INTRODUCTION

Dioscorea alata L. commonly recognized as greater yam or water yam, is an important plant species that has desirable agronomic properties for sustainable production in dryland and provides essential nutrition sources for alternative food that support food security (Washaya, Mupangwa, & Muranda, 2016). It is considered as the third most important tropical root and tuberous crop after cassava and sweet potato but is second to cassava as the most important tropical root crop (Mau, Ndiwa, Arsa, & Oematan, 2013; Srivastava, Gaiser, Paeth, & Ewert, 2012; Yani, Khumaida, Ardie, & Syukur, 2018). A nutrition standpoint of water yam tuber is the higher vitamin C content than sweet potato (Chandrasekara & Josheph Kumar, 2016) and the higher proteins content than cassava, with a range of water yam protein content (0.2-1.8%) on a dry weight basis (Faustina Dufie, Oduro, Ellis, Asiedu, & Maziya-Dixon, 2013; Ferraro, Piccirillo, Tomlins, & Pintado, 2016). The tuber of water yam contains essential nutrition sources such as carbohydrates, protein, fat, vitamins and other essential nutrient sources (Ogidi, Wariboko, & Alamene, 2017; Oko & Famurewa, 2014). Therefore, water yam can be a reliable staple food and an alternative to the food source. In addition, water yam also has a wide range of miscellaneous uses, such as for cosmetics and medicinal purposes, that can be developed in industrial sectors (Chandrasekara & Josheph Kumar, 2016; Wang, Lii, Huang, Chang, & Yang, 2011).

Despite the various nutrition advantages possessed by water yam, in fact, in Indonesia, it was considered as an unpopular crop for consumption and less economic importance.
(Fauziah & Mas‘udah, 2015; Trimanto & Hapsari, 2015). It has long been cultivated by rural communities extensively and rarely on a large commercial scale. Further, the production area and statistics for water yam in Indonesia are not yet available (Hapsari, 2014). However, Central Java, East Java, South Kalimantan, Southeast Sulawesi, and Maluku were considered as the water yam producing area (Direktorat Kacang-kacangan dan Umbi-umbian, 2002). Some varieties of water yam found in Indonesia are Uwi Beras, Uwi Beras Legi, Uwi Butun, Uwi Bangkult, Uwi Ungu, Uwi Kuning, Uwi Luyung, Uwi Ullo, Uwi Jingking, Uwi Banggai, Uwi Hitam, and Uwi Jingga (Purnomo, Daryono, Rugayah, & Sumardi, 2012). In Indonesia, water yam is often consumed in the forms of (i) simply cooked as boiled, steamed and fried tubers; (ii) cooked in various culinary such as kolak (slices of uwi were mixed into boiled mung beans, coconut milk, palm sugar, and salt), gumpal (rounded sweet fried food from grated water yam that was mixed with grated coconut and palm sugar) and other culinary; (iii) food processing products, such as chips, flour to make various foods such as breads and noodles (Bargumono & Wongsowijaya, 2013).

Water yam has not been consumed as much as cassava and sweet potato, and the knowledge on the biochemical characteristics of local water yam in Indonesia is limited, especially in East Java. The previous studies of water yam in Indonesia preferred to focus on the nutrition content of flour products (Indrastuti, Harijono, & Susilo, 2012; Winarti & Saputro, 2013). However, the information on the nutrition content of fresh tubers of water yam is still very minimal. Furthermore, little is known about the nutritional value and the methods on how to diversify the consumption of water yam in Indonesia (Fauziah & Mas‘udah, 2015). In addition to its high nutritional values, the water yam also has comparative advantages for sustainable production due to its agronomic characteristics such as easy propagation, drought-tolerant and high yields (Padhan & Panda, 2020; Takada, Kikuno, Babil, Irie, & Shiwachi, 2017).

Water yam is also expected to contribute to the food diversification and diet diversity that has been internationally recognized and recommended as a key component of healthy diets as a food-based approach to meet nutrition, mineral and micronutrients requirements (Blasbalg, Wispelwey, & Deckelbaum, 2011; Dwivedi et al., 2017). Furthermore, food diversification and diet diversity are considered to be effective and more sustainable to alleviate micronutrient malnutrition compared to food fortification and supplementation (Blasbalg, Wispelwey, & Deckelbaum, 2011; Obayelu & Osho, 2020). Moreover, the programs of food diversification have become a national program of the Indonesian government to solve malnutrition or stunting growth and for food security (Kementerian PPN/ Bappenas, 2019). However, current food diversification programs are still limited to utilize the commercial food crops, and still rarely utilize minor tubers, such as water yam.

Purwodadi Botanic Garden (PBG) located in Pasuruan (East Java, Indonesia) has a large number of germplasm collections of minor tubers, including water yam. The collection number of local accessions of water yam in PBG is not less than 50 accessions. It was collected from several regions in Indonesia, particularly from East Java (Lestarini et al., 2012). Furthermore, it shows high morphological variations of the tuber, especially in the shape, size, skin and flesh color also texture (Mas‘udah, Fauziah, & Hapsari, 2019). All those accessions are valuable materials for research and development to support the food diversification program in Indonesia.

The aim of this study was to assess and analyze the biochemical composition and nutritional value of fifteen selected local accessions of water yam fresh tuber from East Java collection of PBG, and followed by the selection of promising accession. The biochemical composition and nutritional value examined comprise both nutrition and anti-nutrition contents for a comprehensive study. This study is expected to provide basic information on water yam nutrition values for public references and dissemination, also obtained promising accessions of water yam based on nutrition values for further breeding and development programs.

**MATERIALS AND METHODS**

**Samples Collection and Preparation**

Plant materials used in this study were fifteen local accessions of water yam collection of Purwodadi Botanic Garden. The accessions were collected from several regions in East Java, i.e. Pasuruan, Malang and Nganjuk. All accessions examined were planted during the rainy season in November 2017 and harvested in July-August 2018, with a crop cycle was approximately 9 to 10 months. The fresh tuber of each accession was characterized by a minimal descriptor for yam and documented (Table 1, Fig. 1).
Prior to analysis, the tubers were washed and peeled off, and then cut into slices. Slices were sampled equally from the distal, middle, and proximal parts of the tubers. The slices were then dried in an oven at 80°C for 24 hours and mashed up into flour in Willey mill 60 mesh sizes then stored in an airtight container for analysis. The flour was subjected to biochemical composition analysis, four replications per accession. The analysis was conducted in PT Saraswanti Indo Genetech, Surabaya, East Java.

Table 1. Local accessions of water yam used in this study and the tuber characteristics

| No. acc. | Local Name      | Collection locality                 | Tuber Weight (kg) | Colour of flesh                  |
|----------|-----------------|-------------------------------------|-------------------|----------------------------------|
| 28       | Uwi Perti/28    | Gajahrejo, Purwodadi, Pasuruan     | 1.0 – 4.3         | Off white                       |
| 29       | Uwi Ulo/29      | Watuagung, Prigen, Pasuruan        | 1.6 – 3.9         | Off white                       |
| 30       | Uwi Perti/30    | Watuagung, Prigen, Pasuruan        | 2.9 – 5.4         | Outer Purple, inner off white   |
| 31       | Uwi Bangkulit/31| Jatisari, Purwodadi, Pasuruan      | 1.9 – 3.5         | Outer Purple, inner off white   |
| 32       | Uwi Kelopo/32   | Oro-or Ombo Wetan, Rembang, Pasuruan| 1.1 – 2.6         | Outer Purple, inner off white   |
| 36       | Uwi Bangkulit/36| Gajahrejo, Purwodadi, Pasuruan     | 3.7 – 3.8         | Outer Purple, inner off white   |
| 42       | Uwi Bangkulit/42| Lengkong Lor, Ngliyu, Nganjuk      | 2.6 – 3.7         | Outer Purple, inner off white   |
| 43       | Uwi Bangkulit/43| Tritik, Rejoso, Nganjuk            | 3.7 – 7.1         | Outer Purple, inner off white   |
| 57       | Uwi Ketan Putih/57| Wonosari, Wonosari, Malang       | 1.8 – 3.1         | Off white                       |
| 58       | Uwi Biru/58     | Sumber Tempur, Wonosari, Malang    | 2.8 – 4.5         | Purple with white               |
| 63       | Uwi Budeng/63   | Slamparejo, Jabung, Malang         | 1.2 – 4.8         | Outer Purple, inner off white   |
| 64       | Uwi Ulo/64      | Slamparejo, Jabung, Malang         | 1.8 – 3.9         | Outer Purple, inner off white   |
| 66       | Uwi Legi/66     | Sumbersuko, Wagir, Malang          | 0.9 – 3.6         | Outer Purple, inner off white   |
| 82       | Uwi Jaran/82    | Sudan, Wonosari, Wonorejo          | 1.8 – 4.1         | Off white                       |
| 86       | Uwi Cemeng/86   | Sumberejo, Purwosari, Malang       | 2.2 – 3.9         | Outer Purple, inner off white   |

Fig. 1. Tuber morphological variations of fifteen local accessions of water yam: A. Uwi Perti/28, B. Uwi Ulo/29, C. Uwi Perti/30, D. Uwi Bangkulit/31, E. Uwi Kelopo/32, F. Uwi Bangkulit/36, G. Uwi Bangkulit/42, H. Uwi Bangkulit/43, I. Uwi Ketan Putih/57, J. Uwi Biru/58, K. Uwi Budeng/63, L. Uwi Ulo/64, M. Uwi Legi/66, N. Uwi Jaran/82, and O. Uwi Cemeng/86
Proximate Composition Analysis

Proximate composition analysis was conducted using SNI (Indonesian National Standards) for food and beverages testing, SNI 01-2891-1992 refers to AOAC (2012). Moisture and ash content was determined by the oven method calculated based on dry matter of the tuber as per the standard procedure. Protein content was estimated on the basis of nitrogen content and dry matter of the tuber using the Kjeldhals distillation method. Protein content was estimated by ‘N’ percent x 6.25, considering that protein contains other grains. Fat content was determined by the Weibul method. Hydrolysis of the sample with HCl passing the digest through filter paper, drying the filter paper, extracting the filter paper in the soxhlet-type extractor, evaporating the solvent and obtaining a subsequent gravimetric determination. The value was expressed in percentage. Carbohydrate (total carbohydrate) content calculated by the different content of fat, protein, ash and moisture. The other constituents were determined individually, summed and subtracted from the total weight. The calculation used the following formula: 100 – (weight in grams [protein + fat + water + ash] in 100 g of food (tubers). Fiber (total crude fiber) was calculated as the weight of the filtered and dried residue subtracted by the weight of the protein and ash.

Mineral Analysis

The content of minerals analyzed comprised Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Phosphor (P), Iron (Fe) and Zinc (Zn). They were examined using strong acids and the atomic absorption spectrophotometer with appropriate hollow cathode lamps (AOAC, 2012) by inductively coupled plasma-optical emission spectrometers.

Anti Nutrition Content

Anti-nutrition content analyzed comprised tannin and oxalic acid. Tannin content was determined by Folin Denis Reagent using UV Spectrophotometry (Pratik, Prakash, & Chandrashekhar, 2016). The number of total phenols was calculated as tannic acid equivalent from the standard curve. Oxalic acid content was analyzed using a high performance liquid chromatography (HPLC) (Du Thanh et al., 2017).

Statistical Analysis

All of the nutrition data with four replications were tabulated and the average and standard deviation were calculated. Further, the data were subjected to analysis of variance (ANOVA) using SPSS 16 to analyze the variance among accessions. Tukey post hoc statistical significance test was also performed (P<0.05). In addition, multivariate hierarchical clustering analysis (HCA) and multivariate ordination of principal components analysis (PCA) also similarity indices subjected to biochemical characteristics (proximates, minerals, anti-nutrition) were conducted by statistical software Paleontological Statistics (PAST) version 3.15. HCA and similarity indices were performed using the Un-weighted Pair Group Method of Arithmetic mean (UPGMA) and Bray-Curtis similarity index. PCA was performed using a variance-covariance matrix and scatter biplot (Hammer, Harper, & Ryan, 2001).

RESULTS AND DISCUSSION

As reported by previous studies, the appearances of fifteen local accessions of water yam tuber examined exhibited high morphological variation (Fauziah & Mas’udah, 2015; Mas’udah, Fauziah, & Hapsari, 2019; Trimanto & Hapsari, 2015). The tuber shape varied from rounded, oval, cylindrical, to irregular; with smooth or coarse peel texture; with fibrous roots or none; etc. The tuber size and weight were various from the small, medium, to large. Variation of the flesh color was from off white, white, purplish to purple (Table 1, Fig. 1). Furthermore, morphology and tuber yield-related traits depend on the genotypes and the influence of the environment on the heritability of the traits (Darkwa, Olasanmi, Asiedu, & Asfaw, 2019). In addition, the tuber flesh color is contributed by its biochemical contents such as proximates, dietary fiber, minerals, vitamins, and bioactive compounds including phenolic acids and anthocyanins (Chandrasekara & Joseph Kumar, 2016). Therefore, this present study was performed to reveal the biochemical composition and nutritional value of fifteen local accessions of water yam which is important to support the improvement and development of water yam as food source for healthy diets and other useful products.

Biochemical composition and nutritional value

The biochemical composition and nutritional value of fifteen local accessions of water yam tuber examined in this study were presented in Table 2. The result showed that there was variation in the biochemical composition and nutritional value among local accessions. The proximate composition...
values including moisture, carbohydrate, and fiber were significantly different (P<0.05), except in protein, fat and ash (P>0.05).

The moisture content of the fifteen local accessions of water yam was considered moderate to high, ranging from 65.47% to 82.46% (average 72.94% ± 4.29%) (Table 2). It was in accordance with some previous studies. Baah, Maziya-Dixon, Asiedu, Oduro, & Ellis (2009) reported that moisture content of water yam accessions in Nigeria ranged between 66.20% to 77.70%. It was also similar to the wild yam species (D. bulbifera) from Nepal (69.50%) (Bhandari, Kasai, & Kawabata, 2003). Furthermore, the moisture content is an important factor which influenced the food quality, preservation, and the endurance to deterioration (Oko & Famurewa, 2014). In the present study, accessions with high moisture content include Uwi Perti/28, Uwi Ketan Putih/57, and Uwi Cemeng/86; whilst accessions with low moisture content include Uwi Bangkulit/36, Uwi Biru/58, and Uwi Perti/30 (Table 2). Accessions with low moisture content are more suitable for long term storage; also more efficient for industrial processing due to higher dry matters (Polycarp, Afoakwa, Budu, & Otto, 2012). Carbohydrates are the body’s main source of energy, they help fuel the brain, kidneys, heart, muscles, and central nervous system. A carbohydrate-deficient diet may cause ketosis (Awuchi, Igwe, & Amagwula, 2020). Water yams could be an alternative food source reliable to supply carbohydrate as it contains a relatively high carbohydrate that could meet the carbohydrate requirement.

The carbohydrate content of fifteen local accessions of water yam was various, ranged from 17.10% to 29.37% (average 23.62% ± 3.95%). Uwi Ketan Putih/57 had the lowest carbohydrate content, followed by Uwi Legi/66 and Uwi Perti/28. Meanwhile, Uwi Bangkulit/36 had the highest carbohydrate content followed by Uwi Biru/58 and Uwi Perti/30 (Table 2). On average, the local accessions of water yam in the present study had higher carbohydrate content than other tuber crops reported by Haytowitz et al. (2019), such as potato (12.44%) and sweet potato (20.10%). However, it is slightly lower than the cassava (38.110%) (Bender, 2014). The high carbohydrate and energy values of the water yams make them reliable for food security crops (Polycarp, Afoakwa, Budu, & Otto, 2012). Carbohydrates are the body’s main source of energy, they help fuel the brain, kidneys, heart, muscles, and central nervous system. A carbohydrate-deficient diet may cause ketosis (Awuchi, Igwe, & Amagwula, 2020). Water yams could be an alternative food source reliable to supply carbohydrate as it contains a relatively high carbohydrate that could meet the carbohydrate requirement.

### Table 2. Nutrition composition and value of fifteen local accessions of water yam tuber

| No. acc. | Local Name | Moisture (%) | Carbohydrate | Protein | Fat | Fiber | Ash |
|----------|------------|--------------|--------------|---------|-----|-------|-----|
| 28       | Uwi Perti  | 82.46±0.76   | 19.63±0.05   | 1.29±0.06 | 0.00±0.00 | 6.70±0.05 | 0.85±0.12 |
| 29       | Uwi Ulo    | 72.26±0.35   | 24.29±0.36   | 2.25±0.08  | 0.18±0.10  | 7.85±0.08  | 0.99±0.01  |
| 30       | Uwi Perti  | 69.31±0.33   | 26.58±0.30   | 2.01±0.04  | 0.00±0.00  | 11.61±1.11 | 1.29±1.11  |
| 31       | Uwi Bangkulit | 72.72±0.14 | 24.56±0.39   | 2.06±0.04  | 0.00±0.00  | 9.57±0.08  | 1.09±0.02  |
| 32       | Uwi Kelopo | 72.49±0.54   | 22.72±1.23   | 2.18±0.03  | 0.14±0.08  | 8.24±0.05  | 1.07±0.03  |
| 36       | Uwi Bangkulit | 65.47±1.20 | 29.37±0.09   | 2.10±0.07  | 0.18±0.10  | 11.62±0.19 | 1.20±0.03  |
| 42       | Uwi Bangkulit | 71.05±0.39 | 24.91±0.19   | 2.53±0.06  | 0.00±0.00  | 11.42±0.20 | 1.18±0.04  |
| 43       | Uwi Bangkulit | 71.66±0.70 | 23.69±0.25   | 2.56±0.12  | 0.25±0.12  | 9.90±1.51  | 1.10±0.06  |
| 57       | Uwi Ketan Putih | 77.88±0.54 | 17.10±1.29   | 2.20±0.04  | 0.13±0.08  | 7.58±0.32  | 0.98±0.03  |
| 58       | Uwi Biru    | 66.76±0.61   | 27.89±0.70   | 2.38±0.06  | 0.16±0.09  | 11.44±0.21 | 1.13±0.12  |
| 63       | Uwi Budeng  | 74.51±0.96   | 25.17±1.12   | 1.54±0.02  | 0.19±0.11  | 8.23±0.08  | 1.23±0.09  |
| 64       | Uwi Ulo     | 76.22±0.46   | 23.05±1.30   | 1.95±0.03  | 0.29±0.17  | 7.09±0.22  | 1.30±0.04  |
| 66       | Uwi Legi    | 74.67±1.54   | 18.54±3.08   | 3.00±0.09  | 0.00±0.00  | 9.20±0.26  | 1.21±0.06  |
| 82       | Uwi Jaran   | 71.93±0.52   | 24.80±0.51   | 2.46±0.09  | 0.23±0.13  | 10.71±0.27 | 1.44±0.12  |
| 86       | Uwi Cemeng  | 74.66±0.26   | 22.78±0.45   | 2.02±0.01  | 0.15±0.08  | 8.33±0.15  | 1.19±0.06  |

| P-value  | 0.000 | 0.000 | 0.445 | 0.241 | 0.000 | 0.468 |
The protein content of the fifteen local accessions of water yam varied between 1.29% and 3.00% (average 2.17% ± 0.42%). The protein content was not significantly different among accessions. However, the highest protein content was observed in Uwi Legi/66 and the lowest was observed in Uwi Perti/28 (Table 2). Those protein content values were in accordance with the previous study by Odebunmi, Oluwaniyi, Sanda, & Kolade (2007) reporting the protein content of Nigerian water yams was 2.51%. However, it was lower than that reported by Baah, Maziya-Dixon, Asiedu, Oduro, & Ellis (2009) that showed protein content ranged from 4.3% to 8.7%. It was also considered lower than the previous study subjected to other local accessions of water yam in Indonesia by Nadia et al. (2015) showing that the protein content ranged between 4.48% to 9.85%. Nonetheless, in average the protein content of water yam local accessions in the present study was higher than that of other tuber and root crops reported by Chandrasekara & Josheph Kumar (2016), such as cassava (1.4%), sweet potato (1.6%), and potato (2.57%). The higher protein content of water yam highlighted their nutritional superiority as a staple food.

The fat content of fifteen local accessions of water yam was low between 0.00% to 0.29% (average 0.13% ± 0.19%). It was not significantly different among accessions. Five accessions had zero fat content i.e. Uwi Perti/28, Uwi Perti/30, Uwi Bangkulit/31, Uwi Bangkulit/42 and Uwi Legi/66. These values were similar to previously reported values for wild yam species of Nepal (Bhandari, Kasai, & Kawabata, 2003) and sweet potato (0.17%) (Alam, Rana, & Islam, 2016). However, it was considered lower than value reported by Haytowitz et al. (2019), such as cassava (1.4%), sweet potato (1.6%), and quite similar to potato (2.57%). The higher protein content of water yam local accessions indicated that the accessions could be recommended as a fiber source in a diet. Fiber is an essential part in a healthy diet and is required in some body systems, such as digestion and cardiovascular systems. It is suggested to consume adequate amounts and recommended levels of dietary fiber from various plant foods as it is beneficial for health, to improve gastrointestinal function, reduce cardiovascular disease, diabetes, some cancers, lower body weights (Dahl & Stewart, 2015; Murphy et al., 2012; Slavin, 2013). Water yam can be recommended as one in a variety of plant foods supplying fiber to meet fiber requirements.

The ash content of fifteen local accessions of water yam ranged from 0.85% to 1.44% (average 1.13% ± 0.2%) and was not significantly different among the accessions (Table 2). It was similar to the previous study by Odebunmi, Oluwaniyi, Sanda, & Kolade (2007) reporting that the ash content of water yam accessions from Nigeria was 1.05%, but lower than that of reported by Baah, Maziya-Dixon, Asiedu, Oduro, & Ellis (2009) and Polycarp, Afoakwa, Budu, & Otoo (2012) which ranged from 3% to 4.1% and 6.19% to 6.29% respectively. The amount of ash in a tuber depends on the genetic and environmental factors (Casler & Boe, 2003). Ash content is a reflection of mineral status, even though contamination may indicate a high concentration (Gemede, 2020).

Total Energy Value

The total energy value of the fifteen local accessions ranged from 82.43 to 130.92 kcal/100g (average 106.32 ± 16.25 kcal/100g). Three accessions with the lowest energy value were Uwi Ketan Putih/57, Uwi Perti/28 and Uwi Legi/66. Meanwhile, three accessions with the highest energy were Uwi Bangkulit/36, Uwi Biru/58 and Uwi Perti/30 (Fig. 2). On average, the total energy value of the accessions ranged from 0.85% to 1.44% (average 1.13% ± 0.2%) and was not significantly different among the accessions (Table 2). It was similar to the previous study by Odebunmi, Oluwaniyi, Sanda, & Kolade (2007) reporting that the ash content of water yam accessions from Nigeria was 1.05%, but lower than that of reported by Baah, Maziya-Dixon, Asiedu, Oduro, & Ellis (2009) and Polycarp, Afoakwa, Budu, & Otoo (2012) which ranged from 3% to 4.1% and 6.19% to 6.29% respectively. The amount of ash in a tuber depends on the genetic and environmental factors (Casler & Boe, 2003). Ash content is a reflection of mineral status, even though contamination may indicate a high concentration (Gemede, 2020).
in the present study was slightly lower than that of water yams from Nigeria (118 kcal/100g), and wild yams from Nepal (119 kcal/100g) (Bhandari, Kasai, & Kawabata, 2003). However, it was considered higher than the other tuber and root crops reported by Haytowitz et al. (2019), such as potato (69 kcal/100g) and sweet potato (86 kcal/100g). Due to the high total energy provided, the local accessions of water yam in this study can be recommended as reliable food sources to support food security.

Mineral Composition and Value

Minerals play an important role in the majority of body metabolisms process. The mineral composition and values of fifteen local accessions of water yam in the present study were highly variable. Analysis of variance of fifteen local accessions showed that potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn) and phosphorus (P) were significantly different among the accessions (P<0.05) (Table 3).

In the present study, sodium (Na) was not detected in most of water yam accessions. Only two accessions that had sodium content, i.e. Uwi Perti/30 (39.53 mg/100g) and Uwi Cemeng/86 (48.22 mg/100g) (Table 3). On average, the sodium content of local accessions of water yam in the present study was 43.87 ± 5.14 mg/100g) and it was considered lower than sweet potato (55 mg/100g) as reported by Haytowitz et al. (2019). The potassium (K) contents were various ranging from 224.54 to 483.21 mg/100g (average 330.48 ± 77.08 mg/100g). Uwi Perti/30 had the highest K content while Uwi Perti/28 had the lowest K content. The potassium content of the fifteen local accessions of water yam in the present study was higher than that of sweet potato, potato, and cassava. However, it was lower than other yams (816 mg/100g) as reported by Haytowitz et al. (2019). Potassium functions as an important electrolyte in the nervous system (Burgos, Zum Felde, Andre, & Kubow, 2020). Sodium and potassium are the main elements that regulate the distribution of fluids within the body, especially for the normal kidney function and for the control of blood pressure. The deficiency of potassium can cause debility and diseases such as weakness, fatigue, muscle cramps, heart palpitations, etc. (Tsuji, Canter, & Rosso, 2016). High potassium content in the body increases the iron utilization which is beneficial for controlling hypertension (Padhan & Panda, 2020). The lower sodium and higher potassium intake help to prevent hypertension and reduce high blood pressure (Gemede, 2020; Padhan, Biswas, & Panda, 2020)

![Fig. 2. Total energy value of fifteen local accessions of water yam tuber](image-url)
| No. Acc. | Local Name          | Na        | K          | Ca          | Mg          | Fe          | Zn          | P          |
|---------|---------------------|-----------|------------|-------------|-------------|-------------|-------------|------------|
| 28      | Uwi Perti           | 224.5±4.82 | 25.8±1.75  | 16.7±0.64   | 1.4±0.05    | 0.4±0.02    | 329.3±10.6 |          |
| 29      | Uwi Ulo             | 250.7±21.28 | 21.6±4.06  | 20.3±0.49   | 4.7±0.43    | 0.6±0.11    | 415.9±34.23 |          |
| 30      | Uwi Perti           | 48.2±0.75  | 36.6±10.95 | 43.0±6.9    | 6.2±2.70    | 2.8±1.19    | 600.6±3.8   |          |
| 31      | Uwi Bangkulit       | 292.9±0.26 | 27.7±4.38  | 30.3±3.63   | 2.8±0.47    | 1.0±0.22    | 512.6±0.73  |          |
| 32      | Uwi Kelopo          | 315.2±18.11 | 19.2±0.62  | 22.6±1.46   | 4.9±0.91    | 0.43±0.03   | 424.3±28.17 |          |
| 36      | Uwi Bangkulit       | 361.4±18.48 | 24.1±2.72  | 26.7±1.50   | 2.1±0.12    | 0.6±0.03    | 665.3±1.91  |          |
| 42      | Uwi Bangkulit       | 342.2±23.51 | 15.6±2.14  | 27.1±1.39   | 1.9±0.31    | 0.6±0.01    | 561.5±21.12 |          |
| 43      | Uwi Bangkulit       | 353.2±18.68 | 25.17±5.34 | 27.8±5.77   | 9.4±1.40    | 2.45±1.12   | 650.9±35.71 |          |
| 57      | Uwi Ketan Putih     | 267.2±9.63  | 36.1±7.47  | 32.8±4.83   | 13.4±3.52   | 2.51±1.08   | 400.2±4.70  |          |
| 58      | Uwi Biru            | 307.9±8.43  | 27.1±0.76  | 19.7±0.10   | 2.2±0.14    | 0.7±0.07    | 500.0±7.95  |          |
| 63      | Uwi Budeng          | 322.8±7.63  | 16.2±0.91  | 17.4±0.53   | 2.1±0.15    | 0.5±0.03    | 478.0±8.3   |          |
| 64      | Uwi Ulo             | 369.5±12.24 | 61.9±16.99 | 21.7±0.89   | 3.8±0.34    | 0.9±0.35    | 484.3±17.39 |          |
| 66      | Uwi Legi            | 283.5±17.18 | 31.6±7.54  | 27.9±5.56   | 8.9±3.19    | 2.2±0.94    | 563.0±74.29 |          |
| 82      | Uwi Jaran           | 442.3±15.92 | 30.8±1.65  | 25.8±0.58   | 3.3±0.72    | 0.6±0.02    | 699.9±11.50 |          |
| 86      | Uwi Cemeng          | 39.5±0.59   | 34.0±28.14 | 29.7±4.05   | 35.6±3.35   | 7.6±2.03    | 504.7±23.96 |          |

**P-value**

|          | 0.005 | 0.000 | 0.003 | 0.001 | 0.001 | 0.034 | 0.000 |
Calcium (Ca) content of the fifteen local accessions of water yam in the present study ranged from 15.63 to 61.97 mg/100g (average 28.64 ± 15.65 mg/100g). The Ca content of Uwi Bangkulit/42 was the lowest, while the highest of Ca content was found in Uwi Ulo/64. Calcium is vital for the development of healthy bones and teeth. It is also needed for muscle contraction and regulation of the heartbeat and is involved in the formation of blood clots. A long-term shortage of calcium can lead to osteoporosis when the bones become brittle and break easily (Chandrawanshi, Sheaddha, Rutuja, Neha, & Nishant, 2018). The fifteen local accessions in the present study can contribute to supply calcium for calcium requirement.

Magnesium (Mg) contents in the present study ranged from 16.75 to 43.06 mg/100g (average 26.40 ± 9.85 mg/100g). Uwi Perti/28 had the lowest Mg content, while Uwi Perti/30 had the highest Mg content. Magnesium has various functions in the acid-base balance, bone formation, and functioning of many vital enzymes. On average, the Mg content of fifteen local accessions in the present study was higher than that of other yams, sweet potato, potato, and cassava with an average of 21-25 mg/100g as reported by Haytowitz et al. (2019).

Iron/Fe contents in the present study ranged from 1.40 to 13.40 mg/100g (average 5.01 ± 4.70 mg/100g). Uwi Perti/28 had the lowest Fe content, while Uwi Ketan putih/57 had the highest Fe content. In average, the Fe content of fifteen local accessions of water yam in the present study was higher than that of other yams, sweet potato, potato, and cassava with an average of 21-25 mg/100g as reported by Haytowitz et al. (2019).

Zinc (Zn) content of the fifteen local accessions of water yam in the present study ranged from 0.43 to 2.83 mg/100g (average 1.22 ± 1.35 mg/100g). Uwi Kelopo/32 had the lowest Zn content, while Uwi Perti/30 had the highest Zn content. In average, the zinc content of the fifteen local accessions of water yam was much higher than that of other yams, sweet potato, and cassava, as reported by Haytowitz et al. (2019). The height of iron and zinc concentrations are significantly affected by the growing environment (Burgos, Zum Felde, Andre, & Kubow, 2020). Zinc is one of the essential elements which enhances the essential functioning of the immune system. It is essential for the growth and also needed for the functioning of the brain cells. Furthermore, Zinc is a component of insulin, a vital hormone that regulates the metabolism of carbohydrates, fat, and protein (Oti & Nwabue, 2013). Thus, the fifteen local accessions of water yam in the present study were very potential as the source of zinc to overcome the zinc deficiency problems.

The phosphorous (P) content of the fifteen local accessions of water yam in the present study varied between 329.37 and 699.91 mg/100g (average 519.41 ± 112.47 mg/100g) (Table 3). The values were considered much higher than that of the previous studies by Udensi, Oselebe, & Iweala (2008) reporting that the phosphorous content of water yam from Nigeria ranged from 120 to 340 mg/100g. Along with calcium, phosphorous plays important functions in bones and teeth formation, also carbohydrates and fats metabolism. In general, the fifteen local accessions of water yam in the present study contain high and valuable minerals that can supply minerals for mineral requirements, which is essential for body metabolism processes.

**Anti-nutrition Value**

The level of anti-nutrition value in the forms of tannin and oxalic acids of the fifteen local accessions of water yam examined in the present study was shown in Table 4. Tannins are water-soluble polyphenols present in many plant foods and are known as anti-nutritional factors, as it can inhibit food digestion and absorption of various nutrients, bind and shrink proteins, reduce protein digestibility, and cause inactivation of digestive enzymes (Bele, Jadhav, & Kadam, 2010; Delimont, Haub, & Lindshield, 2017; Popova & Mihaylova, 2019). Higher concentration of tannin affects the protein quality of the food and interferes with iron absorption (Padhan, Biswas, & Panda, 2020). Tannin concentration in water yam tubers in the present study ranged from 63.3-167.6 mg/100g (average 109.17 ± 25.98 mg/100g). Uwi Jaran/82, Uwi Bangkulit/42, and Uwi Perti/28 had relatively high tannin content. These values were consistent with the previous study by Udensi, Oselebe, & Onuoha (2010) who reported the tannin content of water yam ranged from 46.5 to 180.25 mg/100g.
Hence, it is important to note that heat treatment or cooking to yams tuber is strongly recommended before consumption to eliminate or reduce the level of tannin in the food to make the protein available for digestion (Ezeocha & Ojimelukwe, 2012; Lewu, Adebola, & Afolayan, 2010).

Oxalic acid is known to adversely affect mineral bioavailability. Oxalic acid can have a harmful effect on human nutrition and health, especially by reducing calcium absorption and aiding the formation of kidney stones (Popova & Mihaylova, 2019). High oxalic acid concentration in food causes nutritional deficiency and severe throat irritation (Padhan & Panda, 2020). Oxalic acid levels of the fifteen local water yam accessions ranged from 12.7 to 44.9 mg/100g (average 20.52 ± 8.72 mg/100g). Uwi Jaran/82 and Uwi Ulo/64 were considered high in oxalic acid content. However, it was considered much smaller values than that of Dioscorea alata “bètè-bètè” variety from Abidjan, Ivory Coast, West Africa with the oxalic acid content was 650 mg/100 g raw tuber (Didier et al., 2014). Thus, the fifteen water yam local accessions in this study were considered safe for consumption. Nevertheless, the kidney problem patients are advised to limit their intake of foods with oxalic acid content not exceeding 50–60 mg per day (D’alessandro et al., 2019).

### Hierarchical Cluster Analysis Based on Biochemical Characteristics

About fourteen important biochemical characteristics comprised of carbohydrate, protein, fat, fiber, moisture, Na, K, Ca, Mg, Fe, Zn, P, tannin, and oxalic acid were subjected to statistical multivariate analysis to assess the hierarchical clustering among fifteen local accessions of water yam. Grouping of landraces based on their similarity is crucial. The result of UPGMA clustering showed that the fifteen local accessions of water yam were clearly separated into three major clusters, with a similarity of 67% to 96% (Fig. 3). The clustering pattern among fifteen local accessions of water yam was associated with their biochemical characteristics as the basis of the accession selection.

Cluster I consisted of five accessions including Uwi Perti/30, Uwi Kelopo/32, Uwi Bangkulit/43, Uwi Biru/58, and Uwi Ulo/64, with similarity ranged between 85% and 92%. Those five accessions were associated with its high content of carbohydrates and low content of tannin and oxalic acid. Meanwhile, cluster II was considered as the largest comprising nine accessions. Further, it was separated into two sub-clusters. Sub-cluster 1 consisted of two accessions i.e. Uwi Perti/28 and Uwi Ulo/29. Most of the biochemical characteristics of both accessions were not significantly different with a similarity of 93%.

### Table 4. Anti-nutrition value of fifteen local accessions of water yam tuber (mg/100g)

| No. Acc. | Local Name     | Tanin       | Oxalic Acid     |
|----------|----------------|-------------|-----------------|
| 28       | Uwi Perti      | 127.39±2.50  | 27.25±1.01      |
| 29       | Uwi Ulo        | 130.58±0.13  | 13.99±0.55      |
| 30       | Uwi Perti      | 92.52±0.11   | 13.05±1.05      |
| 31       | Uwi Bangkulit  | 112.49±0.27  | 17.69±1.09      |
| 32       | Uwi Kelopo     | 76.73±3.04   | 12.73±1.68      |
| 36       | Uwi Bangkulit  | 113.62±0.31  | 17.77±0.22      |
| 42       | Uwi Bangkulit  | 128.20±4.09  | 17.80±0.28      |
| 43       | Uwi Bangkulit  | 63.36±0.15   | 16.88±0.42      |
| 57       | Uwi Ketan Putih| 105.45±0.48  | 23.31±0.24      |
| 58       | Uwi Biru       | 90.89±0.18   | 22.18±1.48      |
| 63       | Uwi Budeng     | 107.96±0.81  | 14.34±1.14      |
| 64       | Uwi Ulo        | 79.98±0.21   | 30.99±0.87      |
| 66       | Uwi Legi       | 118.43±6.41  | 21.64±1.29      |
| 82       | Uwi Jaran      | 167.88±8.93  | 44.92±3.64      |
| 86       | Uwi Cemeng     | 122.27±0.57  | 17.25±0.50      |

P-value: 0.000 0.001
Meanwhile, sub-cluster 2 comprised seven accessions including Uwi Bangkulit/31, Uwi Gedek/36, Uwi Bangkulit/42, Uwi Ketan Putih/57, Uwi Budeng/63, Uwi Legi/66 and Uwi Cemeng/86; with similarity 79% to 96%. Uwi Bangkulit/43 and Uwi Cemeng/86 were considered as the closest pair, whilst Uwi Bangkulit/43 and Uwi Ketan Putih/57 were the farthest pair.

Cluster III comprised only one accession i.e. Uwi Jaran/82 and served as an outgroup. It was because of its highest content of phosphorous, tannin, and oxalic acid which was very significantly different from others (Table 3 and Table 4). Although this accession has high anti-nutrition content, it contains moderate nutrition values. Pre-cooking treatments are required to reduce the tannin and oxalic acid contents such as soaked in the water and/or cooked in the boiling water within a certain time, etc. (Gemede, 2014; Kumar, Patel, & Gupta, 2017).

**Principal Component Analysis Based on Biochemical Characteristics**

The patterns of variation and the relative contribution of each biochemical characteristics in explaining the observed variability among local accessions was assessed through principal component analysis (PCA). In this present study, PCA was carried out separately between proximate, minerals, and anti-nutrition characteristics due to different value units. The result of PCA grouped the variables into six components based on six proximate characteristics, with the first two are significant (eigenvalue >1) and explained 97.64% of the total variability. The first principal component (PC1) contributed 90.01% to the total variation and was correlated positively with carbohydrate (0.572),

![Dendogram clustering pattern of fifteen local accessions of water yam based on nutrition, minerals and anti-nutrition characteristics](image)

**Fig. 3.** Dendogram clustering pattern of fifteen local accessions of water yam based on nutrition, minerals and anti-nutrition characteristics
fiber (0.278), protein (0.022), ash (0.015), and fat (0.003). Whilst, the second principal component (PC2) contributed 7.63% to the total variability and mainly positively correlated with carbohydrate (0.796), moisture (0.472), and fat (0.015). The PCA scatter biplot showed that some accessions were clustered around the proximate variables which can be used to confirm the accession selection. Accessions clustered in quadrant I and II were mostly associated with high carbohydrate, high protein, high fiber, and low fat; including Uwi Ulo/29, Uwi Perti/30, Uwi Bangkulit/31, Uwi Bangkulit/36, Uwi Bangkulit/42, Uwi Bangkulit/43, Uwi Biru/58, and Uwi Jaran/82 (Fig. 4). Those local accessions of water yam are readily selected as promising accessions based on nutrition of proximate value.

On the other hand, PCA based on nine minerals and anti-nutrition characteristics grouped the variables into nine components, with the first eight are significant (eigenvalue >1). However, the first two principal components were enough to explain 94.12% of the total variability (PC1=83.81%; PC2=7.63%). The first principal component (PC1) was correlated positively to almost all variables except Fe (-0.0008). Whilst, the second principal component (PC2) was also correlated to almost all variables except P (-0.474), and anti-nutrition of tannin (-0.184) and oxalic acid (-0.004). The PCA scatter biplot clearly illustrated that an accession Uwi Perti/30 clustered in quadrant was mostly associated with high minerals of K, Na, Ca, and Mg; and low anti-nutrition (tannin and oxalic acid). Meanwhile, accessions clustered in a quadrant II were mostly associated with high minerals of P, Zn, and Fe; but also high in anti-nutrition of (tannin and oxalic acid); including Uwi Bangkulit/36, Uwi Bangkulit/42, Uwi Bangkulit/43, Uwi Legi/66, and Uwi Jaran/82 (Fig. 5). Nonetheless, promising accession selection will be chosen one with low anti-nutrition value i.e. Uwi Perti/30.

Selection of Local Accessions of Water Yam Based on Nutrition and Minerals Content

Variation in the nutrition, mineral, and other biochemical values among accessions of water yam is useful for breeding and development programs to select accessions with certain nutritional characteristics (Udensi, Oselebe, & Iweala, 2008). According to ANOVA, HCA and PCA result from this present study, some promising local accessions of water yam were selected for its prominent nutrition value better than some other tuber and root crops. Promising local accessions with high carbohydrates considered higher than potato and sweet potato, including Uwi Perti/30, Uwi Bangkulit/36, Uwi Bangkulit/42, Uwi Bangkulit/43 and Uwi Biru/58. Likewise, promising local accessions with high protein considered higher than cassava and sweet potato, including Uwi Bangkulit/42, Uwi Bangkulit/43 and Uwi Legi/66.

![Fig. 4. PCA scatter biplot based on proximate characteristics of fifteen local accessions of water yam](image-url)
Meanwhile, promising local accessions with low fat i.e. Uwi Perti/28, Uwi Perti/30, Uwi Bangkulit/31, Uwi Bangkulit/42 and Uwi Legi/66; high fiber i.e. Uwi Perti/30 and Uwi Bangkulit/36; and high minerals i.e. Uwi Perti/30.

In general, six out of fifteen water yam local accessions are recommended for further breeding and development, including Uwi Perti/30, Uwi Bangkulit/36, Uwi Bangkulit/42, Uwi Bangkulit/43, Uwi Biru/58 and Uwi Legi/66, on the basis of the highest carbohydrate and protein content, and the lowest fat content. Those promising accessions of water yam are potential as alternative food sources to support food diversification and food security with high nutrition value.

CONCLUSION

The present study has shown the biochemical composition and nutritional value of fifteen local accessions of water yam (D. alata) from East Java which varied among accessions. They had comparative advantages with other tuber and root crops such as potato, sweet potato and cassava. They contained moderate to high moisture, high carbohydrate, moderate protein, low fat, high fiber and low ash. The mineral composition and values were highly variable from low, moderate to high, comprised Kalium, Calcium, Magnesium, Iron, Zinc, Phosphor and Natrium. The anti-nutrition of tannin and oxalic acid were detected in moderate to high value, but they can be overcome by pre-cooking treatments. Promotion and dissemination of the potential nutrition value of water yam tuber as a nutritious food sources are required.

Results of the accessions selection showed six promising accessions i.e. Uwi Perti/30, Uwi Bangkulit/36, Uwi Bangkulit/42, Uwi Bangkulit/43, Uwi Biru/58 and Uwi Legi/66, on the basis of the highest carbohydrate and protein content, and the lowest fat content. Further study on the breeding of those promising accessions is required.

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