without soaking duration is an effective method for achieving high TPC and AA values, whereas strip-picking with 12-hour soaking durations is the most effective method for CC. The quality of Liberica coffee beans will be enhanced by the most effective combination of treatments. In further research exploring phytochemical compound variables, it is recommended to comprehensive profiling of Liberica coffee.

6 AUTHOR CONTRIBUTIONS

Conceptual idea: Maxiselly, Y.; Maulana, H.; Maharani, Y.; Sari, D.N.; Zaw, Z.N.; Methodology design: Maxiselly, Y.; Sari, D.N.; Zaw, Z.N.; Data collection: Maxiselly, Y.; Maulana, H.; Maharani, Y.; Data analysis and interpretation: Wahyudin, A.A.; Maxiselly, Y.; Writing and editing: Maxiselly, Y.; Wahyudin, A.A.; Maulana, H.

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8 DATA AVAILABILITY STATEMENT

Data available upon request to authors.

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