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Exploiting the Diversity of Wild Yams for Food and Nutritional Security- A Review

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Abstract

In many countries around the world, food security and nutrition are major concerns. Wild yams (Dioscorea spp.) are an economically and nutritionally valuable crop for over 300 million people all over the world. There are diversities in the gene pool of wild yams. Utilising the diversity found in the wild yam gene pool has become necessary in order to address food and nutritional security. Wild yams (Dioscorea spp.) are crops that occupy a remarkable position toward achieving nutrition and food security due to their high yield, caloric value, superior carbohydrate content, and good source of essential dietary supplements such as protein and many dietary minerals. Yam provides food for millions of people in the world, especially in the tropics and subtropics. Yam is known as a famine food and is a staple in the diets of small, marginal rural families and communities during the food scarcity periods. Dioscorea tubers have a nutritional advantage over other root crops. This review highlights the diversity in wild yams and their potential for nutrition and food security.

Keywords: Wild Yam, Dioscorea, nutrition, food security

INTRODUCTION

Yams (Dioscorea spp.) are an important source of dietary energy and a source of livelihoods and income in West Africa (Mensah, 2005). Yam is described as an annual or perennial climbing plant with an edible underground tuber which is native to warmer regions of both the Southern and Northern Hemispheres (IITA, 2004). Yam is considered a famine crop which plays a major role in the food habits of small and marginal rural families and forest-dwelling communities in times of food scarcity (Ngo Ngwe et al., 2015). Yams play an important role in food security, pharmaceuticals and the economy in the developing countries. Dioscorea tubers have a nutritional advantage over other root crops (Shajeela et al., 2011), and their importance places them as the fourth most essential and utilised root and tuber crop globally after potatoes, cassava and sweet potatoes and the second most essential root and tuber crop in West Africa after cassava (Dansi et al., 2013).

Yams' potential as a source of food is attributed to their high levels of carbohydrates (fibre, starch and sugar), well-balanced essential amino acids, lipids, vitamins and minerals (Epping and Laibach, 2020; Padhan and Panda, 2020; Sajiwanie et al., 2016; Mensah, 2005; Charles et al., 2005; Bhandari et al., 2003).

There are over 600 species of the genus Dioscorea (Amanze et al., 2011). Out of the 600 species, only six are cultivated for food in the tropics, namely D. alata (water yam), D. rotundata (white guinea yam), D. esculenta (Chinese or lesser yam), D. cayenensis (yellow guinea yam), D. bulbifera (aerial or bulbils yam), and D. dumetorum. trifoliate or bitter yam) (Degras, 1993, Tetteh and Saakwa, 1994). Apart from these commercial yam species, there are other edible wild yams, such as D. burkilliana, D. minutiflora and D. praehensilis. These edible wild yams are grown on a subsistence basis. They are mostly found in forest areas and were the main source of food for hunter-gatherers (Sato, 2001). Most of the wild yams are unique for their food, medicinal and economic values. There is an enormous diversity in the wild and domesticated species which are used by tribal communities as traditional food.

Among the edible wild yams, bush yam is the most reliable staple food in Africa (Sato, 2006). Yields of these underutilised wild yam species could be three- to sevenfold greater than that of the known commercial species of yam (Treche and Agbor-Egbe, 1996; Brillouet et al., 1981).

There is therefore the need to utilise the full potential of wild yam species (Dioscorea spp.) given their contributory role in food security as a staple crop to a large number of the world's population as well as their nutritional benefits. This review highlights the diversity in wild yams and their potential for nutrition and food security.

Diversity of Wild yams and their importance as nutrition and food security crop

Diversity of Wild Yams

Yam (Dioscorea spp.) is the common name for over 600 species in the Dioscorea genus. Out of these 600 species, six (D. alata (water yam), D. rotundata (white guinea yam), D. esculenta (Chinese yam), D. cayenensis (yellow guinea yam), D. bulbifera (aerial yam), and D. dumentorum (trifoliate or bitter yam) are cultivated extensively in tropical and subtropical areas for their starch underground or aerial tubers (Degras, 1993; Tetteh and Saakwa, 1994). Apart from the six yam species that are cultivated commercially, there are other edible wild and semi-domesticated yams that are grown on a subsistence basis. These wild yams are mostly found in forest areas and are used by farmers and rural dwellers as a staple in filling the hunger gap during food scarcity periods as well as a source of traditional medicine (Andriamparany et al., 2014; Sato, 2001; Sato, 2006). Some of the edible wild yams are D. burkilliana, D. minutiflora and D. praehensilis (bush yam). The cultivation and the domestication of D. praehensils as the most reliable species with a notable contribution potential to food security and poverty alleviation have been reported in some African countries, such as Nigeria, Benin and Ghana (Dansi et al., 2013; Scarcelli et al., 2006; Scarcelli et al., 2019; Pitalounani et al., 2017).

Yields of these edible wild yams could be three- to sevenfold greater than the known commercial species of yam (Treche and Guion, 1979; Brillouet et al., 1981). Despite the importance of wild yams and their potential role in tackling the problem of food insecurity, their potential is underutilised (Scarcelli et al., 2019). Some initiatives have been put in place to increase yield, minimise losses and increase the profitability of yam in Ghana and some West African countries. Some of the initiatives are the West African Agricultural Productivity Programme (WAAP) and Root and Tuber Improvement and Marketing (RTIMP) (World Bank, 2007). However, these efforts for yam improvement have largely been targeted at the known commercial species and failed to exploit the potential of the edible wild yams. In Ghana, Dioscorea praehensilis (bush yam, known locally as 'kokoase bayere") has been an important food and income security crop for cocoa farmers for so many years, but this yam species is on the verge of disappearing (Anokye et al., 2014). Bush yam thrives well under secondary forests for which there is penetration of sunrays within the forest trees' canopy (Dumont et al., 2005; Hart and Hart, 1986; Hladik et al., 1984), hence its ability to grow under cocoa plantations in the rainforest zone of Ghana. Bush yam can also thrive in other tree crop plantations that provide some shade and also serve as stakes for the vines of the yam (Ajibola et al., 1988). Bush yam has several advantages over the commercial yam species. The benefits are that there are no known pests that have been documented, it is environmentally friendly to cultivate as it does not require elaborate land preparation, agronomic management or additional land as it can grow under established tree crop plantations, bush yam, when matured, can remain wholesome in the soil for several months if not harvested, the yield per mound of bush yam is much greater than that of the known commercial species, there is a great diversity to be exploited, and it readily flowers and produces seeds profusely, making it amenable to crop improvement through hybridisation (Awo Fianu, 2017).

Yam as a food security crop

Yam offers a significant contribution to the food security of households (Akromah and Bennet-Lartey, 1993; Kenyon and Fowler, 2000). Yam accounts for approximately 11.6 per cent of Ghana's total cultivated crop land, with an estimated 5.8 million metric tonnes produced annually (FAO, 2007). Yam revenue generation enhances the standard of living for resource-poor farmers, particularly women (Bennet-Lartey and Akromah, 1996). In some Sub-Saharan African countries, yam is a preferred food and a crop for food security (IITA, 2014). Yam can be processed into yam flour or pounded, and it can be consumed boiled or fried in oil (Ayensu and Coursey, 1972). Additionally, yams are a source of industrial starch, though the quality of this starch varies by species. However, some species' starches are on par with cereal starches (Osisiogu and Uzo, 1973). It offers a crucial food safety net between growing seasons and can be stored for four to six months without refrigeration (Babaleye, 2003).

Bitter yams, like Dioscorea dumetorum, are consumed during times of food scarcity as a typical "famine crop" despite their unpleasant taste and occasionally toxic qualities (Bhandari et al., 2003). Before consuming bitter yam, it must be detoxified by soaking and cooking. The West African yellow yam (Dioscorea cayenensis) gets its colour from the presence of carotenoids, and it is a good source of vitamin A (Bradbury & Holloway, 1988). The protein content of cooked yam is about 2 per cent, which is about twice as much as cassava. Therefore, yams can offer nutritional security in West Africa, where an estimated 60 million people rely on them to provide more than 200 dietary calories per day (FAO, 2002). Wild yams have the potential to contribute significantly to food and nutritional security, particularly in regions where they are traditionally consumed. The high nutritional value and diversity of wild yams make them an ideal crop for addressing micronutrient deficiencies and improving food security. Additionally, wild yams can be integrated into sustainable agriculture systems, providing a low-input and climate-resilient option for smallholder farmers.

Nutritional Value

Scientific studies have assessed and documented the nutritional qualities of various Dioscorea species over the years (Wu et al., 2016; Bekele and Bekele, 2018). The major component of yam is water.

Water contributes up to 93 per cent of the fresh weight of the tuber, especially in D. bulbifera, D. delicata, and D. pentaphylla (Mohan and Kalidass, 2010; Shanthakumari et al., 2018). The moisture content of other Dioscorea species ranges between 51 and 90 per cent (Shanthakumari et al., 2018). Dioscorea hespida varieties are said to have the lowest moisture content, ranging from 15.8 per cent to 37.8 per cent of fresh weight (Saleha et al., 2018). High values of moisture have also been reported in other root and tuber crops, with values ranging from 60 to 79 per cent in cassava, potatoes and sweet potatoes (USDA, 2018; Ayeleso et al., 2016). Maintaining the shelf life of produce and assessing the crops' vulnerability to microbial spoilage are significantly influenced by the moisture content of the roots and tubers (Polycarp et al., 2012; Sanful et al., 2013). The FAO estimates the postharvest losses of yams in the major and minor seasons are approximately 22 per cent and 39 per cent due to high moisture content, which greatly reduces revenue for both farmers and traders (FAO, 2011). Apart from high moisture content leading to spoilage, it is important to emphasise the significance of moisture in relation to the nutritional content of yam. According to a study on the impact of storage on yam nutritional content, it was observed that a drop in moisture content from 67.8 to 56.5 per cent led to protein content, total sugar, and reducing sugar increasing from 13 to 14.6 per cent, 6.5 to 9.8 per cent and 1.7 per cent to 2.3 per cent, respectively (Zhang et al., 2014).

Yam as a source of Dietary Energy

Yam is classified as an energy food source for consumers, especially in sub-Saharan Africa, due to its high starch content, which amounts to 80% on a dry weight basis (Zhu, 2015). Among the Dioscorea spp., D. alata has been reported by Wanasundera and Ravindran (1994) to contain a relatively high starch content of 84.3% when compared to other yam species. A study by Afoakwa et al., 2013, evaluated the starch composition of seven of the cultivated yam species (D. cayenensis, D. rotundata, D. alata, D. bulbifera, D. esculenta, D. praehensilis and D. dumenturum) in sub-Saharan Africa and reported between 63.2% and 65.7% starch content. The variation observed in the starch content depended on several environmental factors, agronomic practices and the degree of maturity. The granules of yam starch are composed of a combination of branching (amylopectin) unbranched (amylose) chain polymers of D-glucose usually occurring at a percentage ratio of 78:22 (El Seoud et al., 2013). These values may vary depending on species as well as genotype.

Yaw as a source of Dictary fibre

Yaw contains dietary fibre, which plays a vital role in the digestive systems of humans and animals. Adequate intake of fibre increases water holding capacity , aids in regular bowel movement, increases faecal bulkiness and decreases intestinal transit. Dietary fibre also promotes beneficial physiological effects such as reduction of blood sugar and bad cholesterol levels, trapping of toxic substances and encourages the growth of natural microbial flora in the gut (Dhingra et al., 2012, Satija and Hu, 2012, Slavin, 2013, Sanchez-Zapata, 2015).

Yam as a source of protein

Protein is an essential nutrient that is required for growth and development in humans and animals. It helps in the repair of body tissue and synthesis of enzymes and hormones. Protein also contributes to energy supply. Even though roots and tubers are known for their low protein content when compared to legumes and cereals, yam is reported to have higher dietary protein when compared to other root and tuber crops such as cassava (FAO, 2020; Chandrasekara and Kumar, 2016). Yam tubers are a considerable good source of essential amino acids, including phenylalanine and threonine, but are limited in tryptophan and sulphur amino acids (Baah et al., 2009; Epping and Laibach, 2020; FAO, 2020). A study on amino acid profiling of eight wild Dioscorea species (D. alata, D. bulbifera, D. esculenta, D. tomentosa and D.

wallichi) revealed the prevalence of aspartic acid and glutamic acid in all the eight species investigated (Doss et al., 2019).

Yam as a source of Lipids

Lipids have also been reported in yam. Though the components of lipids are present at a minimal fraction, they have a great impact on the functionality of starch (Shu, 2015). A wide range of concentrations of lipids have been reported in D. hamiltonii (Mohan and Kalidass, 2010). Lipids supply energy blocks for the cell membrane.

Yam as a source of Minerals

Yam contains minerals which play vital roles in the body's metabolism. These minerals include macrominerals such as potassium, sodium, calcium, phosphorus, magnesium, chloride and sulphur, as well as trace elements which are needed in smaller quantities, such as copper, iron, manganese, zinc, iodine, cobalt, fluoride and selenium. A study done on the mineral profiling of 43 genotypes from five yam species revealed an intra- and inter-species variation in the mineral content of yam (Otegbayo et al., 2018).

Potassium, sodium and chloride play a key role in the maintenance of total body fluid volume and charge gradients across cell walls and are also responsible for nerve transmission and muscle contraction (Khaw and Barrett-Connor, 1987). Yams are better sources of potassium than other root and tuber crops such as cassava, potatoes and sweet potatoes, as well as in cereals such as maize, rice and wheat (Neela and Fanta, 2019). Another important macromineral present in yam is calcium. Calcium plays an important role in muscle functions, nerve transmissions, vascular contraction, intracellular signalling, vasodilation and hormonal secretion (Beto, 2015). Calcium content in yam varies depending on the species. It is reported that D. Bulbifera has the highest calcium content (Ezeocha et al., 2014). The metabolism of calcium involves other nutrients such as amino acids, vitamin D and phosphorus.

Phosphorus plays a role in maintaining healthy bones and teeth, the acid-base balance of the body, and DNA and RNA structure (Karp et al., 2007). The recommended daily allowance of phosphorus for a healthy adult is 700 mg/100 g, but a study done by Soto et al., 2014, on the yam species D. remotiflora recorded 720 mg/100 g. This means that the yam species D. remotiflora can provide the needed phosphorus that the body requires.

Yam is reported to be a good source of magnesium. Magnesium plays an important role in the body's metabolic process, nerve transmission, and synthesis and stability of DNA (Saris et al., 2000; Sales and Pedrosa, 2006). A study on assessing the magnesium content in three yam species (D. oppositifolia, D. pentaphylla and D. wallichi) came out that D. oppositifolia recorded the highest magnesium content, followed by D. wallichi, then D. pentaphylla, respectively (Shajeela et al., 2011).

Macrominerals, such as iron, manganese, zinc, and copper, have also been reported in different yam species. Iron plays a role in the formation of haemoglobin in red blood cells, which bind and transport oxygen in the body. Otegbayo et al., 2018, conducted a study on the iron content in five yam species, and after the study, the order of importance as far as iron in these yam species is concerned was D. dumetorum > D. bulbifera > D. alata > D. cayenensis > D. rotundata.

Copper, zinc and manganese have also been reported in different species of yams. Two yam species, D. pentaphylla and D. bulbifera, are said to contain the highest amounts of copper, zinc and manganese.

Wild yams are a rich source of essential nutrients, including starch, fibre, protein, macro- and micronutrients.

CONCLUSION

The commercial and wider cultivation and utilisation of wild yam species is not without its challenges and limitations. Some of the major limitations are short postharvest shelf life, some of the species have their tubers being hardened when cooked, which makes it difficult to consume, and other species have a bitter taste. These challenges restrict the consumption and marketing of freshly harvested tubers. Despite these challenges, yam has an abundant storage of water, carbohydrates, dietary fibres, protein, macro- and micronutrients. These nutrients are needed for the normal functioning of the body and to minimise malnutrition among people. Wild yam can remain wholesome and can be harvested in pits (piece meal) over several weeks and months. This attribute of wild yam makes it a potential food security crop for most parts of the year and a source of income. Moreover, wild yam produces seeds that are naturally dispersed, and the seeds germinate in the wild, and this creates diversity in the population with regard to yield, quality and post-harvest shelf life. Wild yams offer a rich source of genetic diversity and nutritional value. Despite their potential, wild yams remain underutilised and understudied. To harness the potential of wild yams for food and nutritional security, further research and development are needed, along with efforts to conserve and sustainably use these resources.

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