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Bioactive components, food applications and health benefits of yam (*Dioscorea* spp.): A review

Pranav Singh and Twinkle

Abstract
The quest for a food secure and safe world has led to continuous effort toward improvements of global food and health systems. While the developed countries seem to have these systems stabilized, some parts of the world still face enormous challenges. Yam (*Dioscorea* species) is an orphan crop, widely distributed globally; and has contributed enormously to food security especially in sub-Saharan Africa because of its role in providing nutritional benefits and income. Additionally, yam has non-nutritional components called bioactive compounds, which offer numerous health benefits ranging from prevention to treatment of degenerative diseases. Pharmaceutical application of diosgenin and dioscorin, among other compounds isolated from yam, has shown more prospects recently. Despite the benefits embedded in yam, reports on the nutritional and therapeutic potentials of yam have been fragmented and the diversity within the genus has led to much confusion. An overview of the nutritional and health importance of yam will harness the crop to meet its potential towards combating hunger and malnutrition, while improving global health.

There are many types of spread and jams that are consumed in day to day life. They are usually having a good taste and some of them are nutritious, providing health benefits along with preventing from various health diseases. In this regards, yam could be a appropriate alterative in respects of providing health benefits because of the presence of various bioactive components in it that act effectively on the human body. Apart from this what changes occurred in the biochemical, minerals and anti-nutritional composition of yam spread when it is blended with processed cheese. This review makes a conscious attempt to provide an overview regarding the nutritional, bioactive compositions and therapeutic potentials of yam spread. Insights on how to increase its utilization for a greater impact are elucidated.

Keywords: Yam, *Dioscorea*, nutritional composition, bioactive compounds, therapeutic potential

Introduction

Yam an edible tuber and the fourth largest growing plant species belong to genus *Dioscorea* of the family *Dioscoreaceae.* Being starchy by nature, it is consumed in the form of fresh vegetables after boiling or cooking the tubers that are sliced and peeled. Many value-added products like spreads, jams, chips, dehydrated slices, flour, pickles, etc. can be made from it (Odigbo *et al*., 2015) [1]. Yam is popular by its common namesas *Ole*, *Balukand*, *Suran* or *Zamikand* and constitutes a sufficient and cheap source of energy-giving food (Kumar, *et al*., 2018). The nutritional acceptability of yam is because of the presence of carbohydrates (17.10-29.37%), proteins (0.2-3%), fats (0.00-0.29%), vitamins especially vitamin C and minerals (P, K, Ca, Mg, Fe, Na) (Chandrasekara & Kumar, 2016; Falade *et al*, 2015; Ogidi *et al*, 2017) [3, 4, 5]. Besides, the presence of various bioactive compounds like phenols, flavonoids, and alkaloids offers certain health benefits. The present paper, therefore; focuses on the health-promoting, immune system alleviating, disease prevention, and industrial utilization of yam.

There are 870 no. of species of yam available of which the principal economic species are the Enantiophyllum yams which usually produce one to three tubers, which may be of any shape i.e. globular, cylindrical arelongated, branched or lobed, having a weight ranges from 3 to 15 kg. The Lasiophyton yams form several medium size tubers, that sometimes fused into an irregular clusters. Asian Combilium yams and the American Macrogynodium yams produce a large number of tubers that have a small spindle-shape that are somewhat similar to sweet potatoes. Tubers are act as a storage organs and often grown to a considerable size, they produce fibrous, short adventitious roots and annual shoots also, which are twining (except in dwarf species) in nature, there are specific direction of twining. Usually Each yam plant may produce one large tuber, but some varieties also constitutes several smaller tubers also.

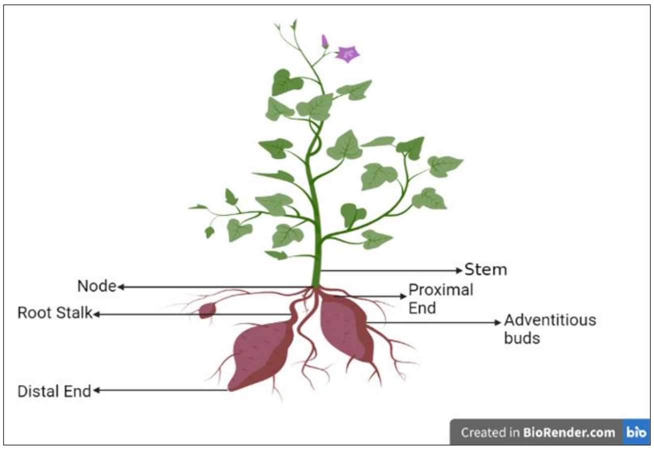

Fig 1: Typical cross section of a yam (FAO, 2010)

Biochemical and Nutritional Composition of Various Yam Varieties

The biochemical composition and nutritional value of six different species yam tuber examined in this study were presented in Table 1. The result showed that there was variation in the biochemical composition and nutritional value among species. The proximate composition values including moisture, carbohydrate, fiber, protein, fat and ash.

Biochemical and Nutritional Information of Yam (in % dry weight): Proximate analysis of Yam like, (Nutritional Composition) analysis testing which include Moisture, Ash, Fat, Crude Fiber, Protein and Carbohydrates content are depicted in table-1 as under.

Table 1: Biochemical Properties of Different *Dioscorea* Varieties

Varieties	Moisture Content	Ash Content	Crude Fibre Content	Fat Content	Protein Content	Carbohydrate Content	References
Dioscorea purpurea	9.90 – 13.64	3.40–4.03	3.38 – 6.35	0.99- 1.90	10.46 – 10.77	70.88 - 74.46	Fauziah *et al*, 2015 [6]
Dioscorea atropurpurea	9.20 - 12.41	3.45 – 4.72	3.50 – 3.57	1.15 – 1.83	10.15 – 11.97	71.55 – 72.67	Baah *et al*, 2009 [7]
Dioscorea liliopsida	9.90 – 12.77	3.53 – 3.78	3.53 – 6.21	2.39 – 3.26	8.71 – 8.85	71.95 – 73.90	Otegbayo *et al*, 2012 [8]
Dioscorea vilgaris	10.30 – 15.39	2.48 – 5.26	3.31 – 4.57	0.62–0.91	8.40 – 9.98	73.90 – 74.02	Beyene *et al*, 2018 [9]
Dioscorea villosa	9.50 – 13.59	3.14 – 3.98	3.33 – 4.63	2.41 – 3.15	10.02 – 10.05	71.57 – 71.81	Beyene *et al*, 2018 [9]

Mineral Composition (in mg/kg)

The content of minerals analyzed comprised Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Phosphorus (P) and Iron (Fe) 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. Mineral Composition of different yam varieties are as under table-2 below.

Table 2: Mineral Composition of *Dioscorea* Varieties

Varieties	Sodium	Potassium	Calcium	Magnesium	Phosphorus	Iron	Reference
Dioscorea purpurea	18.38	134.68	79.99	25.58	114.65	20.61	Fauziah *et al*, 2015 [6]
Dioscorea atropurpurea	16.38	141.14	269.75	29.77	211.63	19.25	Baah *et al*, 2009 [7]
Dioscorea liliopsida	16.99	127.04	168.09	21.04	117.10	16.86	Otegbayo *et al*, 2012 [8]
Dioscorea Vilgaris	24.84	111.30	196.90	18.55	205.10	30.86	Beyene *et al*, 2018 [9]
Dioscorea villosa	21.06	97.78	140.07	31.53	169.76	15.18	Beyene *et al*, 2016 [9]

Antinutritional Composition (in mg/100g)

Anti-nutritional content analyzed comprised tannin, total flavonoids content, total phenolic content, alkaloid and saponin. Tannin content was determined by Folin Denis Reagent using UV Spectrophotometry (Pratik, Prakash & Chandrashekhar, 2016) [10]. The number of total phenols was calculated as tannic acid equivalent from the standard curve. Total Flavonoid Content was calculated as Quercetin equivalent from the standard curve which were analyzed through UV spectrophotometry. Anti-nutrition values of six different varieties of yam are as under table 3.

Table 3: Comparative analysis of Anti-Nutritional compositions of different varieties of *Dioscorea*.

Varieties	Saponin	Total Flavonoid Content	Tannin Content	Alkaloid	Total Phenolic Content (TPC)	References
White Yam (*Dioscorea alata)*	2.88	4.21	0.00	0.34	0.02	Adebowale *et al*, 2018 [11]
Yellow Yam(*Dioscorea villosa)*	17.21	6.81	0.01	0.76	0.06	Udensi *et al*, 2010 [12]
Bitter Yam (*Dioscorea dumetorum)*	15.8	15.69	0.02	0.97	0.00	Ogbonna and Ibeji, 2015 [13]
Air-potato Yam (*Dioscorea bulbifera)*	14.90	9.94	0.09	0.94	0.00	Okorie, 2018 [14]
Yellow Guinea Yam (*Dioscorea cayenesis)*	0.43	11.03	0.50	0.60	0.85	Shajeela *et al*, 2011 [15]
Guinea Yam (*Dioscorea rotundata)*	0.44	13.57	0.44	0.48	0.66	Mohan *et al*, 2011 [15]

Pharmacology

It have been reported *Dioscorea* species have anti-microbial, anti-fungal, antimutagenic, hypoglycaemic, and immunomodulary effects (Kumar *et al*., 2017) [2]. Like, On *Botryodiploidia theobromae*, extracts of *Dioscorea bulbifera* and *Dioscorea alata* identified to have an antifungal activities (Eleazu *et al*., 2013) [17]. Several researchers also have been validated the traditional knowledge by reporting the antimicrobial and anti fungal activities of wild yam *D. pentaphylla* against both gram positive and gram negative bacteria such as *Staphylococcus aureus*, *Pseudomonas aeruginosa, Streptococcus mutans*, *Streptococcus pyogenes, Vibrio cholera, Salmonella enteric-typhi, Shigella flexneri* and *Klebsiella pneumoniae*, and also the anti fungal activity against pathogenic fungi as well (Prakash & Hosetti, 2010; Kumar *et al*., 2013) [18, 16]. Similarly, *D. hamiltonii* leaf extract also reported to have antimicrobial and antifungal potential against gram positive bacteria as well as fungi (Kaladhar *et al*., 2010) [20]. The silver nano-particles that are synthesized from *D. bulbifera* tuber extracts reported to possess potent synergistic antibacterial activity against both gram-negative and gram-positive bacteria (Ghosh *et al.*, 2012) [21]. The bulbils of *D. bulbifera* have analgesic and anti-inflammatory properties against paw oedema (Mbiantcha *et al*., 2011) and it has also anthelmintic activity against *Fasciola gigantica* and *Pheritima posthuma* (Adeniran & Sonibare, 2013) [23].

The Presence of anticancerous components of *D. alata* extract on human cancer cell lines has proven that they have cytotoxicity effect (Das *et al*., 2014) [24]. The wild yam species *D. oppositifolia* also have anti-ulcer activity that have observable effect on adult wistar rats (Jhansi Rani *et al*., 2012; Mohan, 2012) [25, 38]. *D. oppositifolia* contain Methanolic extract have retarded the castor-oil induced intestinal transit and diarrhoea in rat (Jhansi Rani *et al*., 2012; Mohan, 2012) [25, 38]. The anti-diabetic activities of *D. alata* (Maithili *et al*., 2011) and *D. bulbifera* (Ghosh *et al*., 2012; Okon and Ofeni, 2013) [21, 28] has been validated for type II diabetes management.

The tubers contain proteins, potassium and micronutrients, by this it can improve our health (e.g., vitamin C in *D. rotundata*). Yam also counteract sickle cell anemia in humans, because it have thiocyanate in abundant amount. (Diby *et al*., 2011) [29].

Antimicrobial potential of yam

Research has intensified plant sourced antibiotics and the antimicrobial potentials of certain yam species have been investigated and reported by using crude extracts and compounds that are isolated from the bulbils of the African medicinal plant D. bulbifera, (Kuete *et al*., 2012) [30] showed that these compounds and extracts can be effective drugs against a wide range of resistant gram negative bacteria. The extracts have inhibitory effect and was dependent on the concentration but still less effective compared to standard antibiotics. Likewise D. *esculenta* tuber mucilage extract have exhibited antibacterial properties against three human bacterial strains including *Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* (Begum & Anbazhakan, 2013) [31]. The D. *alata* tuber extracts inhibitory potential against *Salmonella typhimurium*, *Vibrio cholerae, Shiegella flexneri, Streptococcus mutans* and *Streptococcus pyogenes* have also been reported (Kumar, Mahanti, Sk, Jk, 2017) [32] In addition *D. Zingiberensis* rhizome extract which contain endophytic fungi, a Chinese medicinal plant, has shown its antibacterial potential (Xu *et al*, 2008).By using the agar well diffusion and pour plate method, authors reported extracts of *D. dumetorum* and *D. hirtiflora* tubers has possible sources of antimicrobial agents with their antimicrobial efficacy directly linked to the phenolic contents of the plants and DPPH scavenging activity. (Kumar *et al*, 2017) [35] compared the antibacterial activity of *D. pentaphylla* tuber extracts and antibiotics (penicillin and kanamycin)on five selected bacterial strains (*Vibrio cholera, Shigella flexneri, Salmonella typhi, Streptococcus mutans* and *Streptococcus pyogenes*).These findings revealed a significant inhibitory activity against tested bacteria by using *D. pentaphylla* tuber extracts. This activity was attributed to diosgenin content in the tubers.

Antioxidant Activities of Yam

Different species of *Dioscorea,* including *D. alata, D. bulbifera, D. esculenta, D. oppositifolia* and *D. hispida*, antioxidant activities have been reported (Lubag *et al*, 2008; Chunthorng *et al*, 2012; Murugan *et al*, 2012; Nagai *et al*, 2006; Theerasin *et al*, 2009) [36, 37, 38, 39, 40] Using a DPPH assay, Murugan and Mohan (Murugan & Mohan, 2012) [41] reported radical scavenging activity of 79.3% for 1000 µg/mL D. esculenta extract with IC50 value of 38.33 µg/mL, whereas IC50 value of 18.25 µg/mL was recorded for the reference standard (ascorbic acid). The same trend was observed by the author when the ABTS assay was used, with radical cation scavenging activity range from 46.1% to 64.1% at concentration between 125 and 1000 µg/mL and IC50 value of 40.50 µg/mL while IC50 value was 20.67 µg/mL for trolox. The author attributed the antioxidant and free radical scavenging activity to high content of total phenolic and flavonoid compounds. Similarly, among the yam species evaluated, antioxidant capacities of *D. pubera*, *D. pentaphylla* and *D. bulbifera* were significantly higher with lower IC50 values than the standards when compared to the other species. Scavenging activities observed in the different yam species is attributed the variation to the disparity in the content of the bioactive compounds in the yam species (Padhan, Nayak & Panda, 2020) [42].

Anti-inflammatory activity of yam

Chiu *et al*., 2013 confirmed that D. japonica ethanol Foods 2020, 9, 1304 23 of 45 extract elicited an *in vivo* anti-inflammatory effect on mouse paw oedema induced by λ-carrageenan. Pre-treatment using dried yam (*Dioscorea* spp.) powder on Sprague-Dawley rats before inducement of duodenal ulcer by intragastric administration of cysteamine-HCl (500 mg/kg) revealed that dried yam powder have a significant protective effect by reducing the incidence of perforation caused by cysteamine and preventing duodenal ulcer, comparable to the pantoprazole effect (Park, 2013) [45] Yam powder have observed effect attributed to its potential to lower inflammatory cytokines as well as scavenging free radicals at the same time up-regulating activity of carbonic anhydrase. The *D. alata* tubers contain hydro-methanol extract which contain different bioactive phyto-compound has also shown to significantly down-regulate the pro-inflammatory signals in a gradual manner when compared to a reference control (µg/mL) (Dey *et al*., 2016) [46]. Mollica *et al*., 2013 [46] reported that*D. trifida* contain anti-inflammatory activity of extract on food allergy induced by ovalbumin in mice. In addition extracts from leaf, rhizome and bulbil have exhibited anti-inflammatory activity also.

Anticancer activity of yam

In vitro-cytotoxicity screening provides insights and preliminary data that help select plant extracts with potential anticancer properties for future work and *in vivo* replication. A study by (Itharat *et al*., 2004) [48] showed that aqueous and ethanol extracts of rhizome of *D. membranacea* and *D. birmanica* were cytotoxic against three human cancer cell lines while remaining non cytotoxic to normal cells as well. The use of active compounds naphthofuranoxepins (*Dioscorea* lide A and B) and dihydrophenanthrene from *D. membranacea* (locally known as Hua-Khao-yen) rhizome in Thai medicine is highly potent and has exhibited cytotoxic activity against five types of human cancer cells (Itharat *et al*, 2003; Itharat *et al*, 2007; Itharat *et al*, 2014) [49, 50, 51]. This was supported by a more recent study, which highlighted the utilization of *Dioscorea* lide B as a possible anticancer agent for liver cancer and cholangiocarcinoma (Thongdeeying, 2016) [61]. The hepatotoxic compound diosbulbin B has also been reported as a major anti-tumor bioactive component of *D. bulbifera* (air potato), with no significant toxicity *in vivo* at dosage between 2 and 16 mg/kg] (Wang *et al*, 2012; Chan & Ng, 2013) [92, 58]. Plants with steroidal saponins have exhibited anticancer effects (Kashiw *et al*, 2012; Kashiw *et al*, 2009; Tong *et al*., 2011) [54] and these bioactive compounds are abundant in different *Dioscorea* species. According to Zhang *et al*, (2013) [55] an apoptosis-inducing effect exerted by deltonin, which may correlate with ROS-mediated mitochondrial dysfunction, signaling pathways, as well as suggesting deltonin as a potential cancer preventive and therapeutic agent through the activation of ERK/ATK (Shu *et al*, 2011) [56]. Under *in vitro*conditions, Cytotoxicity studies using steroidal saponins from *Dioscorea collettii* var. hypoglauca showed they were active against human acute myeloid leukemia (Hu *et al*, 1996) [57] Another study by Chan and Ng (Chan *et al*, 2013) [58] investigated the biological activities of lectin purified from D. polystachya cv. Nagaimo. The authors observed after 24 h treatment the inhibitory role of lectin on the growth of some cancer cell lines including nasopharyngeal carcinoma CNE2 cells, hepatoma HepG2 cells and breast cancer MCF7 cells, with IC50 values of 19.79 μM, 7.12 μM and 3.71 μM, respectively. Through the induction of phosphatidylserine externalization and mitochondrial depolarization, it has been revealed that D. polystachya lectin can evoke apoptosis in MCF7 cells (Chan *et al*, 2013) [63] Furthermore, *In vivo*, diosgenin has been reported to significantly inhibit the growth of sarcoma-180 tumor cells while enhancing the phagocytic capability of macrophages *in vitro*, thus suggesting that diosgenin has the potential to improve specific and non- specific cellular immune responses (He *et al*, 2012) The anticancer mechanism of action for diosgenin may be attributed to modulation of multiple cell signaling events including molecular candidates associated with growth, differentiation, oncogenesis and apoptosis (Raju & Mehta, 2008) [60].

Anti-Diabetic Activity of Yam

Plants' anti-diabetic potential stems from their ability to restore the function of the pancreatic tissues which leads to three possible outcomes: increasing the insulin output, inhibiting the intestinal absorption of glucose and restoring the facilitation of metabolites in insulin dependent processes (Malviya *et al*, 2010) [64]. There is minimal evidence on specific action pathways in the treatment of diabetes; however, we can infer that most plants that contain bioactive substances such as flavonoids, alkaloids and glycosides offer a buffer to patient management Mukesh & Mamita, 2013) *D. dumetorum*, because of its hypoglycemic effect, has long been proven to play active role in the treatment of diabetes in traditional medicine (Iwu *et al*., 1990) [66]. Literature reveals that aqueous extract of *D. dumetorum* tuber, known for its alkaloid (dioscoretine) content, control hypercholesterolemia, hyperlipidemia and hyperketonemia (Malviya *et al*, 2010) [64]. Another study showed, however, consumption of *D. bulbifera* by female diabetic rats decreased hyperglycemia and bone fragility. A similar trend was observed on dexamethasone-induced diabetic rats treated with *D. polystachya* extract (Gao *et al*., 2007) The quest for novel drugs in the clinical treatment of diabetic complications such as peripheral neuropathy has led to the discovery of DA-9801, an ethanol extract of D. japonica, *D. rhizoma* and *D. nipponica*, as a potential therapeutic agent (Choi *et al*, 2011; Choi *et al*, 2011) [67, 68]. An investigation conducted by Song *et al* (2014) [69] on the inhibitory effects of DA-9801 on transport activities of clinically important transporters showed that inhibitory effects *in vitro* did not translate into *in vivo* herb drug interaction in rats. Interestingly, Jin *et al*. (2013) [70] and Moon *et al*. (2014) [71] further buttressed the potential therapeutic applications of DA-9801 for the treatment of diabetic peripheral neuropathy. These studies show that DA-9801 reduced blood glucose levels and increased the response latency to noxious thermal stimuli. It is anticipated that DA-9801 can be used as a botanical drug for the treatment of diabetic neuropathy. Transporters are critical in the absorption, distribution and elimination of drugs, thus modulating efficacy and toxicity (Song *et al*., 2014) [69]. This prediction of interaction is vital in clinical studies and the drug development process. Sato *et al*. (2014) demonstrated that the natural product diosgenin remains a candidate for use in acute improvement of blood glucose level in type I diabetes mellitus. Also, Omoruyi F.O. (2008) [72] supports the use of D. polygonoides extracts in clinical management of metabolic disorders such as diabetes.

Anti-Obesity and -Hypercholesterolemic Activities of Yam

Jeong *et al*. (2016) [73] reported the anti-obesity effect of D. oppositifolia extract on diet-induced obese mice. In their study, a high-fat diet was given to female mice with 100 mg/kg of n-butanol extract of D. oppositifolia for 8 weeks. The authors observed a significant decrease in total body weight and parametrial adipose tissue weight; as well as decrease in total cholesterol, triglyceride level and low density lipoprotein (LDL)-cholesterol in blood serum; female mice associated with the ingestion of D. oppositifolia n-butanol extract. The observed effect of D. oppositifolia n-butanol extract is mediated through suppression of feeding efficiency and absorption of dietary fat (Jeong, 2016) [73] An earlier study, which evaluated the anti-obesity effect of methanol extract of D. nipponica Makino powder, reported theeffectiveness of the extract against body and adipose tissue weight gains in rodents induced by a high-fat diet (Kwon *et al*., 2003) [74] The anti-obesity potential of extract of D. steriscus tubers extracted using a solvent cold percolation method have been reported (Kwon *et al*, 2003) [74]. When compared with a commercially available anti-obesity medication (herbex), D. steriscus tubers extract showed a significantly higher anti-obesity activity. The author attributed the result to be associated with the bioactive compounds of D. steriscus tubers, which can act as lipase and α-amylase inhibitors and thus are useful for the development of anti-obesity therapeuticals (Kwon *et al*, 2003) [74]. Extracts of *Dioscorea* species have been used in clinical management of other metabolic disorders such as abnormal cholesterol level. Several animal studies have shown the antilipemic effects of sapogenin and diosgenin-rich extract of *Dioscorea* species like D. polygonoides (Jamaican bitter yam) on hypercholesterolemic animals such as mice and rat, thus resulting in the reduction in the concentrations of blood cholesterol (McKoy *et al*, 2014) [75]. Another study which investigated the effect of D. alata L. on the mucosal enzyme activities in the small intestine and lipid metabolism of adult Balb/c mice showed constant improvement in the cholesterol profile of the liver and plasma of mice fed with 50% raw lyophilized yam for a duration of 21 days (Chen *et al*, 2003) [3]. The authors also observed an increase in fecal excretions of neutral steroid and bile acids whereas absorption of fat was reduced in mice fed with 50% yam diet. Yeh *et al*, (2007) [77] observed a significant reduction in plasma triglyceride and cholesterol in male Wistar rat as a result of consumption of a 10% high cholesterol diet supplemented with 40% D. alata.

Usage of crude yam starch from white yam *(Dioscorea rotundata poir)* in production of Paracetamol

Starch is a widely available natural macromolecule which is used among things like, as a pharmaceutical excipient. It works mainly as a binder in the formulation of solid oral dosage drugs in the form of tablets. In pharmaceutical formulations corn starch BP is widely used. Yam starch has also been well reported. Starch utilization as it extracted from locally sourced white yam (*Dioscorea* rotundata poir) and act as a pharmaceutical excipient in the formulation of paracetamol tablets and hence evaluate its binding properties in comparison to corn starch. For the confirmation of the extracted yam starch Iodine test and Molisch test were carried out. The active pharmaceutical ingredient (API) was confirmed to be Paracetamol BP via chemical tests, FTIR and then compared with a standard. The physicochemical properties of the starch were evaluated using standard methods as well as machinery. Three batches each (YS1, YS2 and YS3 for yam starch binder and CS1, CS2 and CS3 for corn starch binder) of 300mg paracetamol tablets (250mg API) with increasing binder concentrations (5% w/w, 7.5% w/w and 10% w/w respectively) were made for each binder and tablet properties and then comparison processed. An average particle size of 14.6±2.43μm and the yield of extracted yam starch was 61%.Through a micrometric studies good flow character and compressibility index with a bulk density of 0.65±0.00004 g/ml, tapped density of 0.86±0.00001g/ml, angle of repose of 25.5 ±6.90, Hausner's ratio of 1.322 ±0.00004 and Carr's index 24.32 ± 2.03of the yam starch evaluated. The pre-compression analysis of granules showed excellent granular flow properties, with yam starch slightly better than corn starch. Increasing concentrations of the yam starch binder in the tablets showed an increasing effect on the mechanical strength of the tablets and also led to an increase in the disintegration time of the tablets. Yam starch showed better hardness as compared to the corn starch which gave a slightly better friability in the tablets. Results showed that *Dioscorea rotundata poir* starch had comparable better tablet binding properties when compared to corn starch. There were fairly obvious variations in tablet hardness, friability and disintegration time also. Yam starch, when extracted at pharmaceutical grade can therefore be considered an effective and viable alternative binder in the pharmaceutical formulation of tablets. Its concentration in tablets can be optimized depending on the physicochemical properties of other excipients present (Awunor *et al*, 2019) [78].

Food applications of yam

The inherent food quality trait of yam includes nutritional, anti- nutritional factors and physico-functional composition, which have significant utilization in human nutrition (Otegbayo *et al*, 2010) [79]. The health-promoting phytochemicals are referred as nutritional factors whereas the components have inhibitory effect on health are regarded as anti-nutritional factors. Understanding the necessity of these chemicals with their impacts on human health is the major challenges for consumers and researchers for implement them in yam improvement program. These phytochemicals should be highlighted in order to understand their beneficial or inhibitory effect on human health.

In the humid tropical countries of West Africa, yam is one of the most highly regarded food products and it is closely integrated into the social, cultural, economic and religious aspects of life (Ackah *et al*., 2014) [80]. The traditional uses of yam, though diverse, are mainly for food, aimed at providing relatively cheaper source of calories to its consumers. As food, yam is prepared in various forms across West Africa. In Ghana, yam is normally consumed by boiling and pounding into a dough-like consistency called "fufu", and then eaten with a soup (Obadina *et al*., 2007) [81]. Yam is also consumed by boiling and eating as boiled slices (ampesi), fried as yam
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Industrial Applications of Yam

Yams used for industrial usage has not been completely exploited yet. However, potential applications include yams which is a source of starch also used for industrial purposes. The quality of yam tubers for potential industrial applications is influenced by its dry matter content. Yam can be processed into yam chips, which will later be grounded as yam flour popularly known as 'amala.' This foodstuff fetches high price in places like Nigeria and other African countries. Farmer sources of income increase all year round through processing of these yam products. In addition, yam also has a wide range of miscellaneous uses also, like in cosmetics and medicinal purposes, that can also be used in industrial sectors as well (Chandrasekara & Kumar, 2016; Wang & Wang, 2011) [3]. (Maliki *et al*, 2012.) [91].

Use of yam starch/chitosan for the development of biodegradable films

Edible portion of the purple yams produce purple yam flour (PYF) which was obtained by milling and then air-drying at 105 C until constant weight was achieved. The PYF was further stored at 8 C for analysis. Using a methodology adapted from (Ascheri *et al*, 2014) [94] the purple yam starch (PYS) was obtained, where the purple yam was milled, successively washed, decanted and filtrated in the room temperature using a polyester mesh (40 cm 40 cm width and 0.1 mm pore size) until the entire sample had visual characteristics of starch. Subsequently, it was air-dried at 105 Cin a Solab oven until constant weight was attained and to homogenize the samples it passed through a 48 mesh sieve (50 with 0.297 mm opening).

The PYS (2 g) was dissolved in 100 mL of distilled water and with constant magnetic stirring subsequently heated at 70 C until complete starch gelatinization occurred (20–30 min), then left to cool to room temperature. CS (0.5 and 1.0 g) were dissolved in 5.0% (v/v) acetic acid in 100 mL solution under magnetic stirring for 4 h at 25 C. Then, then the film-forming solutions obtained through mixing of PYS and CS solutions. A plasticizer, Glycerol, was added to these film-forming solutions at concentration of about 2% (w/v) under stirring for 20 min. These film-forming solutions at 0.0, 0.5 and 1.0% of CS were named YS/CS0, YS/CS0.5 and YS/CS1.0, respectively.

By using the casting method, films were prepared. On glass plates (14 cm in diameter) Aliquots (20 mL) of the film-forming solution were casted and air-dried in a Solab oven at 50 C until constant weight was attained. In desiccators the dried films were conditioned containing a modified atmosphere of saturated NaCl solution at a 75% relative humidity (RH) for 7 days, and then peeled off manually and properly stored at room temperature for further analysed. All the casted solutions were prepared in triplicate.

Future Scope

Yam are highly nutritious, versatile and have many benefits on the human body i.e yam are rich in vitamins, minerals and fibres, may have cancer fighting properties, reduce inflammation, improve blood sugar level, enhance brain function, improved digestive health, help in weight loss, may have anti-microbial effects and also improved cholesterol levels. So, it is required to make product like spread from it and check whether spread provide all these above benefits or not after formulation. It is optimum important in today's world that the product apart from it taste and aroma also provide some health benefits alongside with it. Apart from this yam spread made through blending with cheese. Cheese is a great source of calcium, fat and protein. It also contains high amount of vitamins A and B-12. Along with zinc, phosphorus and riboflavin. Cheese made from the milk of 100 percent grass-fed animals is the highest in nutrients and also contains omega 3-fatty acids and vitamin K-2. Today all the spread whether it is peanut butter spread, jam, chutney, Mayonnaise, all of them contain high amount of fat. But yam contain very little amount of fat in it about 0.2 grams per 100 gram. So, it will be optimum choice for those who want to take fat free spread.

Conclusion

Dioscorea yam species provide a unique product that serve as a foods and conventional and unconventional medicine during famine and endangered periods. Yam contain constituents such as flavonoid, dioscorin, saponin, tannin and total phenols act as a good source of bioactive compounds to consumer. The understanding of the pharmacologically active compounds within *Dioscoria* diversity will assist in standardizations and analysis of formulations. So it is necessary to understand and gather knowledge of this important plant.

Till now purple yam jam which is also called ube halaya that's commonly used in desserts and sweet breads mainly consumed in Philippines. This recipe calls for frozen, granted ube, which is especially convenient since it's ready to use. It is nutritious and have many health benefits but it is not blended with any particular processed product. In this study, yam will be blended with processed cheese in order to make the better product that have more health benefits than purple yam jam.

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