CHAPTER 1

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What is cocoyam?

Cocoyam is a tuber crop used mainly for human food in the tropical and subtropical regions of the world. It is commonly grown amongst small scale farmers who operate within the subsistence economy. In the past, it was regarded as a less important crop and its cultivation and consumption still lie within the less privileged farmers.

In some of the world literature, the term cocoyam is collectively used to describe *taro* (*Colocasia esculenta*) and *tannia* (*Xanthosoma sagittifolium*). They are both attaining world importance as energy foods and are also the most important members of the edible aroids which form part of the Araceae family (Onwueme, 1978). The starch-rich tubers are the main product, but the young leaves are also eaten as a leafy vegetable (Aregheore and Perera, 2003). However, *taro* should not be confused with the related aroid- *tannia*. The main distinguishing feature between these two is the attachment of the petiole to the lamina. In *C. esculenta*, the attachment of the petiole to the lamina is peltate, meaning that the petiole is attached, not at the edge of the lamina, but at some point in the middle (Fig. 1). This peltate leaf attachment generally distinguishes *C. esculenta* from *X. sagittifolium*. The latter has a hastate leaf with the petiole attached at the edge of the lamina. Depending on the locality, *taro* could be called cocoyam, elephant ears, dasheen or eddoe. In South Africa however, both *taro* and *tannia* are called *amadumbe*.

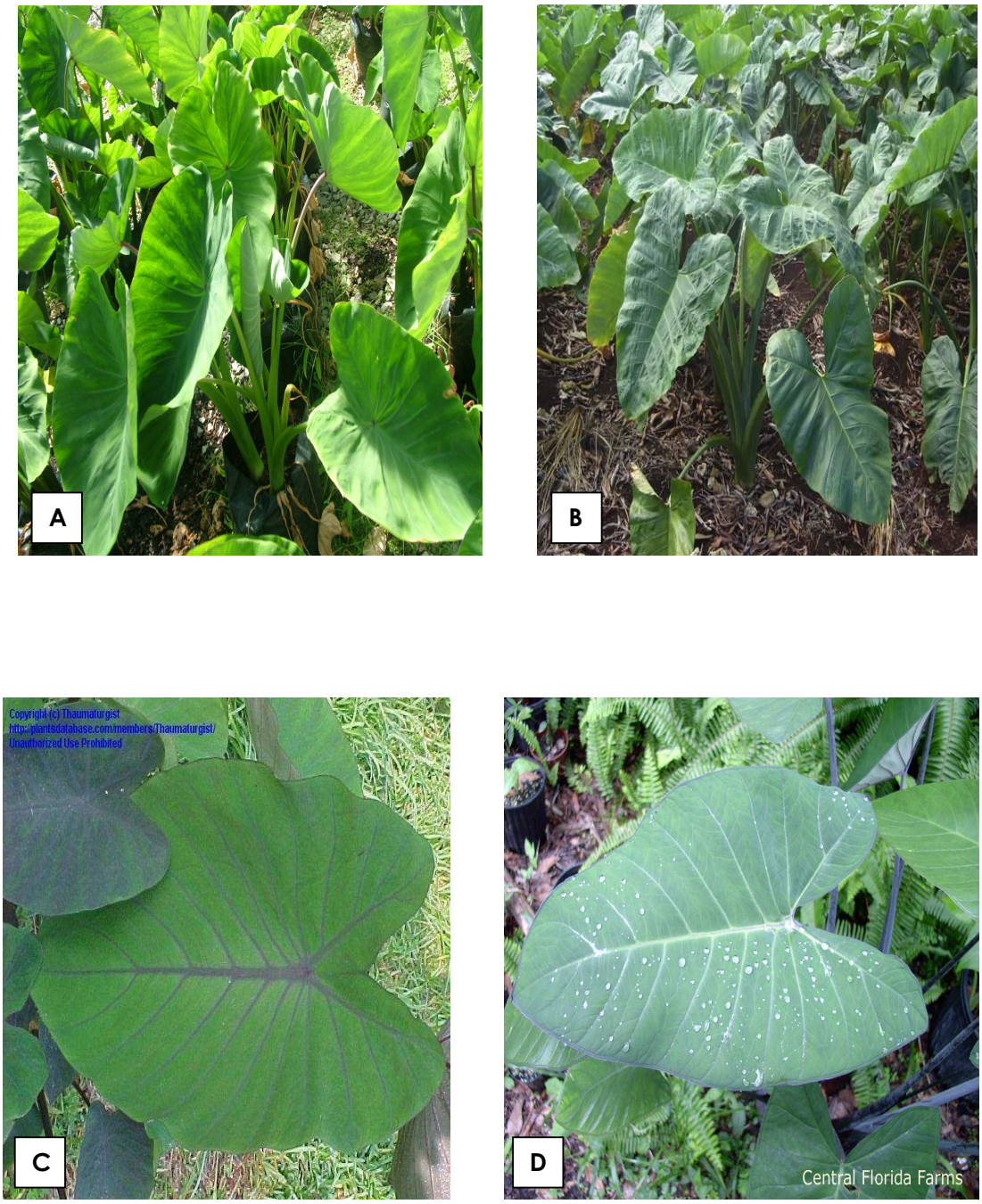

Figure 1 (A) *Colocasia esculenta* and (B) *Xanthosoma sagittifolium*. Note the attachment of the petiole towards the middle of the lamina in *C. esculenta* leaf (C) and the attachment of the petiole to the edge of the lamina in *X. sagittifolium* leaf (D).

Colocasia esculenta (L.) Schott

For the purpose of this work, the study therein is limited to *Colocasia esculenta* (*taro*). *Taro* originated in the Indo-Malayan region of Asia (Chang, 1958; Ivancic, 1992), from where it spread to the Pacific and Mediterranean regions and later to Africa. It is a staple food in many developing nations of Asia, Africa and the Pacific. There are two major botanical varieties: (i) *Colocasia esculenta* (L.) Schott var. esculenta, and (ii) *Colocasia esculenta* (L.) Schott var. antiquorum (Purseglove, 1972).

Colocasia esculenta (L.) Schott var. esculenta has a large cylindrical central corm and a few small cormels that are generally not eaten. Agronomically, it is referred to as the dasheen type (Fig. 2A). *C. esculenta* (L.) Schott var. antiquorum has a small globular central corm with several relatively large cormels arising from the main corm (Fig. 2B). These cormels are the main harvestable yield. This variety of *taro* is agronomically called the eddoe type (Masalkar and Keskar, 1998; Lebot and Aradhya, 1991; Purseglove, 1972). However, the eddoe type cultivars are more drought tolerant than the dasheens and the cormels have longer storage life than dasheen corms.

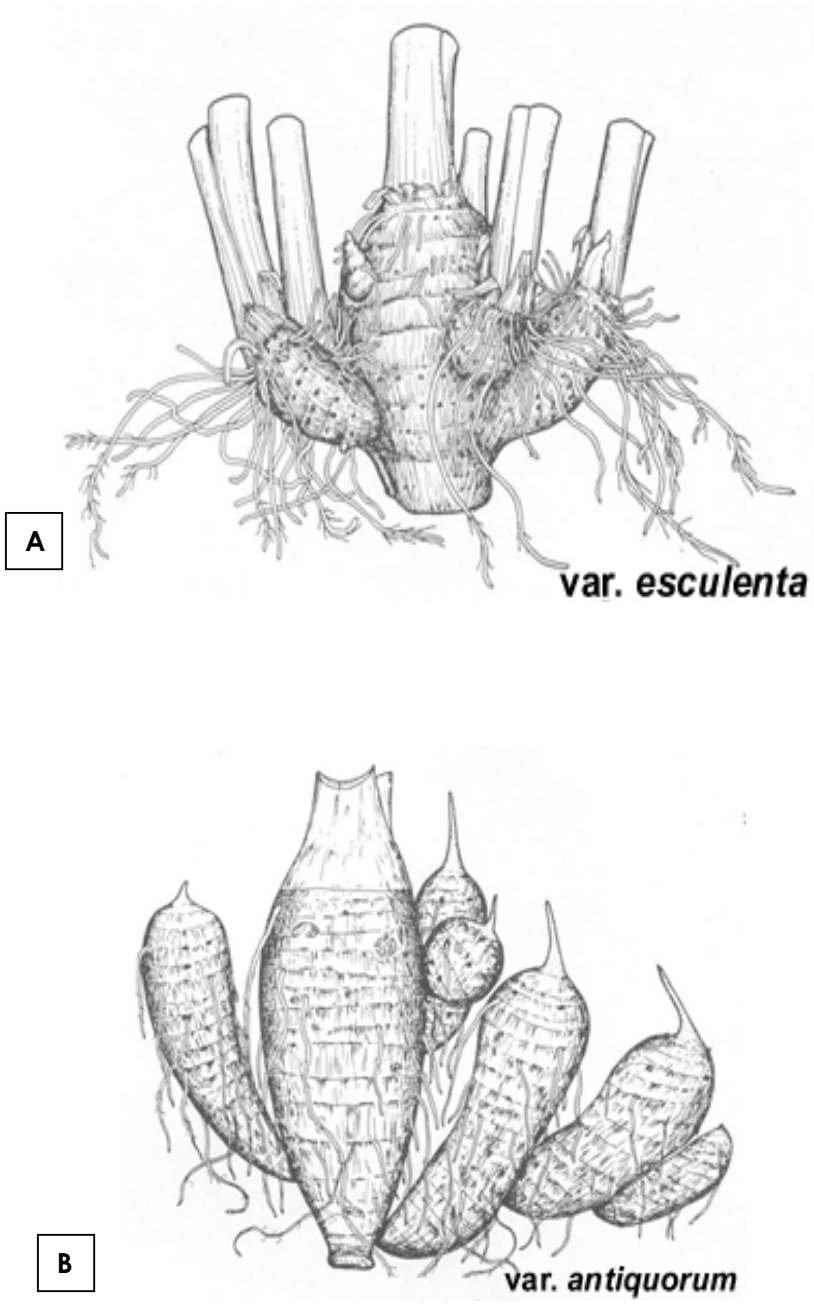

Figure 2 (A) *Colocasia esculenta* var. esculenta and (B) *Colocasia esculenta* var. antiquorum.

Nutritional value of taro

The nutritional value of a food depends upon its nutritional contents, digestibility and the presence or absence of antinutrients or toxic factors. Several authors have evaluated the chemical composition of whole corms and cormels of taro (Wills *et al*., 1983; Bradbury and Holloway, 1988). It has been observed that in spite of the fact that cocoyams are neglected crops, their nutritional value is high. Apart from the low fat content, the crop is nutritionally superior to other root and tuber crops in protein, mineral and vitamin contents (Onwueme, 1978; Standal, 1983; Hussain *et al*., 1984). Investigations have shown that cocoyams contain digestible starch, protein of good quality, vitamin C, thiamine, riboflavin, niacin and high scores of proteins and essential amino acids (Onayemi and Nwigwe, 1987). Though relatively low, the protein content of cocoyam is nevertheless higher than that of other tuber crops (Onwueme, 1978; Hussain *et al*., 1984). This implies that cocoyam-based food should be improved by consuming recipes made from the crop with other high protein sources for good nutritive value. The crop is also very rich in dietary fibre, thus, it could be employed in the treatment of diseases such as obesity, diabetes, cancer and gastrointestinal disorders (Saldanha, 1995).

Cocoyam leaves, like most higher plants, is rich in protein. The high protein content of the leaves favourably complements the high carbohydrate content of the tubers. In other parts of the world, the leaves of *C. esculenta* have been reported to be rich in nutrients, including minerals such as calcium, phosphorus, iron, and vitamins like vitamin C, thiamine, riboflavin and niacin (FAO, 1993; Baruah, 2002).

Anti-nutritional factors in cocoyam

One major limiting factor in the consumption of cocoyam is the presence of oxalates which impart acrid taste or cause irritation when foods prepared from it are eaten (Sakai, 1979). The anti-nutritional factors found in *taro* or cocoyam include oxalates, proteinase inhibitors, phytates, tannins, alkaloids, steroids and cyanogenic glucosides (Oke, 1965; Bassir, 1969). All parts of the raw *taro* plant contain the toxic compound, calcium oxalate, which must be destroyed by thorough cooking before eating (Noonan and Savage, 1999). Other secondary metabolites found in *Colocasia esculenta* include alkyl-resorcinols, phenolics, saponins, essential oils, resins, numerous sugars and organic acids (Coursey, 1968; Plowman, 1969; Fox and French, 1988; Ghosh *et al*., 1988; Dring *et al*., 1995).

Acridity has been attributed to the presence of bundles of calcium oxalate crystals in the tissue of cocoyam known as raphides. Contact of the raw tuber and leaf with the mouth or skin results in considerable itchiness, acridity and discomfort. Ingestion of foods containing oxalates has also been reported to cause caustic effects, irritation to the intestinal tract and absorptive poisoning (Sakai, 1979). Moreover, consumption of large doses of oxalic acid causes low plasma calcium and renal damage (Fassett, 1973; Kelsey, 1985). Oxalates are also known to interfere with the bio-availability of calcium (Fink, 1991). Calcium in this form (calcium oxalate) is not available because oxalates tend to precipitate calcium and makes it unavailable for use by the body, thereby, causing kidney stones.

Effect of cooking on cocoyam

Cocoyam must always be eaten cooked because it is toxic when raw (Noonan and Savage, 1999). In order to reduce the effect of antinutrients, which may have some health-hazards, proper processing before consumption is necessary. Cooking improves digestibility, promote palatability, improve keeping quality, and also makes root crops safer to eat (FAO, 1990). However, cooking may reduce the nutritive value of root crops as a result of losses and changes in major nutrients during cooking (FAO, 1990). Akpan and Umoh (2004) observed a general decrease in the mineral contents when corms of *X. sagittifolium* were cooked for two hours. Cooking could also be effective in reducing the anti-nutritional factors in foods (Sakai, 1979, 1983; Crabtree and Baldry, 1982), thus making foods safe for consumption. As reported by Iwuoha and Kalu (1995) boiling resulted in a marked reduction in oxalate contents when three cultivars of *C. esculenta* flours were compared for calcium oxalate and some physicochemical properties.

In African countries, cocoyams are processed into food in various ways in order to make them safe for human consumption. They can be eaten boiled, fried, baked, roasted, pounded into a paste or prepared as flour, chips, porridge or pottage. Likewise in Hawaii, *taro* is processed into a packaged food '*Poi*', a sour paste made from boiled pounded *taro* corm – it is a popular traditional Hawaiian food.

Medicinal uses of cocoyam

The medicinal uses of *C. esculenta* are few. Despite this, the species has quite a number of

medicinal uses. Its corm is used as an abortifacient, and to treat tuberculous ulcers, pulmonary congestion, crippled extremities, fungal abscesses in animals, and as an anthelmintic. Its foliage is used as a styptic and poultice. The stem sap is used as a treatment for wasp stings (Wilbert, 1986). *Poi* is used to improve muscle tone by bathing the sickly person in it and allowing the *poi* to dry on the body (Greenwell, 1947; Plowman, 1969; Ghosh *et al*., 1988). *C. esculenta* is also a good source of dietary fibre when compared with other root and tuber crops (Bradbury and Holloway, 1988). This highlights its superiority with regards to good digestion when consumed (Sotozono, 1989). Cocoyam-based foods could therefore be employed in the treatment of diseases such as obesity, diabetes, cancer and gastrointestinal disorders (Saldanha, 1995). High levels of dietary fibre in foods are also advantageous for their active role in the regulation of intestinal transit, increasing dietary bulk and faeces consistency due to their ability to absorb water (Jenkin *et al*., 1986).

Cocoyam in South Africa

Taro has been cultivated in suitable parts of southern Africa for centuries and was possibly first introduced into this region by Portuguese traders before 1500. Like in other African countries, the starch-rich corms are a staple diet in many parts of southern Africa where many people consider sliced and fried form of it to be comparable to fried potatoes. The leaves and stalks are popular as pot herbs, and are often mixed with other ingredients (van Wyk and Gericke, 2000).

In South Africa, cocoyam is known as *amadumbe*, the term that had its origin from Zulu language. *Amadumbe* is widely cultivated in KwaZulu-Natal Province of South Africa where

a number of landraces or farmers' varieties already exist. It is mainly grown in this area because of the crop's unique climatic requirement of warm environment, high annual rainfall and a long wet season. *Amadumbe*, a yam-like tuber also known as the African potato is a traditional vegetable grown for subsistence by the people of KwaZulu-Natal. It is mainly cultivated for the cylindrical rhizomes or corms both for food and commercial purposes.

The rationale for this study

Despite the fact that South Africa is regarded to be self-sufficient in food and even able to export some food items, hunger and malnutrition are still common in many rural and urban areas (Van den Heever, 1995). Unlike Asia, the Pacific and other African countries, where cocoyam is a commercialized staple (Miyasaka *et al*., 2003), the crop is not commercially popular in South Africa. Though, several landraces of the crop have been cultivated in some remote parts of KwaZulu-Natal Province for centuries where they are collectively called *Amadumbe*, cocoyams are not well known like maize (*Zea mays*) and potato which are the main staples in the country. Rather, the crop is cultivated in association with other subsistence food crops like sweet potatoes, landrace potatoes, and green beans mainly for subsistence. The species is considered as food for the poor and the commercial farmers have not shown much interest in the crop. Consequently, there is very little information on scientific research carried out on cocoyam in South Africa compared with conventional root and tuber crops like sweet and landrace potatoes. There is, therefore, a need for a systematic investigation on the nutritional values of cocoyam in South Africa.

In addition, although *C. esculenta* is consumed by humans in some rural communities in the country, to the best of our knowledge, no toxicological information on rodent or other species of livestock is available to date. The crop is just assumed to be safe and this safety is based on its long usage as staple food in the rural communities where they are cultivated. Therefore, there is a need to assess different accessions of *C. esculenta* growing in South Africa for their toxic effects. Moreover, this study was the first attempt to compare available land races of the species in order to report possible differences in nutritional quality and potential difference in the antinutritional properties of the species found growing in farmers' fields.

This study therefore aims to find out the effect of cooking on the proximate, mineral and the antinutrient compositions as regards the tubers and leaves of seven accessions of *C. esculenta* growing in South Africa. Studies like this may further elucidate the variation in the nutritional value of the accessions tested in the current work. This will help to know what is actually contained in this crop in terms of nutrition after it has been cooked and also to promote the cultivation of cocoyams and probably increase food options for South Africans.

The *in vivo* toxicological studies on these accessions will also establish quantitative data on possible toxicity effects on humans after consumption using albino rats as a model. The compared accessions may serve as baseline information for cultivar development or the promotion of preferred lines for commercial cultivation.

Objectives of the study

The objectives of this study therefore are to:

1. collect local landraces (accessions) of *C. esculenta* from the growing areas within the country.

2. determine the chemical composition (proximate and mineral composition) of the tubers and leaves (Fig. 5) of some local landraces available in the country.

3. determine some of the antinutritional factors present in both the leaves and tubers of the selected accessions.

4. compare the nutritional value of cocoyam tubers with that of commercially available potatoes (*Solanum tuberosum*) within the nation (Fig. 3).

5. to verify the nutritional composition of rat pellets made from the cooked tubers (*in vivo*) of these accessions.

6. to determine the toxicological properties of these accessions.

7. to provide and document scientific information on *C. esculenta* growing in South Africa. The study could further promote the cultivation of cocoyams and probably increase food options for South Africans, thus, popularizing the crop as an additional tuber crop in South Africa.

Why seven accessions of *C. esculenta*?

The seven accessions of cocoyam [*Colocasia esculenta* (Fig. 4)] named University of Fort Hare *Colocasia esculenta* 1 to 7 (UFCe1 - UFCe7), used for this study were collected from seven farmers' fields located in four different villages (Umbumbulu, Makhathini, Mthwalume and Maphumulo) in KwaZulu-Natal Province, which is the main growing area for cocoyam

in South Africa. Seven fields were sampled because those were the areas where we had contacts and the farmers were also ready to release their crop samples for this study.

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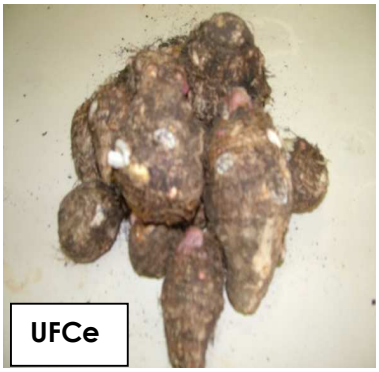
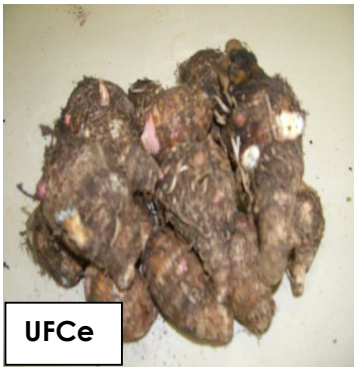
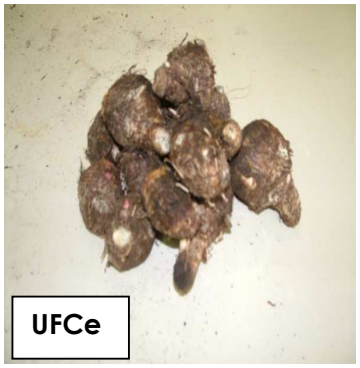
Figure 3 (A) Commercially available *Colocasia esculenta* tubers and (B) commercially available *Solanun tuberosum* tubers used in this study.





UFCe



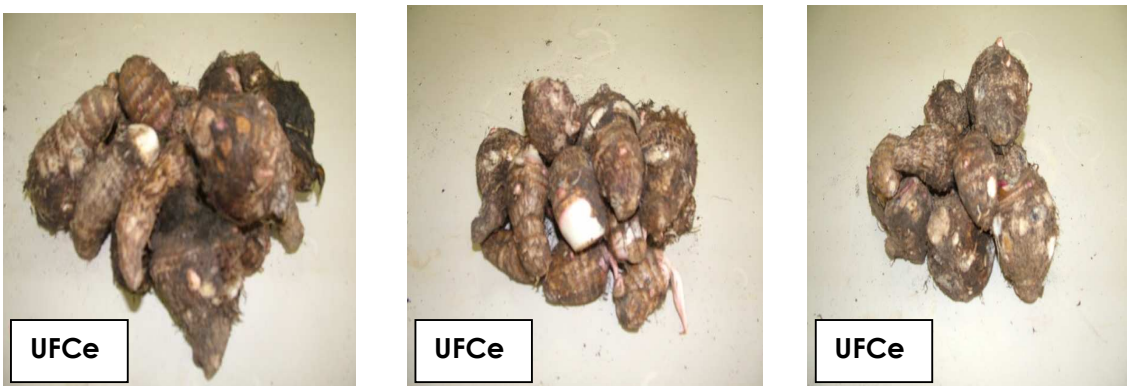


Figure 4. The seven accessions (UFCe1-UFCe7) of *Colocasia esculenta* tubers used for this study.

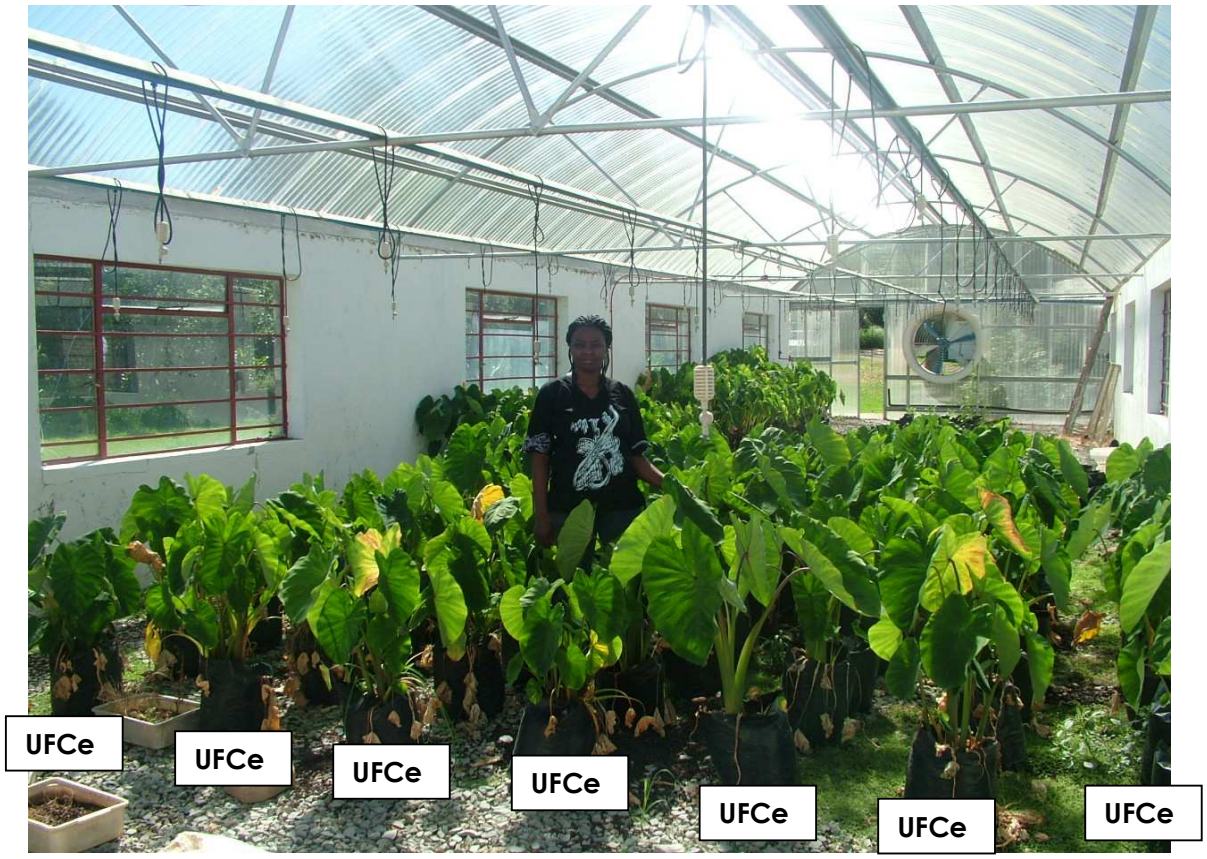


Figure 5. The vegetative parts of the seven accessions (UFCe1-UFCe7) of *Colocasia esculenta* whose leaves were used for this study, planted in rows in the green house.

Structure of the thesis

This thesis consists of contributions in form of manuscripts submitted for publication and reprints of published papers. Each scientific Chapter was prepared according to the reference citation and listing format of the specific journal the manuscript was submitted to. The thesis is structured as follows: Comparative assessment of the nutritional value of commercially available cocoyam and potato tubers in South Africa is presented in Chapter 2. Chapters 3 and 4 present the proximate, mineral and anti-nutritional factors in seven accessions of cooked and uncooked tubers of *Colocasia esculenta* tubers growing in South Africa. The effect of cooking on the proximate, mineral and antinutrient contents of the leaves of seven accessions of *Colocasia esculenta* growing in South Africa are reported in Chapters 5 and 6, while Chapter 7 reports on the effect of cooked accessions of *Colocasia esculenta*-based diets on the hepatorenal endpoints of weanling Wistar rats. The general discussion and conclusions of the entire study are presented in Chapter 8, in an attempt to present a coherent picture of the results obtained from investigating these cocoyam accessions.

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