World Journal of Biology Pharmacy and Health Sciences
eISSN: 2582-5542
Cross Ref DOI: 10.30574/wjbphs
Journal homepage: https://wjbphs.com/

(RESEARCH ARTICLE)

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Morpho-anatomical and phytochemical diversities in selected members of family Aroideae

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World Journal of Biology Pharmacy and Health Sciences, 2024, 18(03), 403-410

Publication history: Received on 19 May 2024; revised on 26 June 2024; accepted on 29 June 2024

Article DOI: https://doi.org/10.30574/wjbphs.2024.18.3.0402

Abstract

Many root and tuber crops are grown throughout the world in hot and humid regions for their use as vegetable as most of them contain starch as the major carbohydrate in them. They are important diet component for human and add variety to it. Taro is used as a staple food or subsistence food by millions of people in many of the developing countries. It can be grown as a root crop, as a leafy vegetable, as an ornamental and as medicinal plant. The present study focused on some selected members of the family Araceae. A total of seven species belonging to the family Araceae from the same locality were collected and identified. Some Araceae leaves possess vital nutritive and nonnutritive components in significant amounts, but are underutilized, and lesser explored. Seven members of Araceae family were compared for morphological, anatomical and phytochemical characteristics. Anatomically the samples were compared for anatomy of leaf, petiole, stomatal types, grains etc. Phytochemically the samples were analysed for flavanoid, alkaloid, tannin, saponin, flavanol, reducing sugar, terpenoid and phenol.

Keywords: Colocasia; Corm; Taro; Phytochemical; Starch Grain

1. Introduction

Aroideae is a subfamily of flowering plants in the family Araceae. *Colocasia* (Taro) is a genus of flowering plants in the family Araceae, native to south-eastern Asia and the Indian subcontinent. Despite adverse climatic conditions, such as drought, corms can persist underground. When the next favourable season begins, corms will sprout and produce new plants if they are not harvested. When the environment is favourable, plants can grow for a number of years.

Colocasia esculenta poses a serious risk of introduction, particularly in regions close to agricultural fields. It is an aggressive weed that has spread to tropical and subtropical regions of the world after escaping from farmed areas. Commercially available underground corms and stems are produced by plants and used as animal feed and human nourishment. It is used as an adornment as well. The plant *Colocasia esculenta* grows quickly and can be spread by seed or corms, which readily resprout to generate new plants. These perennial herbaceous plants have a sizable corm on top of or near the ground. The leaves have a sagittate form and range in length from 20 to 150 cm.

According to WHO about 1.62 billion people are suffering from anaemia. The most common type of anaemia is iron deficiency anaemia. Taro root contains two most important minerals which help to fight against anaemia - iron and copper. Everyone needs iron to make haemoglobin; it is a protein which helps red blood cells that carries oxygen in our blood. Without enough oxygen in your brain, you may feel confusion, restlessness, headache, shortness of breath, and lack of coordination. It is important to eat foods which contain enough iron to prevent our self from diseases like anaemia.

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Taro roots and leaves are rich in carbohydrates, protein, and dietary minerals. Micronutrients include iron, copper, magnesium, potassium, and zinc. Colocasia leaves contain phytochemicals, such as anthraquinones, apigenin, catechins, cinnamic acid derivatives, vitexin, and isovitexin. Genus of Colocasia leaves has demonstrated the potentiality of antidiabetic, antihypertensive, immunoprotective, neuroprotective, and anticarcinogenic activities.

Taro is a staple food for many people in developing countries in Africa, Asia and the Pacific [1]. The corm and cormels which are the major economic parts have a nutritional value comparable to sweet potato [2], while the young leaves and petioles which are occasionally used for food contain about 23% protein on a dry weight basis. It is also a rich source of calcium, phosphorus, iron, vitamin C, thiamine, riboflavin, and niacin which are important constituent of human diet. Taro corms and cormels have a high economic value in urban markets. Its production provides employment to many people and the crop maintains good ground cover or canopy in the fields [3].

The *Colocasia* varieties, *Colocasia esculenta* cultivated and *Xanthosoma sagittifolium* contain numerous essential nutrients needed for daily activities, it can be considered as a good staple food. The leafs of *Colocasia* sps. (gigantea) are used as vegetables. Whereas *Alocasia macrorrhiza*, *Colocasia esculenta* wild, *Caladium bicolor* not used as dietary source, it contains large amount of $CaCO_3$. *Alocasia macrorrhiza* and *Colocasia* sps (gigantea) lacks tubers. Hence the present study focuses on the comparative analysis of seven Araceae members.

2. Materials and methods

2.1. Materials

Seven most locally found Colocasia members namely *Colocasia esculenta* (S1), *Xanthosoma sagittifolium* (S2), *Colocasia esculenta* variety (S3), *Alocasia macrorrhiza* (S4), *Colocasia esculenta* wild (S5), *Caladium bicolor* (S6), Colocasia sps (S7) were considered for the present study. The selection was based on the acceptance or avoidance of some of these tuber crops from the daily diet of Keralites. The study materials were collected from the farm lands of Padanilam locality in Kerala, India. Materials such as leaf, petiole and underground tuber were carefully collected without making any damage.

2.2. Methods

- **Morphological characters of plant:** Morphological parameters like height of the plant, length of petiole, number of leaf per plant, length, width and colour of the leaf and number of veins per leaflet were taken for consideration.
- **Anatomical characters of plant:** The plants were compared for analysing petiole, leaf and stomatal variation in leaves and starch grains of tuber crops. With the help of razor, thin sections of petiole and leaf were taken and observed under microscope for the comparison of internal structure. Epidermal peels from leaves stained with saffranine and observed microscopically for stomatal variation. For starch grain analysis a small portion of rhizome were taken using a needle and evenly spread on a glass slide. It was then stained with saffranine and observed under the microscope.
- **Phytochemical studies:** The different chemical tests were performed for analysing the phytochemical parameters like flavanoid, alkaloid, tannin, saponin, flavanol, reducing sugar, terpenoid and phenol.
- **Test for flavanoids – Alkaline Reagent Test:** The aqueous plant extract was mixed with 2 ml. of 2% NaOH; concentrated yellow colour was produced, which became colourless when 2 drops of diluted acid was added to the mixture. This result showed the presence of flavanoids.
- **Test for alkaloids – Mayer's Reagent Test:** To about 3 ml. of extract, a two drops of Mayer's reagent was added. Cream precipitate showed the presence of alkaloids.
- **Test for tannins:** To about 2 ml. of sample, 1 ml. of $FeCl_3$ was added. Blue, black or greyish black colour indicates the presence of tannins.
- **Test for saponins:** Five millilitre of distilled water was mixed with aqueous plant extract in a test tube and shaken vigorously. Foam appearance showed the presence of saponins.
- **Test for flavanol:** To about 2 ml. of the extract, a pinch of boric acid and 5 ml. of acetic acid were added; yellow colour with green fluorescence indicates the presence of flavanol.
- **Test for reducing sugar:** An amount of 0.5 gm of selected plant sample was added in 5 ml. of distilled water. Then 1 ml. of ethanol mixed in plant extract. Measured 1 ml. of Fehling solution A and 1 ml. of Fehling solution B in a test tube, heated it to boiling and then poured it in the aqueous ethanol extract. Observance of colour reaction shows the presence of reducing sugar.
- **Test for terpenoids:** Two millilitre of chloroform was added to 5 ml. aqueous plant extract followed by 3 ml of concentrated H_2SO_4. Formation of layer shows the entity of terpenoids.

- **Test for phenol:** About 2 gm. of plant extract was taken and add 20% of H_2SO_4 followed by two drops of NaOH. A blue colour showed the presence of phenol.

3. Results and discussion

3.1. Morphological parameters and leaf variations

Most of the members in Araceae family were large herbs. *Colocasia esculenta*, *Xanthosoma sagittifolium* and *Colocasia esculenta* variety were edible staple food and leaves and petiole of Colocasia sps was also edible. Whereas *Alocasia macrorrhiza*, *Colocasia esculenta* wild and *Caladium bicolor* were inedible. *Colocasia esculenta* was a member of Colocasia family in which the plant was small to medium in size. Petiole length contributes to the height of the plant. Number of leaves per plant varied from 5 to 7, it was small sized with greenish yellow colour. The number of veins per leaflet varied from 6 to 10.

Colocasia esculenta plant was medium to large in size. Number of leaf per plant varied from 6 to 10, it was large sized and dark greenish in colour. Number of veins per leaflet was usually 8. *Colocasia esculenta* variety was usually small. Number of leaf per plant varied from 1 to 3, small sized and greenish in colour. Number of veins per leaflet varied from 6 to 11. *Alocasia macrorrhiza* lacks tubers. The plant was medium sized. Number of leaf per plant varied from 2 to 4, medium sized and greenish in colour. Number of veins per leaflet varied from five to nine. *Colocasia esculenta* wild plant was usually medium to large. Leaf was glossy light green with a central pink spot. Number of veins per leaflet varied from 6 to 8.

Caladium bicolor was considered as a wild variety, but now included in ornamentals. The plant was small to medium sized. The leaf was small to medium, showy green coloured with pink veins and whitish patches. Number of leafs per plant varied from 2 to 4 and number of veins varied from 3 to 5. Colocasia sps was an important Araceae member which lacked underground tuber. The plant was medium sized; the number of leaves varied from 4 to 8. The leaves were highly nutritious and light green in colour. Number of veins per leaf varied from 5 to 7 (Figure 1). A comparative morphological observation of the selected plants was conducted and the parameters observed are presented in Table 1.

Figure 1 Leaf variation of selected Colocasia

Table 1 Morphological parameters

Characters	S1	S2	S3	S4	S5	S6	S7
Height of the plant (cm)	18-38	54-60	24-26	11-37	55-61	7-15	18-35
Petiole length (cm)	16-33	36-42	19-22	6-25	39-54	5-11	13-26
Number of leaf	5-7	6-10	1-3	2-4	5-7	2-4	4-8
Leaf length (cm)	7-12	27-31	7-10	6-18	27-28	4-8	7-12
Leaf width (cm)	3-10	13-23	5-8	2-12	8-12	2-5	4-9
Leaf colour	Green to greenish yellow	Green	Green	Green	Glossy light green with central pink spot	Greenish with purple midrib and whitish patches	Light green
Number of veins	6-12	8	6-11	5-9	6-8	3-4	5-6

3.2. Anatomical characters

Considerable anatomical variation was met with the different plant materials. Cross section of petiole showed variation. In *Colocasia esculenta* there was a single layered epidermis. Ground tissue was not differentiated into cortex and pith in most of the species. Small collateral vascular bundles were found and numerous air cavities were scattered in the ground tissue. Air cavities were medium sized and all of them had almost same size. It was surrounded by a layer of cell and brush like projections was seen.

In *Xanthosoma sagittifolium*, there was a single layered epidermis. Here also ground tissue was not differentiated into cortex and pith. Vascular bundles were scattered and xylem encircled by uniseriate xylem parenchyma. Number of air cavities considerably less, larger than *Colocasia esculenta* and small bulb like projection was seen. *Colocasia esculenta* variety also shared similar characters with *Colocasia esculenta* except that the air cavities were not at all in same size and in addition to brush like projection there were fibrils. Here also vascular bundles were scattered in ground tissue and xylem surrounded by xylem parenchyma.

In *Alocasia macrorrhiza*, there was a single layered epidermis. Air cavities were large. Fibrils were also found but not as sharp as *Colocasia esculenta* variety. In *Colocasia esculenta* wild, there was single layered epidermis. Vascular bundles were small and have a surrounding layer. Air cavities were large and encircled with a layer of cell. Tongue like projections was found. In *Caladium bicolor*, there was epidermis and ground tissue not differentiated. The vascular were scattered unevenly and they were considerably small. Numerous air cavities of various sizes were dispersed in ground tissue. In Colocasia sps, there was epidermis and ground tissue not differentiated. Vascular bundles were large. Air cavities were considerably large and had single surrounding layer. Bulb like projections was found in it.

Anatomical characters of leaf showed variation. The arrangement of mesophyll was same in all varieties. *Colocasia esculenta* variety shared similar features with *Caladium bicolor*, mesophyll cells were arranged in upper epidermis followed by spongy parenchyma. The vascular bundles were small in size, collateral and closed. The stomata were present in both adaxial and abaxial surfaces. *Alocasia macrorrhiza* shared common characters with *Colocasia esculenta* wild, there was mesophyll cells followed by spongy tissues. In addition to vascular bundles there was calcium oxalate deposition.

3.3. Stomatal variations

Samples showed stomatal variation on adaxial surface. Most of the members in Araceae family had anomocytic stomata and no subsidiary cells. *Colocasia esculenta* and Colocasia sps had small stomata. *Xanthosoma sagittifolium* and *Colocasia esculenta* variety had large stomata with the exception that in the former stomatas were closely packed. *Alocasia macrorrhiza* and *Colocasia esculenta* wild had very small stomata. *Caladium bicolor* contained numerous small stomata.

On the abaxial surface, *Colocasia esculenta* and *Xanthosoma sagittifolium* had numerous stomata. *Colocasia esculenta* variety contained stomata larger than *Colocasia esculenta* and *Xanthosoma sagittifolium. Alocasia macrorrhiza* had numerous small stomata. *Alocasia macrorrhiza* and *Caladium bicolor* had almost similar type of stomata. Colocasia sps had highly chlorophylated stomata.

3.4. Starch grains variations

The starch grains in selected plants were varied in appearance (Figure 2). *Colocasia esculenta* had closely packed simple grains. *Xanthosoma sagittifolium* had round to elipsoidal grains and not closely arranged. *Colocasia esculenta* variety contained very little grains. *Alocasia macrorrhiza* had irregularly shaped grains. *Colocasia esculenta* wild contained numerous thickly packed small round grains. *Caladium bicolor* had comparatively large round starch grains than others.

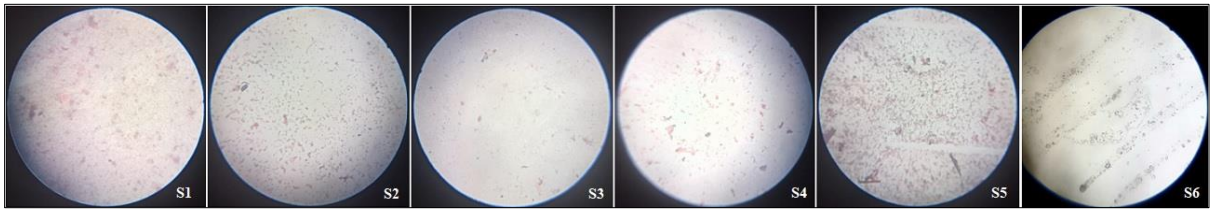

Figure 2 Starch grain variation in tubers

3.5. Phytochemical studies

Comparative study of six samples (Table 2 and Figure 3) revealed that the flavanoids was present in all sample and it was rich in Xanthosoma sagittifolium and Colocasia esculenta variety. Alkaloids was present in all and its presence was rich in Colocasia esculenta and poor in Caladium bicolor. Tannins also present in all, it's rich in Colocasia esculenta and Xanthosoma sagittifolium and poor in Alocasia macrorrhiza. Reducing sugar was present in negligible amounts in Colocasia esculenta and Colocasia esculenta wild. Terpenoids was also present in all and was rich in Caladium bicolor. Flavanols and Phenols were altogether absent in all the six samples.

Table 2 Phytochemical analysis

Sl. No.	Phytochemicals	S1	S2	S3	S4	S5	S6
1	Flavanoids	+++	+++++	+++++	++++	+++	+++
2	Alkaloids	++++	++	+++	+++	+++	+
3	Tannins	+++++	+++++	++	+	++++	+++
4	Saponins	+++	-	+++	++++	-	++++
5	Flavanols	-	-	-	-	-	-
6	Reducing sugar	++	-	-	-	+	-
7	Terpenoids	++	+++	++	+++	++	++++
8	Phenols	-	-	-	-	-	-

No. of + indicates the strength

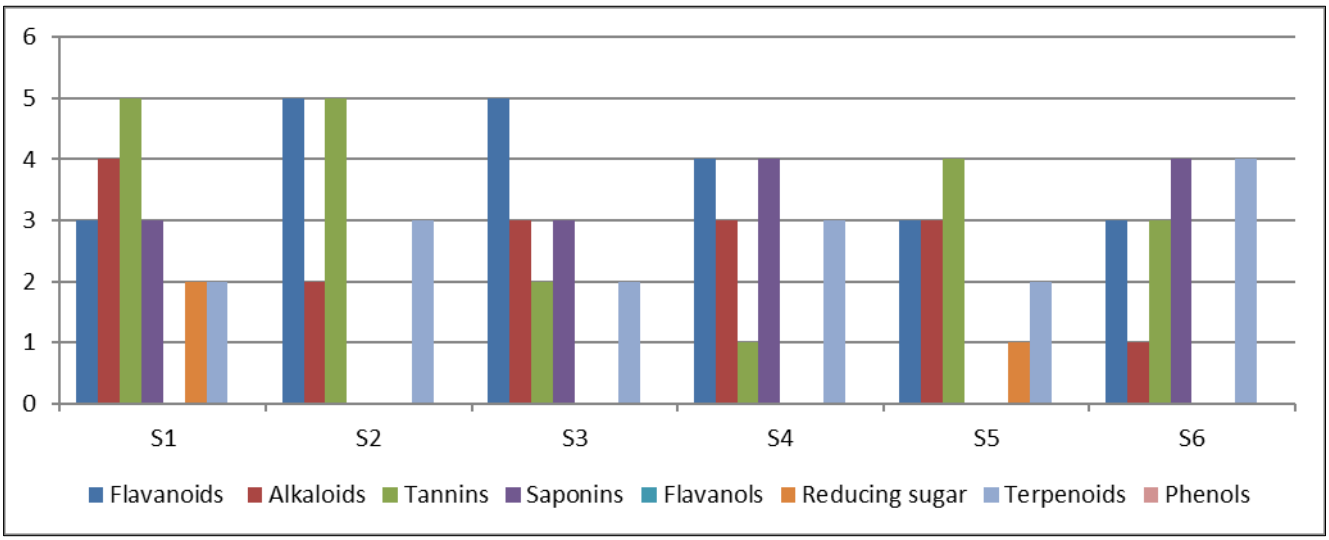

Figure 3 Phytochemical analysis

Araceae is one of the most diversified families of monocots which constitute a very natural and easy recognized group and exhibit great diversity in all morphological attributes and habitat preferences. It is among the limited number of crops that can thrive in a variety of agro-climatic settings [4, 5]. Corms can remain underground and survive through unfavourable environmental conditions (i.e., drought). If they are not harvested, corms will sprout and give rise to new plants at the onset of the next favourable season. Under favourable environmental conditions, plants may continue growth for several years.

The foliage of a number of species contains needle-like calcium oxalate crystals. These crystals can mechanically injure the mouth and throat when eaten, or can precipitate out in the kidneys, plugging the tubules. Currently, taro is established both as a tuber crop and as a leafy vegetable. Nevertheless, it holds significant value as a staple food in numerous cultures across Africa, Oceania, and Asia [6]. In the present investigation the study materials were analysed for their morphological, anatomical and phytochemical characters.

The morphological characteristics are still commonly employed for initial assessments because this method is quick, straightforward, cost-effective, and can serve as a general means of evaluating the genetic diversity of plants [7, 8]. The morphological parameters revealed that the Aroideae members except *Alocasia macrorrhiza* and Colocasia sps lack tubers and showed similarity with each other. The study materials *Colocasia esculenta* cultivated and *Xanthosoma sagittifolium* had edible tuber crops. According to Lebot *et al.* [9], there was high morphological variability in taro accessions in Southeast Asia and Oceania. The variability with regard to morphological traits includes colour, shape and size of tuber, petiole length and colour, and stolon formation.

Colocasia leaves have demonstrated the ability of antidiabetic, antihypertensive, immunoprotective, neuroprotective and antiticarcinogenic activities. The detailed assessment of phytochemical compounds present in extracts of the leaves showed the presence of active chemical compounds like anthraquinones, apigenin, catechins, cinnamic acid derivatives, vitexin, and isovitexin which are possibly responsible for the exhibited biological properties [10]. The leaves of Colocasia sps. had high nutritive value and used as a substitute for spinach. Tubers and leaf stalk of this plant is consumed in the Pacific islands similar to the people of India and Bangladesh [11].

Anatomical characters are also valuable in taxonomy and identification of groups of plant [12, 13, 14]. Cross section of petiole showed variation. All the samples contained a single layered epidermis and undifferentiated ground tissue. Small collateral vascular bundles were found and numerous air cavities were scattered in ground tissue. The only difference among the samples was the size and number of vascular bundles and air cavities and also the raphides present in it.

Anatomical characters of leaf showed variation. The arrangement of mesophyll was same in all. The difference found in them was the presence of calcium oxale crystals in some. The vascular bundles were small, collateral and closed. It has been reported as corms of the wild taro cannot be used as food due to an extremely high concentration of calcium oxalate crystals [15]. The stomata were present in both adaxial and abaxial surfaces. Most of the members in Araceae family had anomocytic stomata with no subsidiary cells. While stomatal characteristics can be influenced by various environmental factors, the processes of stomatal differentiation and development are undoubtedly governed by genetic influences [16, 17]. Some stomatal traits have been identified as potential selection markers for breeding initiatives [18].

The thickness of leaf tissue layers, including the abaxial epidermis, adaxial epidermis, mesophyll, and palisade tissues, demonstrated variability across all assessed accessions. The variations in thickness of these leaf tissue layers may be a result of responses to environmental factors [19, 20, 21]. Consequently, these anatomical features of leaves can serve as markers for selection in the genetic enhancement of plants, particularly to boost their adaptability to diverse environmental conditions. The phytochemical traits also exhibited differences. Taro is a valuable, versatile food crop for subsistence farming and home gardens, contributing to food security. Taro starch is early digestible, the starch grains are fine and very small; it has hypoallergenic nature [22]. The starch grains in selected plants were varied in appearance. *Colocasia esculenta* had closely packed simple grains. *Xanthosoma sagittifolium* had round to elipsoidal grains and not closely arranged. *Colocasia esculenta* variety contained very little grains. *Alocasia macrorrhiza* had irregularly shaped grains. *Colocasia esculenta* wild contained numerous thickly packed small round grains. *Caladium bicolor* had comparatively large round starch grains than others.

In the present investigation, the selected plants in Family Araceae contained various chemical components such as alkaloids, terpenoids, flavonoids, saponins, tannins and reducing sugar in extract. Similar findings were observed by Chandra *et al.* [23], with the exception of saponins. Plants may utilize alkaloids as a defence mechanism against herbivores, given their inability to evade predators due to their stationary nature. Additionally, these compounds could serve as a natural alternative for insecticides and fungicides. Studies have indicated that alkaloids play a biological role in the storage of waste nitrogen, maintaining cation balance, and providing protection against parasites [24]. In medicinal applications, alkaloids are employed to alleviate headaches and reduce fever, and they are recognized for their antibacterial and analgesic effects [25]. Terpenoids encompass a wide variety of compounds associated with therapeutic benefits, including anti-cancer, antiparasitic, anti-microbial, anti-allergic, anti-spasmodic, antihyperglycemic, anti-inflammatory, and immunomodulatory activities [26, 27, 28]. Compounds with significant antioxidant properties have been discovered in edible species of the Araceae family, attracting the attention of food manufacturers as consumers increasingly seek functional foods that offer specific health benefits. Phenolic compounds are regarded as the most crucial antioxidants found in plant materials. They represent one of the main categories of compounds that function as primary antioxidants or free radical terminators. Beyond their antioxidant characteristics, flavonoids also play a role in protecting against clot formation, microbial infections, ulcers, liver toxins, viruses, and tumours [29]. Saponins present in the tubers of *Colocasia esculenta* exhibit a natural ability to fend off microbes, making them promising candidates for the treatment of fungal and yeast infections.

4. Conclusion

Taro serves as a valuable, versatile food crop for subsistence farming and home gardens, contributing to food security. The consumable parts of taro, including corms, leaves and petioles, are rich in carbohydrates, proteins, dietary fibre, minerals (such as calcium, phosphorus, magnesium and iron), and vitamins. A traditional method for evaluating genetic variation among species, populations, or accessions relies on differences in morphological characteristics. Morphological traits continue to be commonly employed for initial assessments due to their speed, simplicity, cost-effectiveness, and their applicability in providing a general evaluation of genetic diversity in plants.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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