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REVIEW ARTICLE

Review on Nutritional Importance, Health Benefits and Industrial Relevance of Purple Yam

Tanushree Chakravarty*, Reena Verma
Department of Home Science, IIS (deemed to be University), Jaipur

Abstract

Dioscorea alata is commonly known as purple yam. It is economically the most important species in Southeast Asia, specifically in Myanmar and Thailand. It is most diversified and extensively distributed across the word, particularly in Africa, Asia Pacific and Southeast Asia. But it remains an underutilized vegetable in India. It is a rich source of carbohydrates. Its flesh ranges in colour from white to pink or purple. This colour can be attributed to the presence of a class of antioxidants, namely anthocyanins. Apart from carbohydrates, it provides appreciable amounts (10% or more of the Daily Value or DV) of potassium, dietary fibre, vitamin C, folate and thiamine. It supplies 118 calories per 100 grams. It has a low glycemic index of 54% glucose per 150 grams serving. It also contains resistant starch, which improves digestion and stimulates the growth of gut microbiota. It plays an important role in the diets of vegetarians across the world by increasing dietary diversity, increasing food security and preventing energy insufficiency. It can be converted to flour in order to enhance its shelf-life and promote round year availability. Scientific studies in the recent past have established a positive association between consumption of plant foods and reduction of Non Communicable Diseases (NCDs). Plants contain varieties of non-nutrient phytochemicals which are synthesized as secondary metabolites and offer a wide range of health benefits. Tuber root crops, such as purple yam, particularly consist of saponins, alkaloids, carotenoids, phenolic compounds which have antioxidant, immunomodulatory, antimicrobial, antidiabetic properties. Purple yam also contains a steroidal saponin called diosgenin, which has free radical scavenging activity. Understanding the impact of these phytochemicals on human health is important for consumers. Purple yam can be considered as functional food owning to the broad range of health benefits that it offers. This review paper focuses on the nutritional importance and health benefits of purple yam while highlighting its industrial relevance as functional food.

Keywords: Antioxidant, *Dioscorea alata,* Functional food, Phytochemicals, Purple yam, Resistant starch.

Introduction

Dioscorea alata, commonly known as purple yam, is an underutilized, vegetable in India. It is, as a vegetable, classified under roots and tubers. It is a rich source of carbohydrates. Its flesh ranges in colour from white to pink or purple. This colour can be attributed to the presence of a class of antioxidants, namely anthocyanins, which are present in purple coloured fruits and vegetables. It is consumed as a cooked starchy vegetable as it cannot be eaten raw. It is native to warmer regions of both hemispheres. In the tropics, yam is the primary agricultural commodity. It is cultivated in tropical and temperate regions such as Africa, South America, Asia, Oceania and the Caribbean islands (FAO, 2020). Purple yam plays an essential role in the diets of vegetarians across the world by increasing dietary diversity, increasing food security and preventing energy insufficiency. It can be converted to flour in order to enhance its shelf-life and promote round year availability. It enhances dietary diversity, food and nutritional security in times of natural calamities such as droughts and famines. Roots and tubers such as yams, taro, sweet potato, cassava and potato contribute to global food production and are chief sources of animal feed and processed products for humans (Chandra-sekara and Joshepkumar, 2016). It is unique because of

*Corresponding Author Email : tanushreechakravarty109@gmail.com

its food, medicinal, economic value and cultural importance (Padhan and Panda, 2020). Yet it remains underutilized in our country. This review paper explores the nutritional importance and health benefits of purple yam while highlighting its industrial relevance as functional food.

Scientific Classification of Purple Yam

The scientific classification of purple yam is given in Table 1.

Table.1. Scientific classification of purple yam

Kingdom	Plantae
Division	*Magnoliophyta*
Class	Monocotyledons
Order	Dioscoreales
Family	Dioscoreaceae
Genus	*Dioscorea l.*
Species	*D. alata*
Binomial name	*Dioscorea alata*
Common name	Purple yam

Source: NCBI taxonomy database (Schoch *et al.*, 2020)

Cultivation of Purple Yam

Yam is cultivated during monsoons by planting the seeds or parts of the tuber in mounds. The location of the plant, the method of planting, sizes of the mounds, interplant spacing and yam specie are some of the factors which influence its yield. Growth takes place in the wet season while the plant remains dormant in the dry season. Humidity has a positive effect on its growth and so does rainfall.

World Production

74.8 million tonnes of yam was produced in the year 2020 in the world spanning a harvest area of approximately 8.7 million hectares. Nigeria contributed 67.04 %, followed by Côte d'Ivoire, Benin and Ghana contributing the remaining 32.96% of the world production. Yam is an important fresh produce in the West African countries (FAO, 2020). Although it is not cultivated in the same quantity as African yam, purple yam is the only type of cultivated yam having the highest distribution across the world (FAO, 2020). It is economically the most important species in Southeast Asia, specifically in Myanmar and Thailand (Tamiru *et al.*, 2007). It is most diversified and extensively distributed throughout the globe (Fig. 1).

Production in Asia

It is mainly cultivated in China, Taiwan, Japan, Sri Lanka, Philippines and India. The annual production of

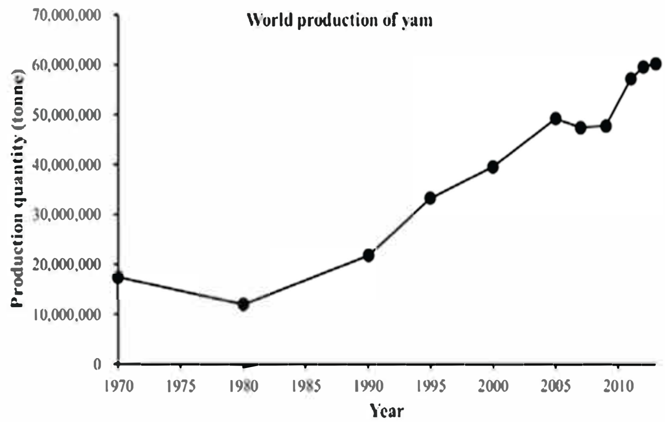

Fig. 1.World production of yam (FAO, 2020)

purple yam in the Philippines is 17,540 metric tonnes (FAO, 2020). It is one of the highly valued and widely cultivated crops, given its export potential and the variety of processed products that are made out of it. In Taiwan, the annual production of purple yam is more than 200 metric tonnes (Chandrasekara and Joshepkumar, 2016). In India, the highest production is in Kerala, where it is locally known as *Mullkizhangu*, followed by Karnataka and Maharashtra (CTCRI, 2012).

Conventional Uses of Purple Yam

It is mainly cultivated for the enlarged, fleshy and starchy root which is a rich source of carbohydrates. It cannot be consumed raw and needs to be cooked for consumption. When purple yam is well cooked, its cell walls become soft. This causes removal of vitamins and minerals. Although it can be skinned, chopped and frozen for a later use, the most common cooking methods are boiling, frying and roasting. It is a very popular component of desserts such as *ube*, bakery products, confectionaries and ice creams in the Philippines due to its bright purple colour. It can also be converted to flour form in order to enhance its shelf-life. Its starch can also be industrially isolated and used as a thickening agent in soups and gravies. In Nepal, it is served as an accompaniment to rice in the form of curry. Purple yam is the primary ingredient of a starchy pudding called *amala* which is consumed in West Africa.

In India, its culinary usage varies from region to region. In Gujarat, purple yam is either used on its own to make dry, stir-fried sabzi or combined with other vegetables in *undhiyu*, a traditional recipe which is consumed on Makar Sankranti. In Rajasthan, it is steamed, then deep fried till it turns crispy and subsequently seasoned with spices. In West Bengal, it is combined with prawns and consumed in the form of a *dalna* or gravy. In Kerala, it is cooked in a curry of coconut milk while in Maharashtra, it is deep fried in the form of fritters. It is consumed in the form of kheer and halwa during fasting and is a winter staple in different parts of the country. It plays an enhanced role in the diet of vegetarians and is preferred by hardcore non-vegetarians on days when they cannot have animal meat due to religious abstinence.

Nutritional Profile of Purple Yam

Apart from starch, yams contain considerable amounts of various dietary nutrients such as proteins, lipids, vitamins and minerals (Mohan and Kalidass, 2010). The nutritive value of raw purple yam is given in Table 2.

Table 2. Nutritive value of 100 g of purple yam

Nutrient	Content
Energy (kCal)	140
Protein (g)	1
Carbohydrate (g)	27
Fat (g)	0.1
Dietary fibre (g)	4
Sodium (% DV)	0.83
Potassium (% DV)	13.5
Iron (% DV)	4
Calcium (% DV)	2
Vitamin C (mg)	40
Vitamin A (mg)	4

(Source: McCabe, 2019)

Raw purple yam has moderate nutrient density with appreciable amounts (10% or more of the Daily Value or DV) of potassium, dietary fibre and vitamin C. It supplies 140 calories per 100 grams (McCabe, 2019). It has a low glycemic index of 54% glucose per 150 grams serving. It also contains resistant starch, which improves digestion and stimulates the growth of gut microbiota (Li *et al.*, 2018).

Health Benefits of Purple Yam

Although yams have been consumed since centuries for their starch content and economical price, it is only in the last couple of decades that their potential health benefits has garnered public interest. Scientific studies in the recent past have established a positive association between consumption of plant foods and reduction of Non Communicable Diseases (NCDs). Plants contain varieties of non-nutrient phytochemicals which are synthesized as secondary metabolites and offer a wide range of health benefits. Tuber root crops, such as purple yam, particularly consist of saponins, alkaloids, carotenoids, phenolic compounds which have antioxidant, immunomodulatory, antimicrobial, antidiabetic properties. Purple yam also contains a steroidal saponin called diosgenin, which has free radical scavenging activity (Chen *et al.*, 2009). Understanding the impact of these phytochemicals on human health is important for consumers as it would help them to make informed choices.

Antioxidant Property

Intake of foods which are rich in antioxidants is associated with anti-aging and decreased susceptibility for Non Communicable Diseases. This can be attributed to the free radical scavenging property of antioxidants. Adebowale *et al.* (2018) explored the anti-nutritional and micronutrient components of yam flour and the effects of drying, species and pre-treatment on the same. The study concluded that pre-treatment and drying method had a significant influence on the vitamin content of high-quality yam flour. The appreciable level of vitamin C recorded in all the flours indicated good quality yam flour which was fit for the consumers. Abeynayake and Sivakanesan (2015) assayed the changes in *Dioscorea alata* once it was boiled. The researchers recommend minimum usage of water for boiling and preserving the same. Moriya *et al.* (2015) studied the anthocyanins in purple yam. The researchers inferred that antioxidant capacity was lower in ferulic acid group in comparison with sinapic acid group. Khan *et al.* (2014) conducted a study on the impact of *Dioscorea alata* on rat models with spleen toxicity. The study concluded that debilitation of splenic toxicity could be attributed to free radical destroying activity of *Dioscorea alata*. Chung *et al.* (2007) examined the effects of various processing methods on purple yam's antioxidant capability. The results revealed that the water extracted from yam peel had more antioxidant than that extracted from the flesh. It was also noted that preserving the peel by freeze drying could retain more antioxidants than the peels which were dried using hot air.

Anti-inflammatory Property

Haggard *et al.* (2018) estimated the protective potential of anthocyanin rich plant extracts on an *in vitro* model of celiac disease. The study deduced that those plant extracts which comprise of anthocyanins, such as water yam, have a positive implication for human health as these extracts could potentially decrease the occurrence of inflammation for gluten sensitive individuals. Dey *et al.* (2016) appraised the anti-inflammatory prospects of *Dioscorea alata*. The researchers concluded that *D. alata* extract significantly downregulated the pro-inflammatory signals in a gradual manner compared with control (0µg/mL). Kwon et al. (2014) studied the effect of Trillin found in *Dioscorea alata*. The results extrapolated that trillin administration in hyperlipidaemic rat model not only improved the bleeding and clotting time, it reinstated cholesterol to the normal range.

Treatment of Menopausal Symptoms

Lu *et al.* (2016) conducted *in vitro* studies on four, different species of yam. The results inferred that the proteins found in *D. alata* and *D. zingiberensis* could potentially reduce the risk of ovarian cancer in post - menopausal women. Peng *et al.* (2013) investigated the anti-osteoporotic activity of *Dioscorea alata L. cv. Phyto* through driving mesenchymal stem cells differentiation for bone formation. The researchers averred that Dispo85E found in *Dioscorea alata L. cv. Phyto* increased bone nodule formation and levels of alkaline phosphatase (ALP). Therefore, it promotes osteoblast-ogenesis in primary bone marrow cultures. Hsu *et al.* (2010) examined the efficacy of *Dioscorea alata* for menopausal treatment in Taiwanese women. The study found that *Dioscorea alata* improved the psychological symptoms in menopausal females. The safety aspects of consumption were taken into account and it was deduced that consuming yam extracts daily for a year was safe. Chen *et al.* (2009) studied the bone protective effect exerted by Taiwanese *Dioscorea alata* on ovariectomised female rats. The study concluded that bone mineral density was enhanced on its consumption.

Effects on Diabetes Mellitus

Chiranthika *et al.* (2021) assayed *in vitro* amylase and amyl glucosidase activities of underutilized roots, yams and cereals. The researchers inferred that inclusion of dietary fibre sources, such as *Dioscorea alata*, in daily diet may provide additional health benefits to consumers. Rosida *et al.* (2016) studied the effect of modified *Dioscorea alata* flour on diabetic rats. The results extrapolated that the flour had the ability to reduce blood sugar level, increase short chain fatty acid formation while inhibiting glucose absorption. Guo *et al.* (2015) analysed the protective effects exerted by Chinese purple yam against oxidative stress and insulin resistance. The study concluded that purple yam extracts protect HepG2 (human liver cancer) cells against insulin resistance and reduce oxidative stress caused due to diabetes. Helen *et al.* (2013) appraised the property of *Dioscorea alata L.* in body weight reduction by reducing food intake and fasting blood glucose level. The study concluded that food intake, fasting blood glucose level and body weight were significantly reduced after a period of 21 days. Thus, it could play a part in weight and diabetes control. Maithili *et al.* (2011) explored the capacity of ethanolic extract of *Dioscorea alata* in diabetic rats. The researchers deduced that ethanolic extract of *D. alata* tubers possess significant antidiabetic activity.

Effects on Digestive Health

In general, increased consumption of resistant starch improves digestion and delays gastric emptying. This in turn, reduces the glycemic index or GI of the food as it slows the entry of glucose in the blood stream. Padhan and Panda (2020) explored the health benefits and capacity of abandoned and underused yam (*Dioscorea spp*). The researchers averred that yam forms an integral part of daily diet of the rural and tribal populations during periods of food scarcity such as droughts and famines. Lavlinesia *et al.* (2019) used *Dioscorea alata* flour to prepare wet noodles. The study found that purple colour of the tuber could be retained in the flour by steaming it for 7 minutes. The flour containing 40% purple yam flour was found to be acceptable, beyond which the texture of the product was compromised. Renata *et al.* (2017) explored oligosaccharide content in cooked roots and tubers during *in vitro* digestion. The study concluded that in case of *Dioscorea alata* the FOS levels increased significantly after digestion on account of hydrolysis. Christina and Rifa'l (2014) evaluated the bioactivity level of purple yam in allergic mice. The results extrapolated that ethanolic purple yam extract triggered the immunocompetent activity of T cells in mice model of digestive allergy. The memory of T cells increased considerably after administration of ethanol extract of purple yam in lower doses.

Functional Food Property

Chiranthika *et al.* (2020) explored potential applications of yam and cereals as functional foods for Non Communicable Diseases (NCDs). The researchers averred that yam products not only promote food security but they exhibit prebiotic effect as well. Awolu and Olofinlae (2016) appraised the properties of two types of yam starch- one natural and the other chemically altered. As part of the study, yoghurt was prepared using purple yam starch. The results of sensory evaluation denoted that acetylated starch variant of yoghurt was most acceptable among all. Obadina *et al.* (2014) investigated the influence of soaking on nutrititive value, functional property and sensory properties of yam flour. The study found that when *Dioscorea alata* was soaked for 18 hours, all other nutrients, except for protein, were retained. When this flour was used to prepare a paste, it enhanced its sensory attributes. Wireko-Manu *et al.* (2011) conducted a study to find out if *Dioscorea alata* was appropriate for preparing their product *Amala.* The researchers concluded that *Dioscorea alata* was not the preferred choice of yam for majority of the developed products. Nonetheless, it was found to be a good choice for preparing *Amala.* The study recommends diversifying its culinary uses to ensure better food security in those areas where it is cultivated.

Resistant Starch Property

Li *et al.* (2019) studied the beneficial effects exerted by resistant starch component of *Dioscorea alata* on hyperlipidaemic hamsters. The results extrapolated that high dosage of resistant starch was more effective in controlling body weight and adipose tissue mass. It also raised HDL concentration and the concentration of prebiotic bacteria such as *Bifidobacterium,* lowered LDL concentration while reducing fat accumulation in the liver. Li *et al.* (2018) conducted an *in vitro* study on the prebiotic effects of *Dioscorea alata* resistant starch on *Bifidobacterium adolescentis.* The study revealed that *bifidobacteria* showed better growth on the media prepared by using the resistant starch extracted from *D. alata.* The researchers deduced that *D. alata* can be used as a prebiotic for the better growth of bifidobacteria to simulate upper gastrointestinal conditions. Mao *et al.* (2018) assayed four types of resistant starch (RS) present in *Dioscorea alata* L. The researchers inferred that resistant starch significantly reduced oxidative stress. RS3 and RS5 were superior to the other types in terms of antioxidant capacity.

Gluten-free Property

Otolewo *et al.* (2021) estimated the mineral, microbial and organoleptic potential of ready to eat food products prepared using a combination of *Dioscorea alata* and *Phaseolus lunatus.* The results showed that the products were nutritious and good alternatives for individuals having gluten sensitivity and celiac disease. Seyguchi *et al.* (2012) assayed the usage of purple yam flour for preparing gluten-free bread. The researchers averred that yam flour is most suitable for producing gluten-free bread having adequate height and volume. Thus, it could be substituted for wheat flour when baking bread for celiac disease patients.

Industrial Relevance of Purple Yam

Oko and Famurewa (2015) estimated the nutritional and starch characteristics of purple yam (*Dioscorea alata*) varieties commonly cultivated in Nigeria. The study concluded that yam varieties have a low glycemic index, low mineral content and are suitable as staple food for the diabetics. Hence, there is a need for intense cultivation of improved varieties of purple yam for the consumers. Zhu (2015) studied the isolation, composition, structure, properties, modifications and uses of yam starch. The researchers averred that amylose content in yam starch ranged from 0-40%. It also has higher gelatinization power compared to starches from other crops like maize and potato. Thus, there is a potential to utilize yam starches in food applications. Oke *et al.* (2013) explored the effect of varieties on physicochemical and pasting characteristics of water yam flour and starches. The research deduced that all varieties had appreciable pasting and gelation properties. The swelling power of starch was also found to be desirable for developing value-added food products. Teixeria *et al.* (2013) studied the use of purple yam as a health promoting ingredient in bread making. The study revealed that the use of purple yam flour instead of wheat flour in preparing ordinary bread raised the antioxidant activity while only bringing about a slight change of colour in the bread. Thus, it highlights the feasibility of purple yam as a health promoting food. Fang *et al.* (2011) studied the phenolic compounds in Chinese purple yam and changes produced in it due to vacuum frying. The study found that the retention rate of phenolic compounds during vacuum frying was 60-69 %, which indicates phenolic compound stability. It also recommended vacuum frying as a practical technology for purple yam processing. Krishnan *et al.* (2010) explored the impact of pre-soaking on sweet potato and yam flours. The researchers recommended the use of citric acid, acetic acid and other cost effective chemical agents in low amounts to combat browning.

Conclusion

This review paper highlights the nutritional profile, health benefits and potential industrial relevance of purple yam as a functional food in improving nutrition and health. Roots and tubers have been staple components of the human diet since a long time. Apart from being rich sources of starch, coloured roots and tubers such as beetroot, carrot, purple yam, purple sweet potato are rich sources of various antioxidants such as betalins, carotenes, anthocyanins, and phenolic acids, which provide a host of benefits such as free radical destruction and inflammation prevention. Yam is an affordable food source of micronutrients and starch and is available across the world. It forms a staple in vegetarian households globally as it by increases dietary diversity, increases food security and prevents energy insufficiency. It can be converted to flour in order to enhance its shelf-life and promote round year availability. It has antioxidant, antihypertensive, antidiabetic and antarthritic properties. It is gluten-free and aids in digestion. Research studies have revealed that it provides several health benefits for those suffering from hypertension, arthritis, coeliac disease, gluten intolerance, gluten insensitivity, heart disease, irritable bowel syndrome (IBS) and post-menopausal women. Thus, a broad spectrum of individuals can reap its benefits, without compromising on their health.

The current review on the health benefits of purple yam largely comprises of *in vitro* studies. Further, it does not include the differences between short term and long term consumption. Intervention studies are needed to determine the impact of these health benefits on diseased individuals and diverse population, at large and to translate them into relevant health outcomes. Although the impact of various processing techniques on the nutritional and non-nutritional constituents of purple yam have been documented, human interventions are needed to bridge the gap and provide evidence for the direct health benefits of consumption.

Future Prospects

Processing of purple yam in the form of flour not only retains the nutrients but intensifies its keeping quality and usage in recipes where it is not incorporated traditionally. Recognizing the tremendous health benefits offered by purple yam and based on the review of available scientific literature related to its property of functional food development, it is important for the global consumers to be made aware about the same. For this purpose, the government should encourage the food industry to invest in the development of functional foods prepared from purple yam. In addition, purple yam extract could also be used as complementary nutrient in fortified, enriched and weaning foods, so as to improve their nutrient profile. These efforts could be an additional source of income generation and export in these testing times, providing a viable alternative to imported food supplies. They could ease the burden of malnutrition. Partnerships between the food industry and researchers (universities) would open more avenues for food product development and enhance their saleability in future. This will not only pave the way for a broader range of functional food products in the market but it will also boost the consumer's confidence in the healing properties of natural food ingredients.

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