Determination of Oxalates in Corms of Selected Taro (Colocasia esculenta) Varieties in Malaysia Using Ultra High-Performance Liquid Chromatography

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Authors’ contributions
This work was carried out in collaboration among all authors. Authors AMZ, MR, AAA, GMN and MNSA designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Author MBU funded the research while author GMN helps with the sample identification. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To determine the oxalate contents in different varieties of taro (Colocasia esculenta) collected in Peninsular Malaysia.
Study Design: Ultra High-Performance Liquid Chromatography (UHPLC) with UV detector (Diode Array Detection, (DAD)) was used to determine the total and soluble oxalate contents in different varieties of taro corms. Meanwhile, the insoluble oxalate content (calcium oxalate) was estimated from the subtraction of soluble oxalate content from total oxalate content.
Place and Duration of Study: Malaysian Agriculture Research and Development Institute (MARDI Headquarters), Persiaran MARDI-UPM, 43400 Serdang, Selangor, Malaysia between December 2018 to December 2019.

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Methodology: 9 different varieties of taro were collected from different locations in Peninsular Malaysia. All the samples were analysed for their oxalate contents. Extractions were carried out to determine the total oxalate and soluble oxalate contents. All the samples were analysed using UHPLC. The generated data of oxalate contents were analysed using Analysis of Variance (ANOVA).

Results: There is a significant difference ($P < .05$) between the oxalate content in the examined varieties with respect to the amount of total, soluble and insoluble oxalate contents. The putih variety has significantly the highest amount of total oxalate content with 218.8 ± 28.2 mg/100 g DW (dry weight) followed by the udang variety with 184.2 ± 24.7 mg/100 g DW and the wangi variety with 178.3 ± 5.1 mg/100 g DW. Tapak badak variety has the lowest total oxalate content with 70.5 ± 20.1 mg/100 g DW. Result showed that wangi variety has significantly the highest soluble oxalate content with 135.1 ± 4.8 mg/100 g DW followed by udang with 100.9 ± 49.8 mg/100 g DW. The lowest soluble oxalate content was found in tapak badak with 17.7 ± 2.9 mg/100 g DW.

Conclusion: Despite many factors contributing to the difference in oxalate content between varieties, this study would help researchers or policy makers to suggest potential taros for commercial cultivation.

Keywords: Corm; taro; Colocasia esculenta; oxalate; hyperoxaluria.

1. INTRODUCTION

*Colocasia esculenta* (L.) Schott is a tuberous crop belonging to the Araceae family commonly known as taro. It is cultivated in humid tropics areas and thrives wildly in Southeast Asia. Considered as a shade-tolerant terrestrial food crop, taro is well-adapted to humid environment and it flourishes under well-shaded conditions [1]. The Food and Agriculture Organization (FAO) (1999) reported that the production of taro is estimated to be 6.6 million tons per year which correspond to 1.07 million hectares worldwide with major taro producers are in Asian countries such as China, Thailand and Philippines [2]. In Vietnam, taro is grown as pure stands or intercropped with sweet potato, maize, cassava, legumes, sugar cane or vegetables [3].

Meanwhile, statistical data recorded by the Department of Agriculture Malaysia (DOA) had shown that the total taro production was estimated to be 356 hectares throughout the country with production up to 3268 metric ton in 2019 [4]. In addition, 43 varieties of taro were cultivated in the Malaysian Agriculture Research and Development Institute (MARDI) germplasm located in Serdang, Selangor for research and conservation purposes. Some varieties available in MARDI germplasm are minyak, putih, cina, hijau, tapak badak, udang, bentan, hitam and wangi [5]. In Malaysia, taro is an essential crop usually grown for their corms and leaf stalks, and sometimes it serves as an ornamental plant due to its beautiful foliage characters cordate or peltate (heart-shaped with stalk attachment inside the boundary of the leaf blade). Taro is cultivated for human consumption due to its starchy corms while the leaves and stems are used in local dishes and also for animal feed. A fresh taro corm consists of two-thirds of water and 13-29% carbohydrates [2]. Several studies on its nutritional contents have been made throughout the years [6,7]. Different varieties of fresh taro corms collected in Taiwan have a starch content ranging from 21.1-26.2% with 1.75-2.57% of which is crude protein and this amounts to the total energy of 97.1-118.3 kcal/100 g. The high content of soluble sugar in taro corms (0.67-1.02%) as compared to other tropical root crops such as cassava and potato suggests their usage as suitable staple food [6]. Previous studies on the mineral contents found in different parts of taro corms showed the presence of several minerals such as Mg, Zn, Cu which are essential in children’s diet as well as Zn and Cu in adults’ diet [7]. Diverse secondary metabolites consisting of carotenoids and flavonoids were found in the 167 varieties of taro [8]. From the study, 43 substances were phenolic compounds, six carotenoids and one indole. These substances contribute to the colour of taro corms. Accumulation of β-carotene in the corms gives the orange colour while richness of flavones in the corms brings yellowish colour to the corms.

Oxalic acid is a dicarboxylic acid commonly found in plants and vegetables. The chemical structure of oxalate consists of two atoms of carbon in its molecule [9]. This antinutrient compound is a minor component in a plant tissue. Antinutrient works as a substance that can hinder the important pathways in human
metabolism especially in digestion by reducing and interfering the availability of valuable minerals in the body [10]. Oxalate is a form oxalic acid salts consisting of water-soluble forms of potassium (K⁺), sodium (Na⁺) and ammonium (NH₄⁺) oxalates and insoluble forms of calcium oxalates [11]. Diet high in soluble oxalates may contribute to the excessive excretion of oxalate in the urine or hyperoxaluria, which may lead to the deposition of kidney stones [12]. This will further increase the risk of oxalosis or deposition of calcium oxalate crystals in renal or extra renal tissues [13]. Meanwhile, several studies have stated that the presence of insoluble oxalate (calcium oxalate) in taro contributes to the acridity or itchiness of its corms when in contact with skin [14]. Later in 1999, Paull et al., suggested that a 26 kDa protein, possibly a cysteine proteinase, is an active factor that contributes to the acridity of the taro [15]. However, it was not until 2015 when Yu et al. suggested that two active compounds, uracil and glycophosphatidylserine taro lectin which were purified in the corms had contributed to nerve stimulation activity on dorsal root ganglion (DRG) neurons in transgenic mice [16]. The presence of calcium oxalate crystals in plants as antiherbivore defence mechanism were also being discussed previously [17,18,19].

Studies on oxalate content in taro have been conducted in Nigeria [20], New Zealand [21], Japan [22], Vietnam [3] and Indonesia [23]. However, until now, no study has been carried out to investigate the oxalate content in various varieties in Malaysia. Thus, this study was conducted to evaluate the oxalate content in different taro varieties collected in Peninsular Malaysia towards providing information to local farmers on the selection of good quality taros for commercial cultivation.

2. MATERIALS AND METHODS

Taro genetic resources represent the essential base for genetic improvement of the crop were conserved as the preliminary basal materials for the breeding study. Collection mission and characterization followed Van Hintum et al. 2000 [24]. Collection trips were carried out throughout Peninsular Malaysia and in order to meet the adequate study materials, 100 varieties of taro and their wild relatives were collected and their passports data were based on morphological characters such as plant habit, leaf, flower and fruits. Morpho-agronomic characterisation and evaluation were based on Ivancic and Lebot 1999 with some modifications [25]. Nine (9) different varieties of taro (Colocasia esculenta L. Schott) identified as minyak, putih, cina, hijau, tapak badak, udang, bentan, hitam and wangi were collected throughout Peninsular Malaysia. The locality of all taro varieties and their morphological characters are shown in Table 1. Vouchers of specimens were deposited in the herbarium of MyGeneBank Complex, MARDI Serdang, Selangor for future reference. Table 2 shows some of the varieties used in this study.

2.1 Sample Processing and Preparation

Fresh taro corms were quickly cleaned from dirt and the skins were peeled off carefully. The corms were cut into cubes and were freeze-dried using a Labconco freeze-dry system (Model; Free Zone -105°C 4.5 Liter Cascade Benchtop, Kansas City, USA). The samples were ground into fine powder using microfine grinder (Model; Ika Werke MF 10 Basic, Germany).

2.2 Oxalate Determination

2.2.1 Total oxalate content

Each sample was extracted in triplicate using the method described previously with some modifications in terms of weight of the sample, volume of chemical used as well as the revolutions per minute (rpm) in the centrifuge machine [11]. A 0.5 g sample was added into a 50 ml volumetric flask with 20 ml of 2 M hydrochloric acid (HCl) (37% Analytical Grade, R&M Chemicals, Malaysia) and incubated at 80°C in water bath for 15 minutes. The extracts were cooled in room temperature and the flask was filled with 2 M HCl to make up for the remaining volume of 50 ml. The extracts were transferred to the centrifuge tube (50 ml). The extracts were centrifuged at 2889 rpm for 15 minutes. The supernatant was separated and filtered through a 0.45 mm cellulose nitrate membrane. The filtrate was subjected to the analysis using Ultra High-Performance Liquid Chromatography (UHPLC) for total oxalate content determination. The amount of oxalate content in the sample was expressed as mg in 100 g of dried weight sample (mg/100 g DW).

2.2.2 Soluble oxalate content

Soluble oxalate content in the sample was determined by extracting the sample with deionized water (Barnstead Smart2 Pure Water
Table 1. List of taro varieties collected and their morphological characters

| Taro varieties | Locality       | Collection date (month, year) | Leaf length (cm) | Leaf width (cm) | Height (cm) | Corm yield/ plant (g) | Corm colour | Leaf colour | Stalk colour       |
|----------------|----------------|------------------------------|------------------|-----------------|-------------|----------------------|-------------|-------------|-------------------|
| Minyak         | Jelebu         | January 2018                 | 30-65            | 25-70           | 100-165     | 680-980              | White       | Green       | Yellow to greenish |
| Putih          | Selangor       | January 2018                 | 25-55            | 28-60           | 100-140     | 820-1800             | White       | Green       | Green             |
| Cina           | Batu Pahat     | March 2018                   | 24.5-50          | 22-54           | 100-150     | 420-1620             | White       | Green       | Green             |
| Hijau          | Selangor       | January 2018                 | 18-26            | 20-47           | 50-100      | 550-1230             | White       | Green       | Green             |
| Tapak badak    | Selangor       | January 2018                 | 25-50            | 23-50           | 65-120      | 600-1550             | White to yellowish | Dark green | Dark green |
| Udang          | Balik Pulau    | April 2018                   | 30-55            | 22-60           | 100-160     | 300-1140             | White       | Pale green | Yellow to reddish |
| Bentan         | Kuala Selangor | January 2018                 | 35-60            | 30-75           | 95-145      | 700-1350             | White       | Green       | Green to reddish |
| Hitam          | Lenggong       | June 2018                    | 30-70            | 25-65           | 100-170     | 510-920              | White       | Green       | Green to purplish |
| Wangi          | Bestari Jaya   | January 2018                 | 25-65            | 35-60           | 100-165     | 900-2680             | White       | Green       | Green to dark purplish |
Purification System, Thermo Scientific, Malaysia) and incubated at 80°C in water bath for 15 minutes. This followed the same method for extraction of total oxalate content. The filtrate was subjected to the analysis using UHPLC for soluble oxalate content.

2.2.3 Insoluble oxalate content

Insoluble oxalate content (calcium oxalate) was calculated by the following difference:

\[
\text{Insoluble oxalate} = \text{total oxalate} - \text{soluble oxalate}
\]

Table 2. Examples of taro varieties used in this study

| Variety | Morphology | Corm |
|---------|------------|------|
| Minyak  | ![Minyak Morphology](image1.png) | ![Minyak Corm](image2.png) |
| Putih   | ![Putih Morphology](image3.png) | ![Putih Corm](image4.png) |
| Udang   | ![Udang Morphology](image5.png) | ![Udang Corm](image6.png) |
| Bentan  | ![Bentan Morphology](image7.png) | ![Bentan Corm](image8.png) |
2.3 Standard Calibration

Two standard calibration curves were prepared using oxalic acid (99.999% purified grade, Sigma Aldrich 658537) in six different concentrations 6.25, 12.5, 25, 50, 100 and 200 µg/ml. One set of standard solutions was prepared by dissolving oxalic acid in 2 M HCl for the analysis of total oxalate content. Another set of standard solutions was prepared by dissolving oxalic acid in deionized water for the analysis of soluble oxalate content. Blank samples were prepared by using 2 M HCl and deionized water to measure the desired signals.

2.4 UHPLC Method for Oxalate Analysis

A 5 µl of each filtered sample from HCl and water extracts was injected through UHPLC system (Agilent chromatography system 1200 Infinity Series) with DAD detector set at 210 nm. The chromatographic separation was carried out using a 300 × 7.8 mm Rezex ROA ion exclusion organic acid column (Phenomenex, Torrance, CA, USA) attached to a cation H+ guard column. The analytical column temperature was set at 50°C. The separation was carried out using an isocratic elution of 60% 0.005 N sulphuric acid (H₂SO₄) and 40% Acetonitrile (ACN) at a flow rate of 0.5 mL/min for 20 minutes.

2.5 Statistical Analysis

The mean oxalate contents in various varieties of taro were analysed using ANOVA and the mean differences were analysed using Fisher LSD method. All the statistical analyses were carried out using MINITAB software (version 17). At the significance level α = 0.05 the hypothesis of various taro varieties having the same oxalate content is rejected and there is a significant difference in oxalate contents.

3. RESULTS AND DISCUSSION

The prepared at six different concentrations (6.25-200 µg/ml) calibration curves of oxalic acid show a linear relationship ($r^2 = 0.999$) for both HCl and deionized water solutions (Fig. 1).

Retention time for oxalic acid in HCl (total oxalate content) was observed at 9.997-10.058 min whereas retention time for oxalic acid in water (soluble oxalate content) was observed at 9.686-9.702 min (Fig. 2). The value of insoluble oxalate content was obtained by the subtraction of soluble oxalate content from total oxalate content.

The mean of three individual oxalate contents (total, soluble and insoluble) in all 9 varieties of taro are shown in Table 3. Results from ANOVA indicate that there is a significance difference between the amount of total, soluble and insoluble oxalate contents in all 9 varieties identified in this study. The mean comparison method was carried out using Fisher LSD method to determine which varieties are different among others.
3.1 Total Oxalate Content

Quantification of total oxalate content using UHPLC revealed that putih variety has the highest amount of total oxalate content with 218.8 ± 28.2 mg/100 g DW. Oxalate content in putih is not significantly different from udang and wangi varieties (184.2 ± 24.7 and 178.3 ± 5.1 mg/100 g DW respectively). Meanwhile, oxalate contents in the rest of the examined varieties, namely tapak badak, hijau, cina and minyak, were significantly lower than the total oxalate content (< 120 mg/100g DW) as compared to other varieties in this study.

3.2 Soluble Oxalate Content

Extraction of samples with deionized water showed that wangi variety has the highest amount of soluble oxalate content with 135.1 ± 4.8 mg/100 g DW, which is significantly different from other varieties. Meanwhile, udang, hitam and bentan varieties are not significantly different to each other with 100.9 ± 49.8 mg/100 g, 97.0 ± 5.3 mg/100 g and 93.1 ± 1.7 mg/100 g DW respectively. Excessive amount of soluble oxalate in the urine (≥ 0.5 mmol/day) will cause hyperoxaluria [26]. Supersaturated soluble oxalates will crystallise in the form of insoluble oxalates (calcium oxalate) that will deposit in human tissues such as in the kidney. These crystals or normally known as kidney stones are detrimental and may lead to complications in human body.

3.3 Insoluble Oxalate Content

Insoluble oxalate value was obtained from the subtraction of soluble oxalate content from total oxalate content [11,12,22]. The insoluble oxalate (predominantly calcium oxalate) digestion in

### Table 3. Mean values (± SE) for oxalate content (mg/100 g DW) in corms of 9 different taro varieties

| Variety   | Total Oxalate** (mg/100g) DW (A) | Soluble Oxalate** (mg/100g) DW (B) | Insoluble oxalate** (mg/100g) DW (C = A – B) |
|-----------|---------------------------------|-----------------------------------|-----------------------------------------------|
| Minyak    | 91.3 ± 59.7 d, e                | 25.7 ± 0.8 e, f                   | 65.6 ± 59.0 d                                 |
| Putih     | 218.8 ± 28.2 a                  | 33.5 ± 4.8 e, f                   | 185.3 ± 30.4 a                                |
| Cina      | 119.0 ± 42.8 c, d,e             | 66.5 ± 3.0 c, d                   | 52.4 ± 39.9 a                                 |
| Hijau     | 76.6 ± 6.1 d, e                 | 53.7 ± 6.7 d, e                   | 22.9 ± 9.5 b                                  |
| Tapak badak | 70.5 ± 20.1 e                   | 17.7 ± 2.9 f                      | 55.1 ± 20.1 b                                 |
| Udang     | 184.2 ± 24.7 a, b               | 100.9 ± 49.8 b                    | 83.3 ± 63.4 b                                 |
| Bentan    | 143.5 ± 16.8 b, c               | 93.1 ± 1.7 b, c                   | 50.4 ± 15.3 b                                 |
| Hitam     | 124.2 ± 26.1 c, d               | 97.0 ± 5.3 b                      | 27.3 ± 30.3 b                                 |
| Wangi     | 178.3 ± 5.1 a, b                | 135.1 ± 4.8 a                     | 43.2 ± 9.5 b                                  |

** Statistically significance at α =.05; Based on fisher LSD method and 95% confidence, means that do not share a letter are significantly different

![Fig. 1. Correlation curve of standard (oxalic acid) in six concentration (6.25-200 ug/ml); a) in 2M HCl ($r^2$=0.999), b) in deionized water ($r^2$=0.999)](image-url)
Fig. 2. UHPLC Chromatogram of extract from taro samples. a) Extraction of sample in 2 M HCl, peak of oxalic acid was observed at retention time 9.997-10.058 min, b) Extraction of sample in deionized water, peak of oxalic acid was observed at retention time 9.686-9.702 min

human body will be excreted in the faeces [27]. Putih variety has the highest amount of insoluble oxalate content with 185.3 ± 30.4 mg/100 g DW and it is significantly different from other varieties. Meanwhile, all the remaining 8 varieties are not significantly different to each other, with hijau and hitam having the lowest amount of insoluble oxalate contents with values of < 30 mg/100 g DW.

These findings suggest a major role of genetic difference between varieties in oxalate content. A study on fifteen different varieties of star fruit had shown a difference in oxalate content in each of the varieties with a 10-fold difference [28]. Meanwhile, recent findings from Olatoye and Arueya in 2019 also found fifteen varieties of air potato (Dioscorea bulbifera) with different oxalate contents [29]. Several studies have been carried out to investigate the oxalate content in different parts of taro such as corms, petioles and leaves [12,22,30]. Total oxalate contents in corms ranged from 73.2-171.4 mg/100 g fresh weight (FW) [22] and 294-694 mg/100 g dry mass (DM) [30]. Apart from that, different analytical methods and growing locations had also indicated differences in oxalate content [31]. Collection of taros in different parts of central Vietnam has
shown a significant difference in the amount of oxalate content [3,12]. Meanwhile, a study on different field cultivations of taro in Taiwan had shown that upland-cultivated taro corms contained higher amounts of soluble oxalate and insoluble oxalate (calcium oxalate) than paddy taro [6]. These previous findings have suggested that several factors contribute to the difference in oxalate content within a species. However, information on the antinutritional compound such as oxalate will help farmers and researchers to have desirable understanding on the nutritional contents in taro.

4. CONCLUSION

Nine varieties of taro collected throughout Peninsular Malaysia were tested for their oxalate contents. Putih variety has the highest amount of total oxalate content with 218.8 ± 28.2 mg/100 g DW. This variety also has the highest amount of insoluble oxalate content with 185.3 ± 30.4 mg/100 g DW. Meanwhile, wangi has the highest soluble oxalate content with 135.1 ± 4.8 mg/100 g DW. However, tapak badak, putih and minyak varieties have the least amount of soluble oxalate content. Hence, these three varieties are preferred for further exploration due to their lowest amount of soluble oxalate content. The information on oxalate contents in varieties of taro in Malaysia would help farmers and researchers to select high quality taros to be elevated and commercialized locally.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Reddy PP. Taro, Colocasia esculenta. Plant protection in tropical root and tuber crops. Springer India, India; 2015.
2. Food and Agriculture Organization. Taro cultivation in Asia and the Pacific; 1999. (Accessed 3 March 2020) Available: http://www.fao.org/3/ac450e/ac450e00.htm
3. Hang DT, Binh LV, Preston TR, Savage GP. Oxalate content of different Taro cultivars grown in Central Viet Nam and the effect of simple processing methods on the oxalate concentration of the Processed Forages. Livestock Res. Rural. Dev. 2011; 23(6):122.
4. Department of Agriculture Malaysia (DOA), Ministry of Agriculture and Agro Based Industry Malaysia. Statistik Tanaman (Subsektor Tanaman Makanan); 2019. (Accessed 15 March 2020) Available: http://www.doa.gov.my/index/resourcess/aktiviti_sumber/sumber_awam/maklumat_pertanian/perangkaan_tanaman/booklet_statistik_tanaman_2019.pdf
5. Mohd Norfaizal G, Mohd Shukri MA, Emy Sabrina MN, Mohd Zulkhairi A, A Latiff, Noor Zainah A, Salmaniza S, Masrom H. Colocasia, Xanthosoma and Conservation of Malaysia’s edible aroid genetic resources. UTAR Agri Sc J. 2016;2(3):16-21.
6. Huang CC, Chen WC, Wang CCR. Comparison of Taiwan Paddy and Upland-Cultivated Taro (Colocasia esculenta L.) Cultivars for Nutritive Values. Food Chem. 2007;102(1):250–56.
7. Mergedus A, Kristl J, Ivancic A, Sober A, Sustar V, Krizan T, Lebot V. Variation of mineral composition in different parts of taro (Colocasia esculenta) corms. Food Chem. 2015;170:37-46.
8. Munoz-Cuervo I, Malapa R, Mihaleta S, Lebot V, Legendre L. Secondary metabolites diversity in taro, Colocasia esculenta (L.) Schott, corms. J. Food Compos. Anal. 2016;52:24-32.
9. Gontzea I, Sutzescu P. Natural antinutritive substances in foodstuffs and Forages. S. Karger AG, Basel: New York; Academic Press Inc., Berkeley Sq., London, W.1.;1968.
10. Dini C, Maria CD, Maria AG, Sonia ZV. Nutritional profile and anti-nutrient analyses of Pachyrhizus ahipa roots from different accessions. Food Res. Int. 2013;54(1):255–61.
11. Savage GP, Vanhanen L, Mason SM, Ross AB. Effect of cooking on the soluble and insoluble oxalate content of some New Zealand foods. J. Food Compos. Anal. 2000;13(3):201–6.
12. Hang DT, Leo V, Savage G. Effect of simple processing methods on oxalate content of Taro Petioles and leaves grown...
in Central Viet Nam. LWT - Food Sci. Technol. 2013;50(1):259–63.
13. Hodgkinson A. Oxalic Acid in Biology and Medicine. Academic Press Inc (London) LTD. London; 1977.
14. Bradbury JH, Nixon RW. The acridity of raphides from the edible aroids. J. Sci. Food Agric.1998;76:608-616.
15. Paull RE, Tang CS, Gross K, Uruu G. The nature of the taro acridity factor. Postharvest Biol. Tec.1999;16:71-78.
16. Yu JG, Liu P, Duan JA, Tang ZX, Yang Y. Itches—stimulating compounds from Colocasia esculenta (taro): Bioactive-guided screening and LC–MS/MS identification. Bioorg. Med. Chem. Lett. 2015;25(20):4382–86.
17. Finley DS. Patterns of Calcium Oxalate Crystals in Young Tropical Leaves: A Possible Role as an Anti-Herbivory Defense. Rev. Biol. Trop.1999;47(1–2):27–31.
18. Tillman-Sutela E, Kauppi A. Calcium oxalate crystals in the mature seeds of Norway spruce, Picea abies (L.) Karst. Trees.1999;13(3):161-37.
19. Villard C, Romain L, Ryosuke M, Alain H. Defence mechanisms of ficus: Pyramiding strategies to cope with pests and pathogens. Planta. 2019;249(3):617–33.
20. Iwohua CI, Kalu FA. Calcium oxalate and physicochemical properties of cocoyam (Colocasia esculenta and Xanthosoma sagittifolium) tuber flours as affected by processing. Food Chem.1995;54(1):61–66.
21. Oscarsson KV, Savage GP. Composition and availability of soluble and insoluble oxalates in raw and cooked Taro (Colocasia esculenta Var. Schott) leaves. Food Chem. 2007;101:559–62.
22. Catherwood DJ, Savage GP, Mason SM, Scheffer JJC, Douglas JA. Oxalate content of cormels of Japanese taro (Colocasia esculenta (L.) Schott) and the effect of cooking. J. Food Compos. Anal. 2007;20:147–51.
23. Kumoro AC, Rr. Dewi AP, Catarina SB,Diah SR. Kinetics of calcium oxalate reduction in Taro (Colocasia esculenta) corm chips during treatments using baking soda solution. Procedia Chem. 2014;9:102–12.
24. Van Hintum, Th. JL, Brown AHD, Spillane C, Hodgkin T. Core collections of plant genetic resources. International Plant Genetic Resources Inst., (IPGRI), Rome (Italy); 2000.
25. Ivancic, A, Lebot, V. Botany and genetics of New Caledonian wild taro, Colocasia esculenta. Pacific Science (University of Hawaii).1999;53(3):273-285.
26. Siener R, Ebert D, Nicolay C, Hesse A. Dietary risk factors for hyperoxaluria in calcium oxalate stone farmers. Kidney Int.2003;63:1037-1043.
27. Holmes RP, Goodman HO, Assimos DG. Dietary oxalate and its intestinal absorption. Scanning Microsc.1995;9(4):1109-1120.
28. Wilson III CW, Shaw PE, Knight Jr RJ. Analysis of oxalic acid in carambola (Averrhoa carambola L.) and spinach by High-Performance Liquid Chromatography. J. Agric. Food Chem.1982;30(6):1106-1108.
29. Olatoye KK, Arueya GL. Nutrient and phytochemical composition of flour made from selected cultivars of Aerial Yam (Dioscorea bulbifera) in Nigeria. J. Food Compos. Anal. 2019;7:23–27.
30. Savage GP, Mårtensson L. Comparison of the estimates of the oxalate content of taro leaves and corms and a selection of Indian vegetables following hot water, hot acid and in vitro extraction methods. J. Food Compos. Anal. 2010;23(1):113–17.
31. Judprasong K, Charoenkitkul S, Sungpuag P, Vasanachitt K, Nakjamanong Y. Total and soluble oxalate contents in Thai vegetables, cereal grains and legume seeds and their changes after cooking. J. Food Compos. Anal. 2006;19(4):340–47.

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