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Evaluation of Cassava (Manihot esculenta Crantz): Antioxidative Activity of Leaves, Peeled Cassava, and Peel Extracts

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Abstract: Cassava is one of the main staple foods in Indonesia. The cassava's organ that is commonly used for food is the tuber part, followed by the leaf part as a vegetable. Meanwhile, cassava peels are mostly treated as waste. Cassava contains flavonoids and phenolic compounds, which are common and correlate with antioxidant properties. The aim of this study is to explore the antioxidant activities of three different parts of cassava: leaves, peeled tuber, and the peel, which is the first step in maximizing the use of cassava parts and reducing food waste. Cassava parts were extracted using three different solvents with different polarities. Then the antioxidant activities were tested using DPPH and CUPRAC methods. To investigate the contributing antioxidant compounds, total phenolic content (TPC) and total flavonoid content (TFC) were measured and subjected to statistical analysis. This study revealed that the antioxidative activity of cassava extracts by DPPH and CUPRAC in the range of 1.309 - 68.182 and 2.095 - 68.050 mg AEAC/g. The highest TPC was obtained from the ethanol leaf extract (11.133 ± 0.423 g GAE/100 g), while the highest TFC was observed in the n-hexane peel extract (7.526 ± 0.526 g QE/100 g). Phenolic and flavonoid compounds in cassava extracts greatly contributed to DPPH and CUPRAC antioxidative activities. Both methods exposed linear results on the antioxidative activity of cassava extracts.

Keywords: cassava; antioxidants; DPPH; CUPRAC; leaves; peeled cassava; peel.

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1. Introduction

Cassava (*Manihot esculenta* Crantz) is a tropical plant primarily consumed as a carbohydrate source in Southeast Asian countries, alongside rice and corn. In Indonesia, cassava plants are commonly found in dry areas [1]. Cassava tuber is commonly used as a staple food and carbohydrate source, while the leaves are consumed as vegetables. Huge cassava tuber consumption in Indonesia generates new waste: cassava peel.

Previous research revealed that cassava leaves contain active flavonoid and phenolic compounds, which correlate with antioxidant properties [2-4]. Another result by Yi (2011) showed that isolates derived from stem cassava, such as isovanillin, scopoletin, 6-Deoxyjacareubin, and others, exhibited antioxidant activity as determined by DPPH and ABTS assays [5].

As other cassava parts have shown antioxidant activity, it is interesting to determine whether the peel waste and the tuber exhibit the same activity. Currently, there is no research comparing the antioxidant properties of cassava leaves, peeled tuber, and peel waste. Furthermore, with the increasing number of patients with degenerative disease caused by excessive free radical exposure, the demand for new natural antioxidants is relevant and highly significant for preventing oxidative stress that could lead to degenerative disease and for improving the quality of life of degenerative disease patients.

This research is conducted to evaluate the antioxidative activity of cassava plant parts, namely cassava leaves, peeled cassava tuber, and cassava peel using the CUPRAC (Cupric Ion Reducing Antioxidant Capacity) and DPPH (2,2-diphenyl-1-picrylhidrazyl) methods through equivalence with ascorbic acid, determining total phenol, total flavonoids, corelation of total phenol and total flavonoids with antioxidative activity and also the correlation between two methods.

Previous research showed that antioxidant properties are correlated with the presence of flavonoid, phenolic, and terpenoid compounds. Therefore, during the extraction process, three different polarities of solvent, which were n-hexane, ethyl acetate, and ethanol, were used as solvents with the purpose of maximizing the extraction of phenolic, flavonoid, and terpenoid compounds. In this study, the chemical component responsible for the extract's antioxidant properties was also determined [6].

Based on the reaction mechanism, methods for antioxidant detection are categorized into two common assays. The first assay is SET (single-electron transfer), which detects the capacity of potential antioxidants to propagate chemical species, including radicals, metals, and carbonyls. The second assay is HAT (hydrogen atom transfer), which measures the capacity of antioxidants to scavenge free radicals through the donation of hydrogen atoms. In this study, we applied the DPPH and CUPRAC methods. The DPPH method is based on a mixture of HAT and SET, whereas CUPRAC is based on SET [7].

The DPPH testing procedure is based on the principle that DPPH, a stable free radical, is reduced. DPPH free radicals have maximum absorption at a wavelength of 517 nm and have a purple color. During the reaction, DPPH, which has an unpaired electron on one nitrogen atom, is reduced by a hydrogen atom from the antioxidant to give 2,2-diphenyl-1-picrylhydrazine. This causes decolorization from purple to pale yellow, depending on the number of electrons captured. The more intense the decolorization, the greater the reducing ability. The antioxidant properties of the tested compound are examined and determined from the kinetic reaction [8].

2. Materials and Methods

2.1. Materials.

The materials used were three parts of cassava: cassava leaves, peeled cassava tuber, and cassava peel, n-hexane, ethyl acetate, ethanol, weighing paper, filter paper, gallic acid, quercetin, 2,2-diphenyl-1-pircylhydrazyl (DPPH), neocuproine, quercetin ascorbic, acid, gallic acid, cupric chloride, methanol, sodium acetate, ammonium acetate, sodium carbonate, aluminum (III) chloride, Folin-Ciocalteu reagent, and distilled water. All chemicals used were analytical grade and were purchased from Merck.

2.2. Collection and preparation of the sample.

The preparation sample steps include collecting leaves, a peeled cassava tuber, and cassava peel from Cianjur, West Java, Indonesia. Then, cassava plants were determined at the Herbarium Bandungense, Bandung Institute of Technology. The samples were sorted, peeled, washed, and dried in an oven (40-50°C) for 7 days, ground into powder, and stored in a dry and closed container.

2.3. Extraction.

The extraction was performed using the reflux method with gradient-polarity solvents: n-hexane, ethyl acetate, and ethanol. All samples (3 kg) were extracted with 1,5 L of n-hexane, ethyl acetate, and ethanol, each for 2 hours. The liquid extract was evaporated in a rotary evaporator to obtain a thick extract.

2.4. Total phenol determination.

Total phenol content was investigated using Folin-Ciocalteu reagent. The standard was gallic acid, with a concentration of 60-130 µg/ml. 50 µl of each gallic acid concentration was taken, then added to 400 µl of 1 M sodium carbonate and 500 µl of 10% Folin-Ciocalteu reagent. After incubation for 30 min, a UV-visible spectrophotometer was used to measure the absorbance at 765 nm. The extracts of cassava leaves, peeled cassava tuber, and cassava peel were dissolved in methanol (concentration 2000-10000 µg/mL) and analyzed using the same procedure as for gallic acid for comparison. All analyses were replicated six times. The gallic acid calibration curve was used to determine total phenolic content, which was expressed as g gallic acid equivalent per 100 g of extract [9].

2.5. Determination of total flavonoids.

Determination of total flavonoid levels was carried out utilizing quercetin as a standard [10]. A quercetin reference solution was arranged with a concentration of 40-110 µg/ml. Each quercetin sample at different concentrations was diluted to 100 µl, then mixed with 300 µl methanol, 20 µl $AlCl_3$ 10%, 20 µl sodium acetate 1 M, and 560 µl purified water. After incubation for 30 min, a UV-visible spectrophotometer was used to measure the absorbance at 415 nm. The n-hexane, ethyl acetate, and ethanol extracts from the cassava leaves, peeled cassava tuber, and cassava peel were dissolved in methanol (concentration 2000-10000µg/mL) and carried out in the same procedure as the quercetin standard. All extracts were measured six times. The quercetin calibration curve was applied to evaluate the extract's total flavonoid content and presented in g quercetin equivalent per 100 g extract [10].

2.6. Determination of antioxidative activity with the DPPH method.

Determination of the antioxidative activity by DPPH was carried out utilizing ascorbic acid as a standard [8], DPPH 50 µg/ml as a control, and methanol as a blank. After incubation for 30 min, a UV-visible spectrophotometer was used to measure the absorbance at 517 nm. The analysis was carried out three times for each control concentration. The n-hexane, ethyl acetate, and ethanol extracts of the cassava leaves, peeled cassava tuber, and cassava peel were dissolved in methanol (concentration 50 µg/mL) and performed in the same procedure as the ascorbic acid standard. Antioxidative activity was calculated from the ascorbic acid calibration

curve and stated in terms of the equivalent antioxidant capacity of ascorbic acid per g of extract (mg ascorbic acid antioxidant capacity (AEAC)/g extract) [8]. All analyses were conducted six times.

2.7. Determination of antioxidative activity with the CUPRAC method.

The antioxidative activity was determined using the CUPRAC method, with ascorbic acid as the standard, CUPRAC 100 μg/ml as the control, and ammonium acetate buffer as the blank. CUPRAC solution was organized in an ammonium acetate buffer at pH 7. After incubation for 30 min, a UV-visible spectrophotometer was used to measure the absorbance at 450 nm. The analysis was performed three times for each control concentration. The n-hexane, ethyl acetate, and ethanol extracts of cassava leaves, peeled cassava tuber, and cassava peel were dissolved in methanol and carried out within the same procedure as the ascorbic acid standard. Antioxidative activity was calculated from the ascorbic acid calibration curve and exhibited in terms of the equivalent antioxidant capacity of ascorbic acid per g of extract (mg ascorbic acid antioxidant capacity (AEAC)/g extract) [11]. All samples were tested six times.

2.8. Statistical analysis.

Data processing was performed utilizing Minitab 21 software. Each sample analysis was performed six times, and all measurement results were examined using one-way ANOVA with Tukey's post hoc test ($p<0.05$). A correlation test between total phenols or total flavonoids and antioxidative activity, and between methods of determining antioxidative activity, was performed using Pearson’s method.

2.9. Identification and determination of marker compound levels in the selected extract.

High-performance liquid chromatography (HPLC) with a UV-visible detector was used to identify and quantify flavonoid compounds in the selected extract. The separation was performed using methanol and water with a linear gradient of 40-60% methanol for 5 min, followed by 70% methanol for 5 min and 40% methanol for 15 min. The column used for separation was LiChrospher® 100 RP-C18 (5 μm; 100x4 mm). A 20 μL injection volume was used at 30°C with a flow rate of 1 mL/min. The UV-vis detector with a wavelength of 360 nm was applied for detection. The flavonoid content was measured using the one-point method, using standard rutin, kaemferol, and quercetin. All samples were replicated three times [6].

3. Results and Discussion

3.1. Total phenolic (TPC) and flavonoid content (TFC).

TPC in cassava extracts was calculated in gallic acid equivalent (GAE) using the equation of the calibration curve:

$$y = 0.0046x + 0.0025; R^2 = 0.9927$$

TPC in various extracts of Cassava leaves, flesh, and peel was presented in Figure 1. The highest TPC in this experiment was observed in the ethanol leaf extract (11.133 ± 0.423 g GAE/100 g). TFC among various extracts was identified by a quercetin calibration curve, as quercetin equivalent (QE):

$$y = 0.0055x + 0.0004; R^2 = 0.9997$$

TFC in various extracts of cassava leaves, peeled cassava tuber, and cassava peel was exposed in Figure 2. The most elevated TFC in this experiment was expressed by ethanol leaves extract (6.469 ± 0.434 g GAE/100 g).

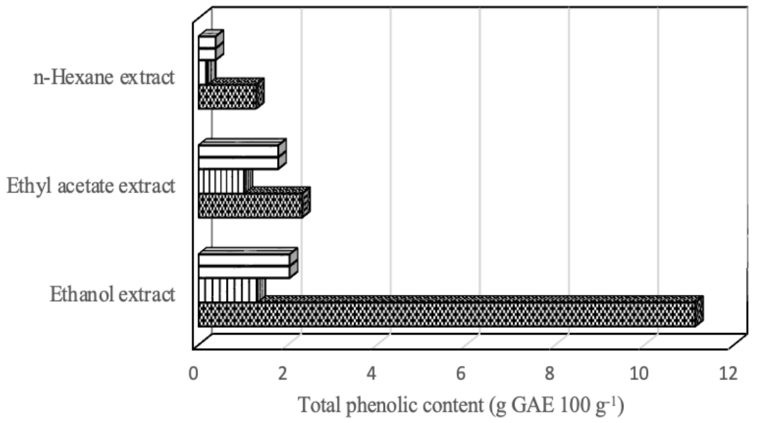

Figure 1. Total phenolic content of cassava extracts, n = 6.

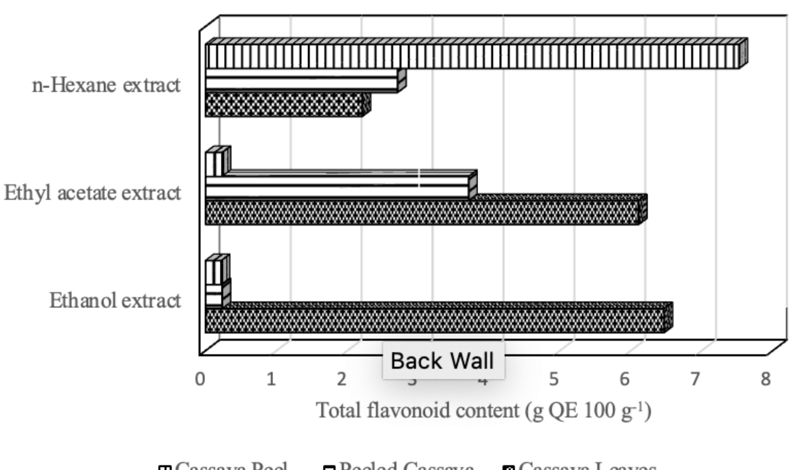

Figure 2. Total flavonoid content of cassava extracts, n = 6.

Based on the results of total phenol determination, the extract with the highest phenol content was ethanol leaves extract (11.133 ± 0.423 g GAE/100 g), while the extract with the lowest phenol content was n-hexane of peeled cassava tuber 0.206 ± 0.022 g GAE/100 g. Research held by Suresh *et al.* [12] reported a total phenol extract of 1% methanol HCl cassava leaves of 136 ± 0.01 mg/g, methanol extract of cassava leaves of 64 ± 0.01 mg/g, and acetone extract of cassava leaves of 164 ± 0.02 mg/g. This is in line with the results of this research, which found that the total phenol of the ethanol extract of cassava leaves was 11.133 ± 0.423 g/100 g or 111.33 mg/g. In another study, the total phenol content of the Medan variety peeled cassava extract was 9.83 mg GAE/g, and the variety cassava root extract was 9.20 mg GAE/g [13]. Meanwhile, the research by Dusuki *et al*. [14] reported a total phenol content of 71.79 ± 5.57 (µg GAE/g) in the cassava peel extract.

A phenolic compound is a compound with a lot of hydroxyl substituents. The presence of hydroxy groups is the reason this compound has high polarity. Thus, phenolic compounds will be soluble in the polar solvent, such as ethanol. This is consistent with our finding that ethanol extract had the highest phenolic content.

Total flavonoid determination was carried out using method from Chang *et al*. [10]. In this method, the absorbance of the sample is determined by adding $AlCl_3$, which forms a

complex with flavonoids. The principle of this test is the formation of a red stable acid complex [10]. The complex is formed between $AlCl_3$ and flavonoids, which have a keto C-4, a hydroxyl group on C-3 or C-5 located in ring A, and a hydroxyl group on C3'-C4' in ring B [10]. Sodium acetate is added to provide an alkaline environment, thereby stabilizing the complex. A UV-vis spectrophotometer was used to read the absorbance at 415 nm. Based on the results of total flavonoid determination, the extract with the highest flavonoid content was the ethanol extract of cassava leaves, namely 6.469 ± 0.434 g QE/100 g, while the extract with the lowest flavonoid content was the ethanol extract of cassava peel, namely 0.221 ± 0.029 g QE/100 g. The result is consistent because most flavonoids are semipolar to polar, thus easily soluble in polar extraction solvents such as ethanol.

In this research, total flavonoids were expressed as quercetin equivalents (QE), whereas in previous studies, catechin equivalents (CE) were used. Research by Faezah *et al.* [13] exposed that the TPC of peeled cassava extract of the Medan variety was 2.47 mg CE/g and that the cassava root extract of the Pontian variety was 2.30 mg CE/g. Research by Dusuki *et al.* [14] reported that the total flavonoid content of cassava peel extract was 4.98 ± 1.00 (µg RE/g), which was used to create a calibration curve. The total flavonoid of the samples was counted as µg rutin equivalent per g (µg RE/g).

The other research [15] found that the total flavonoid extract of 1% methanol HCl cassava leaves was 116 ± 0.01 mg/g, the methanol extract of cassava leaves was 124 ± 0.03 QE/100 g, and the acetone extract of cassava leaves was 238 ± 0.03 QE/100 g. It was distinctive from the current study, which showed that the ethanol extract of cassava leaves had total flavonoids of 6.469 ± 0.434 g QE/100 g, or 64.69 mg QE/g.

3.2. Antioxidant activity using the DPPH method.

The antioxidant activity values were calculated as ascorbic acid equivalence (AEAC). The higher the AEAC value, the greater the antioxidant activity of the extracts. The results of antioxidant activities of cassava leaves, peeled cassava tuber, and cassava peel extracts using the DPPH method are shown in Figure 3.

Based on testing the antioxidative activity of cassava leaves, peeled cassava, and cassava peel extracts using the DPPH method, the ethanol extract showed the highest antioxidative activity value, 68.182 ± 9.757 mg AEAC/g. In this research, the results of the antioxidative activity test were expressed as the equivalent antioxidant capacity of ascorbic acid. This result might be correlated to the presence of flavonoids and phenols in the extract, which are easily soluble in polar solvents such as ethanol and methanol.

This was different from several previous studies, which stated the results of antioxidative activity tests with the percentage of DPPH inhibition. The greater the percentage of DPPH inhibition, the greater the antioxidative activity. Research by Suresh *et al.* [12] denoted that 1% methanol HCl extract of cassava leaves provided 68% inhibition of the DPPH radical, 15.2% for the methanol extract of cassava leaves, and 9.7% for the acetone extract of cassava leaves. Another study [13] revealed that Pontian cassava root extract grown with fertilizers showed a % DPPH radical inhibition of 50.81. In another study [16], it was reported that yellow cassava peel extract exhibited 19% DPPH radical inhibition. Based on research by Yi *et al.* [5] utilizing the DPPH method, the activity was expressed as an inhibitory concentration of 50% or 50% inhibitory concentration (IC_{50}). The IC_{50} value for the cassava leaves aqueous extract was 42.64 µg/ml, and the cassava leaves ethanol extract was 17.69 µg/ml. It was different from this study, which reported the greatest antioxidative activity in the

ethanol extract of cassava leaves (68.182 ± 9.757 mg AEAC/g extract), the ethanol extract of peeled cassava (6.236 ± 0.441 mg AEAC/g extract), and the ethanol extract of cassava peel (9.762 ± 0.462 mg AEAC/g extract).

3.3. Antioxidative activity using the CUPRAC method.

The determination of antioxidative activity with the CUPRAC assay used neocuproine as the ligand. The antioxidative activity values are measured as mg ascorbic acid equivalent antioxidant capacity (AEAC)/g sample. The results of antioxidant activities of cassava leaves, peeled cassava tuber, and cassava peel extracts by the CUPRAC method are demonstrated in Figure 3. In the CUPRAC (cupric ion reducing antioxidative activity) method, Cu^{2+} was reduced to Cu^{+} using the chromogenic oxidizing agent neocuproine in ammonium acetate buffer at pH 7. Reduction of Cu^{2+} to Cu^{+} due to the presence of an antioxidant caused the formation of a yellow-orange Cu^{+}- neocuproine complex with a maximum absorption peak at 450 nm [17]. In the CUPRAC method, the greater the absorbance measured, the greater the percentage increase in CUPRAC capacity. Thus, the sample's antioxidative activity can be calculated by entering the percentage increase in sample capacity into the ascorbic acid regression equation.

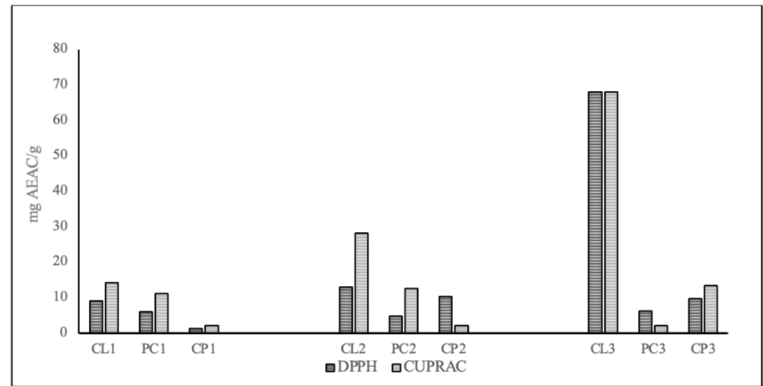

Figure 3. Antioxidative activities of cassava extracts with DPPH and CUPRAC, CL = cassava leaves, PC = peeled cassava, CP = cassava peel, 1 = n-hexane extract, 2 = ethyl acetate extract, 3 = ethanol extract, n = 6.

Based on the results of testing the antioxidative activity of cassava leaves, peeled cassava, and cassava peel extracts using the CUPRAC method, it was found that the strongest antioxidant was presented by the ethanol extract of the leaves, namely 68.050 ± 6.077 mg AEAC/g. Similar to the DPPH result, the high activity of the ethanol extract might be correlated with the highest levels of phenols and flavonoids in the leaves.

Meanwhile, the results of research by Sayakti *et al.* [15] showed an IC50 value of 154.54 µg/ml for the methanol extract of cassava leaves using the CUPRAC method. Indonesia is among the 4 largest cassava-producing countries, along with Nigeria, Brazil, and Thailand. So, it can be concluded that the cassava peel produced will remain abundant. However, cassava peels are rarely used, so they often become waste from cassava processing. Based on the results of this research, cassava leaves and cassava peels had greater antioxidative activity than peeled cassava tubers. Thus, it can be concluded that cassava leaves and cassava peel have the potential to be developed as an antioxidant source.

3.4. Correlation between TPC and TFC to the antioxidative activity.

The statistical correlation analysis was conducted to identify which compound contributed to the antioxidant activities. The correlation analysis between TPC and TFC in

cassava leaves, peeled cassava tuber, and cassava peel extracts on antioxidative activity was carried out using Pearson's method. TPC and TFC were considered to have contributed if they showed a positive, significant correlation with the antioxidative activity value. The results were shown in Table 1. Correlation values of 0.40-0.69 are moderate, 0.70-0.89 are strong, and 0.90-1.00 are very strong [6].

Table 1. Correlation of the total phenol and total flavonoid of cassava extracts with antioxidative activity.

Antioxidant parameter	Pearson correlation coefficient (r)	
	Total phenol	Total flavonoid
DPPH CL1	0.995****	0.978****
DPPH PC1	0.838***	0.737***
DPPH CP1	0.888***	0.786***
DPPH CL2	0.864***	0.895***
DPPH PC2	0.649**	0.809***
DPPH CP2	0.953****	0.914****
DPPH CL3	0.795***	0.832***
DPPH PC3	0.733***	0.649**
DPPH CP3	0.897***	0.764***
CUPRAC CL1	0.938****	0.937****
CUPRAC PC1	0.971****	0.996****
CUPRAC CP1	0.979****	0.884***
CUPRAC CL2	0.970****	0.881***
CUPRAC PC2	0.974****	0.960****
CUPRAC CP2	0.874***	0.958****
CUPRAC CL3	0.840***	0.852***
CUPRAC PC3	0.870***	0.927****
CUPRAC CP3	0.724***	0.996****

**** = very strong correlation, *** = strong correlation, ** = moderate correlation, CL = cassava leaves, PC = peeled cassava, CP = cassava peel, 3 = ethanol extract, 2 = ethyl acetate extract, 1 = n-hexane extract.

The correlation between total phenols and flavonoids in cassava leaves, peeled cassava, and cassava peel extracts on the antioxidative activity values of DPPH and CUPRAC was carried out using Pearson's method. A positive, significant correlation indicated that total phenol or total flavonoid content contributed to the samples' antioxidative activity. The statistical analysis results revealed that the levels of total phenol and total flavonoids in cassava leaves, peeled cassava, cassava peel extracts gave a strong to very strong correlation to the antioxidative activity values of DPPH and CUPRAC, except for total phenol to the antioxidative activity of the ethyl acetate extract of peeled cassava with DPPH and total flavonoids on antioxidative activity of ethanol extract of peeled cassava with DPPH. It was shown that even though the lower values of total phenol and total flavonoid in cassava leaves, peeled cassava, and cassava peel extracts showed a strong to very strong correlation with the antioxidative activity value. From the above results, it can be suggested that the phenol and flavonoid compounds in cassava leaves, peeled cassava, and cassava peel extracts contributed significantly to antioxidant activity as measured by DPPH and CUPRAC. Therefore, we can conclude that phenol and flavonoid are responsible compounds for the antioxidant activity of cassava leaves, tuber, and peel using the DPPH and CUPRAc method.

In another study, there was a correlation between total phenols and total flavonoids. The research results by Faezah *et al.* [13] indicated a positive and significant correlation (r = 0.62) between total phenols and total flavonoids in peeled cassava extract, with total phenols increasing before total flavonoids. The statistical analysis results (Table 2) indicated that the antioxidative activity of each extract measured by the DPPH method showed a significant

positive correlation with that measured by the CUPRAC method. This showed that the two test methods gave linear results.

3.5. Correlation between DPPH and CUPRAC methods.

The correlation between antioxidative activity with two methods in cassava leaves, peeled cassava, and cassava peel extracts was determined statistically using Pearson's method. The results were represented in Table 2.

Table 2. Correlation between DPPH and CUPRAC methods.

Antioxidant parameter	Pearson correlation coefficient (r)								
	CUPRAC CL1	CUPRAC PC1	CUPRAC CP1	CUPRAC CL2	CUPRAC PC2	CUPRAC CP2	CUPRAC CL2	CUPRAC PC2	CUPRAC CP2
DPPH CL1	0.942****								
DPPH PC1		0.738***							
DPPH CP1			0.826***						
DPPH CL2				0.796***					
DPPH PC2					0.675**				
DPPH CP2						0.888***			
DPPH CL3							0.950****		
DPPH PC3								0.727***	
DPPH CP3									0.722***

**** = very strong correlation, *** = strong correlation, ** = moderate correlation, CL = cassava leaves, PC = peeled cassava, CP = cassava peel, 3 = ethanol extract, 2 = ethyl acetate extract, 1 = n-hexane extract.

3.6. Identification and determination of flavonoid compound levels.

AUC of the standard (rutin) for the determination of flavonoid compound level in the ethanol leaves extract of cassava was exposed on the chromatogram in Figure 4 and Table 3. High-performance liquid chromatography was used to identify and quantify the flavonoid compound levels in the selected extract. The chosen extract was the ethanol extract of cassava leaves, which showed the highest antioxidative activity using the DPPH and CUPRAC methods. Identification of rutin, quercetin, and kaempferol in the ethanol extract of cassava leaves was performed.

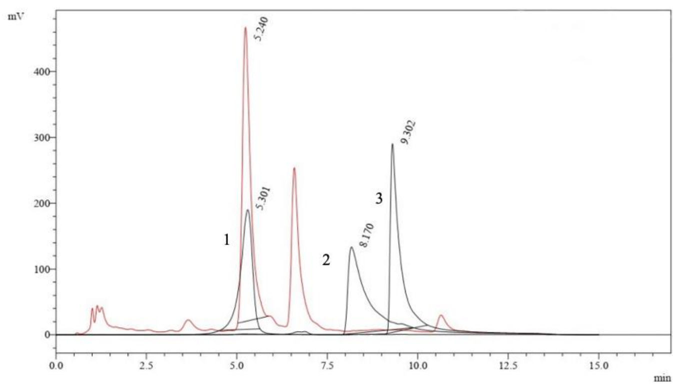

Figure 4. HPLC chromatogram of ethanol leaves extract and standards, 1: rutin, 2: quercetin, 3: kaempferol, black line chromatogram = standard, red line chromatogram = sample.

Table 3. Retention time and AUC data for the determination of flavonoid compound levels.

Flavonoid	Retention time (min)		AUC	
	Standard	Sample	Standard	Sample
Rutin	5.24	5.301	7129864	4132432
Quercetin	8.17	-	4539154	-
Kaempferol	9.302	-	5151874	-

Figure 4 showed that the peak in the sample chromatogram coincided with that of rutin; thus, the ethanol extract of cassava leaves contained rutin. The determination of the levels of rutin compound in the ethanol extract of cassava leaves was conducted using the one-point method, and a rutin level of 0.863% was obtained. This was supported by the research of Chayadi [18] and Intarakasem *et al*. [19], which stated that there was a rutin in cassava leaves. Rutin plays a role in inhibiting free radicals [20]. Thus, it can be inferred that rutin contributes to the antioxidative activity of the ethanol extract of cassava leaves.

4. Conclusions

The DPPH antioxidative activities of cassava leaves, peeled cassava, and cassava peel extracts were in the range of 1.309-68.182 mg AEAC/g, whereas the CUPRAC antioxidative activities were 2.095–68.050 mg AEAC/g. The highest TPC and TFC were observed in the ethanol extract of the leaves, with 11.133 ± 0.423 g GAE/100 g and 6.469 ± 0.434 g QE/100 g, respectively. In general, the phenolic and flavonoid content in cassava leaves, peeled cassava, and cassava peel extracts greatly contributed to the antioxidative activity of DPPH and CUPRAC. The CUPRAC and DPPH methods showed linear results for the value of the antioxidative activity. The ethanol extract of cassava leaves contained 0.863% rutin. Cassava leaves and peel were potentially further developed as sources of natural antioxidants.

Author Contributions

Conceptualization, H.P. and D.R.; methodology, A.R.C., R.H., and I.F.; software, I.F. and S.S.A.; formal analysis, S.S.A.; investigation, S.S.A.; data curation, S.S.A., I.F., and A.R.C.; writing—original draft preparation, S.S.A.; writing—review and editing, A.R.C. and I.F.; supervision, I.F. and A.R.C.; project administration, H.P. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Data supporting the findings of this study are available upon reasonable request from the corresponding author.

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Conflicts of Interest

The authors declare no conflict of interest.

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