

Analysis of Cyanide Content and Antioxidant Activity of Teo Tuber (*Tacca leontopetaloides* (L.) Kuntze) Starch after Soaking in NaCl Solution

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Abstract

Polynesian arrowroot (*Tacca leontopetaloides* (L.) Kuntze) is a local food source of the Torosiaje community, rich in starch and utilized as a carbohydrate source. The processing of Polynesian arrowroot into starch generally involves soaking using NaCl solution to reduce the toxic cyanide content. Additionally, Polynesian arrowroot may contain antioxidant compounds beneficial to health. However, information regarding the analysis of soaking treatment on cyanide content and antioxidant activity remains limited. This research aims to analyze the cyanide content and antioxidant activity of Polynesian arrowroot starch through soaking in NaCl solution. The research was conducted as a laboratory experiment using a quantitative approach. Cyanide content was analyzed using UV-Vis spectrophotometry, while antioxidant activity was assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method. The results showed that the cyanide content in the raw sample was 2.170 mg/kg, while NaCl solution soaking at 15% and 30% concentrations yielded 1.927 mg/kg, respectively. These data indicate a tendency for cyanide content to decrease after three days of NaCl solution soaking. The antioxidant activity was categorized as very strong, as demonstrated by the IC₅₀ values for 15% and 30% NaCl solution soaking at 38.69 ± 0.00 µg/mL and 28.06 ± 0.00 µg/mL, respectively, while the raw sample obtained an IC₅₀ value of 191.76 ± 0.00 µg/mL.

Keywords: Cyanide; Antioxidant Activity; Polynesian arrowroot; NaCl Solution Soaking; Starch.

INTRODUCTION

Food security is an integrated system that reflects the interaction among food availability, distribution, and consumption. As Indonesia's population continues to grow, food security has become a crucial element in ensuring that the basic needs of society are adequately fulfilled (Nurida, 2024). The primary objective of food security is to ensure a healthy, active, and productive life in a sustainable manner (Ula, 2021). Food security is also recognized as one of the key priorities in sustainable development, particularly in the face of climate change challenges and the limited availability of agricultural land. One important strategy for strengthening food security is the implementation of food diversification programs (Sudrajat *et al.*, 2025).

Integrated food diversification from self-sufficiency (synergy brings about the well-being of food-hungry people) is one of the main pillars in building food security. Self-sufficiency is commonly defined as an increase in food availability across the country. The self-food program is one of the top priorities of national development. The program is based on the second goal of the prabowo subianto government and is described in

the national medium-term development plan (RPJMN) 2025-2029, which is based on the vision "joint Indonesia development to Indonesia, 2045 gold." With such policies, governments are targeting the development of national self-reliance and food security over the next 4-5 years (Saragih, 2025). Therefore, alternatives to such an ideal require local food use.

Local food is a food product prepared and served by people in certain areas by tapping into local resources and wisdom. Local food processing is closely linked to the prevalence of public consumption, the application of traditional technologies, knowledge, and the use of local raw materials (Suci, 2024). One of the communities that fed local food was the bajo people.

The local food of the Bajo community is closely associated with their maritime way of life. Marine resources, including tuna, skipjack tuna, and snapper, constitute the primary sources of local food and provide high-quality animal protein as well as omega-3 fatty acids that are beneficial to health. These fatty acids play an important role in maintaining cardiovascular function, supporting brain development, and helping reduce the risk of various disorders associated with the circulatory

system (Hasim, 2021). Not only this, *Euchema cottoni* seaweed is also commonly used as food by coastal communities, as it contains fibers, iodine, and antioxidants that are useful for thyroid health and digestive systems (Sulastri & Abdul, 2022). In addition, people of the bajo tribes also used teo tuber (*Tacca leontopetaloides* (L.) Kuntze) as local food. Teo tuber is utilized by local communities as an alternative food source and is processed into various traditional foods, such as cendol, loho bua (porridge), onde-onde, cucur, and ledo (a traditional sweet dessert) (Lambera *et al.*, 2026). In addition to being processed into various traditional foods, teo tuber also serves as a source of carbohydrate reserves for coastal communities because it contains starch and essential minerals that contribute to meeting energy requirements. This utilization further contributes to local food diversification and food security among coastal communities (Wardah & Arini, 2020).

Teo tuber is known to contain antinutritional compounds, particularly cyanide, which may pose a health risk when consumed without appropriate processing. Ogbonna *et al.* (2017) reported that processed teo tuber starch still contained cyanide at a level of 0.18 mg/100 g. In addition to cyanide, teo tuber also contains other antinutritional compounds, such as oxalates and phytates, which may affect the safety and nutritional quality of the resulting product. Therefore, appropriate processing methods are needed to reduce the cyanide content and ensure that teo tuber can be safely utilized as a food ingredient. One processing method that can be applied to reduce cyanide content is soaking in a sodium chloride (NaCl) solution. Haris *et al.* (2022) explained that NaCl solutions have the ability to detoxify cyanide compounds because their concentration is higher than that of the fluid within the tissues of the material. This concentration gradient promotes osmosis, thereby facilitating the diffusion of cyanide compounds from the tissue into the soaking medium.

Field observations conducted on July 8, 2025, showed that the people of Torosiaje utilize teo tuber by processing it into starch. The processing procedure includes cleaning, peeling, slicing, grating, filtering, and soaking before the starch is used as a food ingredient. The soaking of the starch sediment is an important step in the processing procedure because it aims to reduce the cyanide content of teo tuber starch.

In addition to containing cyanide compounds, teo tuber also has potential as a source of antioxidants. Rachmawati *et al.* (2022) reported that the tuber of *Tacca leontopetaloides* contains bioactive compounds,

including flavonoids, phenolics, and tannins, which contribute to its antioxidant activity. These compounds have the potential to provide health benefits and support the utilization of teo tuber as a functional food. However, the soaking process using a NaCl solution to reduce cyanide content may also affect the antioxidant activity of teo tuber starch. Therefore, this study aimed to analyze the cyanide content and antioxidant activity of teo tuber starch (*Tacca leontopetaloides* (L.) Kuntze) following soaking in NaCl solutions.

MATERIALS AND METHODS

Study area

This study was conducted at the Biology Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Negeri Gorontalo; the Food Processing Laboratory, Department of Food Science and Technology, Faculty of Agriculture (FAPERTA), Universitas Negeri Gorontalo; and the Pharmaceutical Chemistry Laboratory, Department of Pharmacy, Universitas Negeri Gorontalo. The research was conducted from April to May 2026.

The equipment used in this study included an analytical balance, oven, grinder, 80-mesh sieve, 1000 mL graduated cylinder, spatula, volumetric pipette, micropipette, 1000 mL beaker, litmus paper, containers, stirring rod, 25 mL volumetric flask, vial bottles, cuvettes, mortar and pestle, knife, and UV-Vis spectrophotometer.

The materials used included 1 g of teo tuber, 600 g of teo tuber starch sediment, water, 150 g and 300 g of industrial-grade salt (NaCl), distilled water, 70% alcohol, zip-lock plastic bags, alfol containers, tissue paper, plastic gloves, disposable gloves (handscoon), label paper, 5 mL of DPPH reagent, 10 mL of vitamin C, KCN (potassium cyanide), 11.2 mL of ninhydrin (C₉H₆O₄), 11.2 mL of NaOH, and sodium carbonate (Na₂CO₃).

This study employed a Completely Randomized Design (CRD) with one factor, namely the treatment following soaking in NaCl solutions. The study consisted of three treatment groups: fresh teo tuber (Raw sample), teo tuber starch soaked in 15% NaCl solution, and teo tuber starch soaked in 30% NaCl solution. Each treatment was performed in triplicate. The Raw sample was used as a comparison to evaluate changes in cyanide content and antioxidant activity following the soaking treatment. The detailed experimental design is presented in Table 1.

Table 1. Experimental sample groups for cyanide content and antioxidant activity analyses.

No	Sample Group	Description
1	Raw Sample	A total of 1 g of sample was used for cyanide content and antioxidant activity analyses.
2	NaCl 15%	A total of 100 g of ubi teo starch sediment was soaked in a 15% NaCl solution (150 g NaCl dissolved in water to a final volume of 1000 mL). After soaking, 1 g of starch was used for cyanide content and antioxidant activity analyses.
3	NaCl 30%	A total of 100 g of ubi teo starch sediment was soaked in a 30% NaCl solution (300 g NaCl dissolved in water to a final volume of 1000 mL). After soaking, 1 g of starch was used for cyanide content and antioxidant activity analyses.

Population and samples

The population consisted of teo tuber (*Tacca leontopetaloides* (L.) Kuntze) available in Torosiaje Village, Pohuwato Regency. Teo tuber samples were selected using a purposive sampling method based on the following criteria: fresh condition, free from decay, free from spots, and free from physical damage.

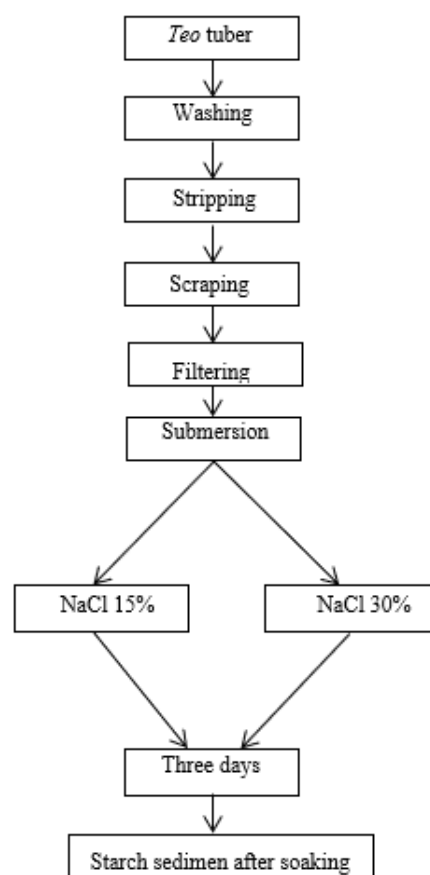
Data gathering techniques

Sample taking

The teo tuber samples used in this study were obtained directly from Torosiaje Island, Torosiaje Village, Popayato District, Pohuwato Regency, Gorontalo Province, with the assistance of local residents. The tubers were harvested from the soil in fresh condition and subsequently selected based on their physical characteristics, namely being free from damage and contaminants. The selected samples were then packed in sacks and transported to the laboratory for further analyses.

Preparation of the materials and inundation

The initial process began with washing the teo tubers with water. The tubers were then peeled, grated, and filtered. Subsequently, 100 g of starch sediment was weighed for each treatment. Soaking solutions of 15% and 30% NaCl were prepared by dissolving 150 g and 300 g of NaCl, respectively, in water to a final volume of 1000 mL. The starch sediment was then soaked for 3 days, with the soaking solution replaced every 24 h, and this procedure was repeated three times. At each replacement of the soaking solution, observations were conducted on changes in water clarity and pH values to monitor cyanide reduction. Thereafter, the material was allowed to stand until starch sediment was formed. The detailed procedures for sample preparation and soaking treatment are presented in Figure 1.

**Figure 1.** Flowchart of sample preparation and soaking treatment.

Starch Production

The starch sediment obtained after the soaking treatment was dried in an oven at 85°C for 24 h. The dried material was then ground using a grinder and sieved through an 80-mesh sieve to obtain starch. The resulting starch was subsequently packaged in clip-seal plastic bags to facilitate storage and improve shelf life during the storage period.

Cyanide Content Analysis

Cyanide content data were obtained using a spectrophotometric method with a UV-Vis spectrophotometer. Measurements were performed on fresh teo tuber (raw sample) and teo starch produced from soaking treatments in 15% and 30% NaCl solutions. The results were expressed as cyanide content (mg/kg). For the analysis, 1 g of each sample was weighed and transferred into a 100 mL volumetric flask. Distilled water was added to the calibration mark, and the solution was homogenized to obtain the sample solution. The solution was subsequently prepared at concentrations of 20, 40, 60, 80, and 100 ppm. To each sample solution, 1.6 mL of ninhydrin reagent, 1.6 mL of sodium carbonate (Na_2CO_3) solution, and 1.6 mL of sodium hydroxide (NaOH) solution were added, followed by homogenization to allow the reaction to proceed completely.

The reaction mixture was then analyzed using a UV-Vis spectrophotometer at a wavelength of 588 nm, and the absorbance values were recorded. The absorbance measurements of the blank solution were used to construct the calibration curve. Based on the linear equation obtained from the cyanide calibration curve, the cyanide concentration in the samples was calculated to determine the final cyanide content (Nazua, 2025).

According to Rasyid *et al.* (2019), the cyanide content in the sample was calculated based on the concentration obtained from the absorbance measurement. The calculation was expressed using the following equation:

$$CN \text{ (mg/kg)} = \frac{a \times b \times Fp}{c}$$

Where:

CN =cyanide content (mg/kg)

a =sample concentration obtained from the spectrophotometric measurement

b =volume of the distillate (100 mL) converted into liters (L)

c =sample weight converted from grams (g) into kilograms (kg)

Fp =dilution factor

Analysis of antioxidant activity

The antioxidant activity of teo samples was determined using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method. The analysis was performed on fresh teo tuber (raw sample) and teo starch obtained from soaking treatments in 15% and 30% NaCl solutions. Each sample was weighed at 1 g and dissolved in distilled water to obtain a stock solution, which was subsequently diluted to concentrations of 25, 50, 75, and 100 ppm. The DPPH solution was prepared by dissolving 5 mg of DPPH in methanol to a final volume of 100 mL, while the positive control solution was prepared by dissolving 10 mg of ascorbic acid (vitamin C) in distilled water to a final volume of 100 mL. A volume of 2 mL of each sample

solution at the respective concentration was mixed with 2 mL of DPPH solution and incubated at room temperature under dark conditions for 30 min. The absorbance of the reaction mixture was subsequently measured using a UV-Vis spectrophotometer at a wavelength of 517 nm. Absorbance measurements were performed in triplicate.

The antioxidant activity obtained was then determined by calculating the percentage inhibition of DPPH free-radical scavenging activity. The percentage inhibition of DPPH radical scavenging was calculated using the following equation (Pujiastuti, 2021):

$$\% \text{ Inhibition} = \frac{\text{Abs. control} - \text{Abs. sample}}{\text{Abs. control}} \times 100\%$$

After the percentage of antioxidant activity had been determined, a calibration curve was constructed based on the relationship between sample concentration and the mean percentage inhibition. The resulting data were then analyzed using linear regression analysis. Based on the regression equation obtained, the IC_{50} value (x) was calculated by substituting a y value of 50 into the equation (Artanti, 2018).

The IC_{50} value (Inhibitory Concentration 50%) is a parameter used to indicate the concentration of a sample capable of inhibiting or scavenging 50% of free-radical activity. The IC_{50} value was determined through linear regression analysis between the concentration of the test solution as the independent variable (X-axis) and the percentage inhibition as the dependent variable (Y-axis). The resulting regression line was expressed in the form of $y = a + bx$. Subsequently, the IC_{50} value was calculated by substituting an inhibition value of 50% into the regression equation, using the following formula (Handayani *et al.*, 2020):

$$\text{IC}_{50} = \frac{50 - a}{b}$$

Where:

Y =percentage inhibition (%)

a =intercept value (the point at which the regression line intersects the y-axis) in the linear regression equation

b =slope of the regression line

x =concentration of the test sample (Handayani *et al.*, 2020)

The antioxidant activity of a sample can be classified into several categories based on its IC_{50} value range. The classification of antioxidant activity is presented in Table 2 (Fikri *et al.*, 2020).

Table 2. Classification of antioxidant activity.

No	IC_{50} Value	Antioxidant Activity Category
1	<50 ppm	Very Strong
2	50 – 100 ppm	Strong
3	100 – 150 ppm	Moderate
4	150 – 200 ppm	Weak

Data analysis

The cyanide content and antioxidant activity data were analyzed using quantitative descriptive and inferential statistical approaches. Inferential statistical analysis was performed using a one-way analysis of variance (One-Way ANOVA) at a significance level of 5% to determine differences among treatments. In addition, Pearson's correlation test was conducted to evaluate the relationship between cyanide content and antioxidant activity.

RESULTS AND DISCUSSION

Levels of cyanide (mg/kg)

The cyanide content of teo tuber (*Tacca leontopetaloides* (L.) Kuntze) in the Raw Sample (without soaking treatment) and after soaking in NaCl solutions is presented in Figure 2.

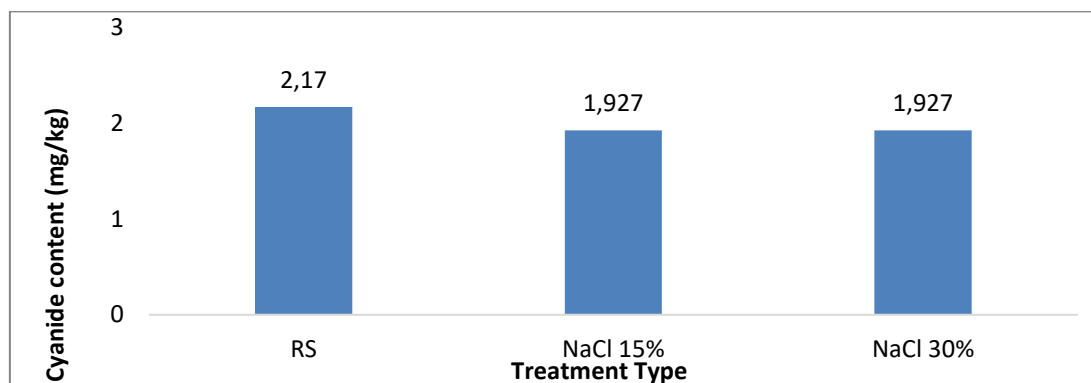


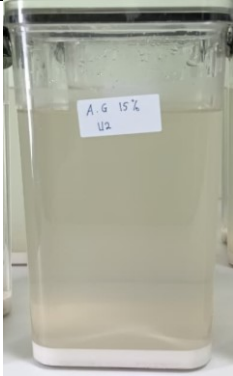
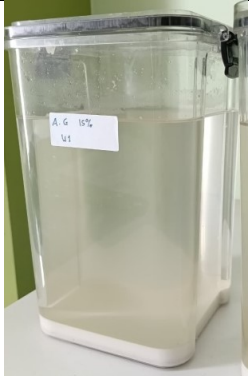
Figure 2. Bar chart of cyanide content in teo yam for RS, NaCl 15%, and NaCl 30% treatments.

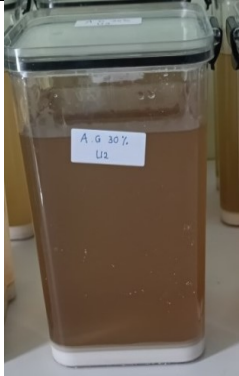
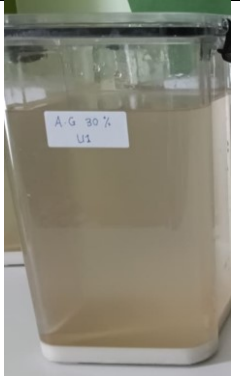
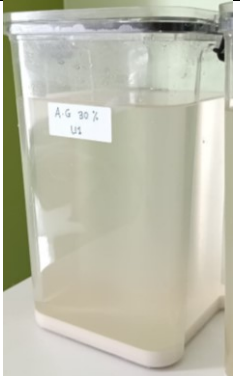
Note: RS (Raw Sample/no soaking treatment); NaCl 15% (soaking in a 15% w/v NaCl solution, prepared by dissolving 150 g of NaCl and adding water to a final volume of 1000 mL); NaCl 30% (soaking in a 30% w/v NaCl solution, prepared by dissolving 300 g of NaCl and adding water to a final volume of 1000 mL).

Furthermore, the effectiveness of soaking in NaCl solutions in reducing cyanide content was evaluated through the physicochemical characteristics of the soaking medium. These characteristics were assessed based on two main parameters, namely changes in the

clarity level of the NaCl solution and pH values measured periodically over a three-day soaking period. The observation data for both parameters at NaCl concentrations of 15% and 30% are presented in Table 3.

Table 3. Observation Results of the Clarity Level and pH Characteristics of NaCl Solutions

Observation Parameters	Day 1	Day 2	Day 3
Clarity of NaCl Solution	 AG 15% (Turbid)	 AG 15% (Slightly clear)	 AG 15% (Very clear)

Observation Parameters	Day 1	Day 2	Day 3
			
	AG 30% (Highly turbid)	AG 30% (Moderately turbid)	AG 30% (Clear)
Value pH	AG 15% : 7 AG 30% : 5	AG 15% : 8 AG 30% : 9	AG 15% : 8 AG 30% : 9

Note : NaCl 15% (soaking in a 15% w/v NaCl solution, prepared by dissolving 150 g of NaCl and adding water to a final volume of 1000 mL); NaCl 30% (soaking in a 30% w/v NaCl solution, prepared by dissolving 300 g of NaCl and adding water to a final volume of 1000 mL).

Antioxidant Activity

The antioxidant activity assay was conducted to measure the ability of teo tuber extract to scavenge free radicals in the raw sample and following soaking in NaCl solutions at concentrations of 15% and 30%. The evaluated

parameters included the inhibition percentage and IC₅₀ (Inhibitory Concentration 50%) values. The data obtained from the antioxidant activity assay are presented in Table 4.

Table 4. Inhibition percentage (%) and IC₅₀ values of the antioxidant activity of teo tuber in the RS, 15% NaCl solution, and 30% NaCl solution.

Treatment	Concentration (ppm)	Mean Absorbance (Abs)	% Inhibition	IC ₅₀ Value	Categories
R S	100	0.547	38.401	191,75	Weak
	75	0.557	37.275		
	50	0.646	27.252		
	25	0.732	17.568		
NaCl 15%	100	0.527	68.927	38,69	Very Strong
	75	0.560	66.981		
	50	0.773	54.422		
	25	1.008	40.566		
NaCl 30%	100	0.414	75.590	28,05	Very Strong
	75	0.453	73.290		
	50	0.670	60.495		
	25	0.884	47.877		

Note: RS = Raw Sample

The IC₅₀ values of the antioxidant activity are presented in Figure 3.

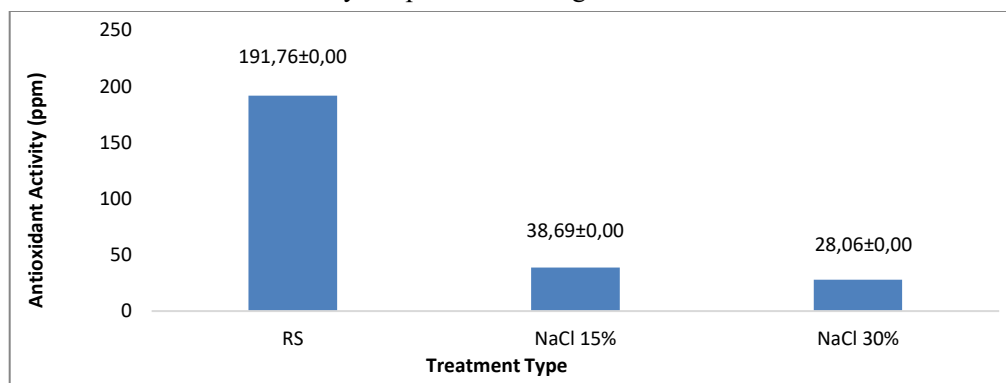


Figure 3. Bar chart of the IC₅₀ values of the antioxidant activity of teo tuber in the RS, 15% NaCl, and 30% NaCl treatments.

Note: IC₅₀ (Inhibitory Concentration 50%); RS (Raw Sample/without soaking); NaCl 15% (soaking in a 15% NaCl solution, w/v, prepared by dissolving 150 g of NaCl and adding water to a final volume of 1,000 mL); NaCl 30% (soaking in a 30% NaCl solution, w/v, prepared by dissolving 300 g of NaCl and adding water to a final volume of 1,000 mL).

Results of Pearson Correlation Analysis between Cyanide Content and Antioxidant Activity

The results of the correlation analysis between cyanide content and antioxidant activity of teo tuber in the Raw

Sample and following soaking in 15% and 30% NaCl solutions are presented in Table 5.

Table 5. Pearson correlation between cyanide content and antioxidant activity of teo tuber in the RS, 15% NaCl solution, and 30% NaCl solution.

Relationship between Parameters	Pearson Correlation Coefficient (r)	Value Sig (p)	Strength of Relationship	Conclusion
Total Cyanide Content ↔ Antioxidant Activity	0,998	0,001	Very strong (positive)	Significant

Note: r = Pearson correlation coefficient, indicating the strength and direction of the relationship; p = significance value. The relationship was considered significant when $p < 0.05$ at a 95% confidence level.

Discussion

Figure 2 shows a decreasing trend in cyanide content after the teo tuber was processed into starch through soaking in NaCl solutions. In the fresh teo tuber or raw sample, the cyanide content was 2,170 mg/kg. Following treatment with 15% and 30% NaCl solutions, the mean cyanide content reached 1,927 mg/kg. This value was lower than the cyanide content of the fresh teo tuber. The difference in values indicates that soaking tended to reduce cyanide content. However, the cyanide content following soaking in 15% and 30% NaCl solutions showed the same value, indicating that the increase in NaCl concentration did not yet demonstrate a noticeable difference in cyanide reduction.

Based on the mean cyanide content, a decreasing trend was observed following the soaking treatments. Nevertheless, the analysis of variance (ANOVA) did not produce an F-statistic or a significance value (Sig.) in SPSS, which were displayed as dots (.). This condition was attributed to the absence of data variation among replicates within each soaking treatment, as indicated by the standard deviation (SD) value of 0.000. Therefore, differences in cyanide content among treatments could not be statistically demonstrated, despite the descriptive difference in mean values.

The decreasing trend in cyanide content observed in this study is consistent with the findings reported by Usman (2019), who stated that soaking in NaCl solution plays a role in disrupting or decomposing cyanogenic glycosidic bonds, which are a source of hydrogen cyanide formation. Consequently, the hydrogen cyanide (HCN) produced can more readily dissolve into the soaking medium and be removed together with the water. During this process, diffusion and osmosis-based mass transfer mechanisms may facilitate the release of HCN compounds from the material. Therefore, increasing the soaking duration in NaCl solution tends to decrease the hydrogen cyanide content in the material. This finding is also consistent with Inayah *et al.* (2025), who reported that soaking cassava leaves in a 2% NaCl solution reduced hydrogen cyanide content by up to 53.3%. These findings indicate that NaCl solution has potential for reducing cyanide compounds through soaking, although

the NaCl concentrations used in the present study were higher, namely 15% and 30%.

Based on Table 3, qualitative visual observations indicated changes in the physicochemical characteristics of the NaCl solutions during the soaking period. The observed parameters included solution clarity and acidity (pH). Visually, both the 15% and 30% NaCl solutions showed a gradual increase in clarity from the first to the third day of soaking. The turbidity observed at the beginning of soaking gradually decreased as particles settled at the bottom of the container. At a concentration of 15%, the physical appearance of the solution changed from turbid on the first day to slightly clear on the second day and very clear on the third day. Meanwhile, at a concentration of 30%, the solution changed from very turbid on the first day to slightly turbid on the second day and clear on the third day.

In line with these physical changes, the pH of the NaCl solution also became increasingly alkaline during the soaking process. At a concentration of 15%, the pH increased from 7 (neutral) on the first day to pH 8 on the second and third days. Meanwhile, at a concentration of 30%, the pH increased from 5 on the first day to pH 9 on the second and third days.

Based on the descriptive observations, the soaking duration and NaCl solution concentration showed a tendency to affect the physicochemical characteristics of the solution, as indicated by the increasingly alkaline pH and the increase in clarity (decrease in turbidity) throughout the soaking process. The alkaline pH values observed from the first to the third day indicate changes in the soluble components transferred from the starch matrix into the soaking medium. This finding is consistent with the increasing clarity of the NaCl solution, indicating that soluble compounds were gradually dissolved and transferred throughout the soaking period. Overall, the changes in pH and the decrease in turbidity indicate that soaking facilitated the transfer of soluble compounds into the soaking medium. The changes in solution clarity and pH were assumed to be associated with the reduction in cyanide content.

These findings are consistent with Nasution (2019), who reported that soaking for three days reduced the cyanide content of cassava from 81.5 mg/kg to 36 mg/kg,

indicating that longer soaking periods resulted in greater reductions in cyanide content in the tuber. According to Kresnadipayana (2019), the reduction in cyanide content in food materials occurs because HCN is highly water-soluble and volatile (easily evaporated). Therefore, the longer the soaking period, the greater the amount of HCN released into the soaking medium or evaporated into the air. This process was indicated by the increasingly strong characteristic odor of HCN around the soaking area. In addition, Putri (2019) reported that during the soaking of rubber seeds, the initial soaking water appeared dark and turbid because HCN dissolved along with other components released from the tissue.

Siqhny (2020) stated that the soaking process causes hydrogen cyanide (HCN) to diffuse from the tuber tissue into the soaking medium, thereby reducing the HCN content in the material as it dissolves in the water. The water used as the soaking medium also contributes to the hydrolysis of cyanogenic glycosidic bonds, allowing HCN to be released from these bonds, dissolved, and transferred into the soaking medium. In addition to diffusion, this process is also accompanied by osmosis, which facilitates the transfer of various soluble compounds from the tuber tissue into the soaking medium.

The processing implication of this soaking process is a reduction in cyanide content in teo tuber. Cyanide compounds are known to be readily soluble in water, allowing diffusion to occur in the presence of a soaking medium. The replacement of the NaCl solution every 24 h was assumed to help maintain a concentration gradient between the material and the soaking medium, thereby allowing the transfer of cyanide compounds to proceed effectively.

Based on the overall descriptive observations, soaking in NaCl solution for three days, with solution replacement every 24 h, showed potential as a processing method for improving the safety of teo tuber before it was processed into starch. This was indicated by changes in the characteristics of the soaking medium and the decrease in the mean cyanide content. Based on the data presented in the bar chart, soaking in both 15% and 30% NaCl solutions resulted in a decrease in the mean cyanide content of fresh teo tuber (Raw Sample) from 2,170 mg/kg to 1,927 mg/kg. This finding indicates that increasing the NaCl solution concentration to 30% did not produce a descriptively significant difference in cyanide reduction compared with the 15% concentration. Therefore, a concentration of 15% was considered adequate for reducing the cyanide content of teo tuber to produce a food material that is safer for consumption.

According to Panghal *et al.* (2019), various cassava processing techniques have been demonstrated to be effective in reducing cyanide content, including peeling, washing, grating, fermentation, drying, and the application of certain chemical treatments. The application of these methods can significantly reduce

cyanide content to reach or even fall below the safe limit of 10 mg/kg established by the FAO/WHO.

Furthermore, the soaking process may also affect the presence of bioactive compounds that contribute to antioxidant activity. Therefore, an antioxidant activity assay was conducted to evaluate the ability of the applied processing method to maintain the functional properties of the resulting teo tuber starch.

The antioxidant activity of teo tuber in the Raw Sample and following soaking in NaCl solutions is presented in Table 4. Antioxidant activity was expressed as the percentage inhibition (%) at concentrations of 25, 50, 75, and 100 ppm. The inhibition percentage data for the Raw Sample indicated a free-radical inhibition capacity of 17.568% at 25 ppm, which increased to 38.401% at 100 ppm. Meanwhile, soaking in 15% NaCl solution resulted in inhibition percentages of 40.566%, 54.422%, 66.981%, and 68.927%, respectively, as the concentration increased. The 30% NaCl solution showed the highest inhibition capacity, with inhibition percentages reaching 47.877%, 60.495%, 73.290%, and 75.590%, respectively. The linear regression equations obtained from these inhibition percentage data were subsequently used to determine the IC_{50} values.

The conversion results indicate that the higher the inhibition percentage of a sample, the lower the resulting IC_{50} value, reflecting greater antioxidant potential. The IC_{50} values showed differences in the mean values, with the Raw Sample exhibiting the highest value of 191,76 $\mu\text{g/mL}$, which was classified as weak antioxidant activity. Soaking in 15% NaCl solution resulted in an IC_{50} value of 38,69 $\mu\text{g/mL}$, whereas soaking in 30% NaCl solution yielded the lowest value of 28,06 $\mu\text{g/mL}$. Both treatments were classified as having very strong antioxidant activity. Under the treatment conditions applied in this study, however, the 30% NaCl concentration resulted in stronger antioxidant activity than the 15% concentration. The decrease in the IC_{50} value from the Raw Sample to the soaked samples was associated with an increased ability of the samples to scavenge free radicals based on the DPPH method.

As shown in Figure 3, the IC_{50} value represents the sample concentration required to inhibit 50% of free-radical activity. Descriptively, differences were observed in the mean IC_{50} values among the RS, 15% NaCl solution, and 30% NaCl solution treatments. However, the analysis of variance showed that the SPSS program did not produce an F-statistic or a significance value (Sig.), which were displayed as dots (.). This condition was caused by identical values among all replicates within each soaking treatment, resulting in a standard deviation (SD) of zero. Consequently, the statistical analysis could not evaluate differences in antioxidant activity among treatments inferentially. Therefore, the observed differences in antioxidant activity can only be described descriptively based on the mean values.

Nevertheless, comparison of the mean values indicated a tendency for the 30% NaCl solution to produce very strong antioxidant activity compared with the 15% NaCl solution and the RS. This was indicated by the lower IC₅₀ value of $28,06 \pm 0.00$ µg/mL, suggesting that a relatively lower sample concentration was required to scavenge 50% of free radicals. Although the statistical analysis did not indicate a significant difference among groups, descriptively, soaking in NaCl solution was associated with a decrease in IC₅₀ values and a change in the antioxidant activity category from weak in the Raw Sample to very strong in the 15% and 30% NaCl treatments. This finding is supported by Wulansari (2018), who stated that antioxidants can be categorized as very strong when the IC₅₀ value is <50 ppm. Furthermore, Mutiara *et al.* (2016) emphasized that a lower IC₅₀ value indicates higher antioxidant activity in a sample.

During the soaking process, changes in the characteristics of the soaking medium occurred, as indicated by a decrease in the turbidity of the NaCl solution. Nevertheless, the antioxidant activity remained within the very strong category, indicating that the soaking process did not result in the loss of most of the bioactive compounds responsible for antioxidant activity. The maintenance of antioxidant activity indicates that some bioactive compounds were able to persist throughout the processing. Therefore, soaking in NaCl solution followed by drying at 85°C has the potential to be applied as a processing method for teo tuber to produce safer starch. This finding is consistent with Ozcan *et al.* (2019), who reported that drying can preserve antioxidant activity when the temperature and processing duration remain within conditions capable of maintaining the stability of bioactive components in food materials.

Furthermore, as presented in Table 5, the Pearson correlation analysis between cyanide content and antioxidant activity yielded a correlation coefficient of $r = 0.998$, indicating a positive and very strong relationship between the two variables. This positive direction indicates that changes in cyanide content tended to be accompanied by changes in antioxidant activity. This relationship was also observed descriptively in the Raw Sample, 15% NaCl solution treatment, and 30% NaCl solution treatment. A correlation coefficient approaching +1 indicates a very strong pattern of association between changes in the two variables.

The significance value of 0.001 ($p < 0.05$) indicates that the relationship between total cyanide content and antioxidant activity was statistically significant at the 95% confidence level. Thus, a significant linear relationship was observed between total cyanide content and antioxidant activity in the teo tuber samples. The Pearson correlation analysis showed that as cyanide content decreased following soaking in 15% and 30% NaCl solutions, the IC₅₀ value became stronger. This finding is consistent with Schober *et al.* (2018), who

stated that the Pearson correlation coefficient is used to describe the direction and strength of the linear relationship between two variables. A positive correlation indicates that the two variables change in the same direction, whereas a coefficient approaching +1 indicates an increasingly strong relationship. Akoglu (2018) also emphasized that the direction of a correlation is indicated by the sign of the r coefficient, whereas the strength of the relationship increases as the coefficient approaches ± 1 . Based on the results of this study, the r value of 0.998 indicates a positive and very strong relationship between total cyanide content and the IC₅₀ value of antioxidant activity in teo tuber starch.

CONCLUSIONS

Based on the research that's been done, it came to the conclusion that:

- Soaking teo tuber starch sediment in NaCl solution for three days resulted in a decrease in cyanide content compared with the Raw Sample. The cyanide content in the Raw Sample was 2,170 mg/kg, whereas after soaking in 15% and 30% NaCl solutions, the cyanide content was 1,927 mg/kg. Both soaking concentrations produced the same cyanide content.
- Teo tuber starch obtained after soaking in NaCl solution exhibited very strong antioxidant activity based on the IC₅₀ value. The 30% NaCl treatment produced an IC₅₀ value of $28,06 \pm 0.00$ µg/mL, which was lower than the other treatments.
- The Pearson correlation analysis showed a positive relationship between cyanide content and antioxidant activity, indicating that a decrease in cyanide content was associated with a stronger antioxidant activity, as reflected by the IC₅₀ value of $28,06 \pm 0.00$ µg/mL in the 30% NaCl treatment.

Conflict of interest: The authors declare that there is no conflict of interest.

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