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Synthesis of research on sweet potato (Ipomoea batatas) with a view to its valorization: A review

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Abstract
Sweet potato (Ipomoea batatas) is one of the major food-producing tubers for human consumption belonging to the convolvulaceae family. Sweet potato provides strategic opportunities to improve nutrition and rural incomes in several countries and regions affected by micronutrient deficiencies. It is grown in most parts of Africa and is well established as a food security crop in many densely populated countries. It is an important source of carbohydrates (96%), in the form of simple carbohydrates and dietary fibers, which play an important role in energy deficiencies. Sweet potato is a good source of vitamins A compared to other roots and tubers. Its vitamin C content is also remarkable. It contains vitamins E, B1, B2 and folic acid. It is rich in minerals essential to the functioning of the body such as zinc and calcium.

Keywords: sweet potato, tuber, micronutrients, food security

1. Introduction
Food security has become one of the major challenges for the development of African countries, particularly for the least developed countries (FAO, 2011) [5]. It is obvious that food production must increase considerably in order to meet the future demand of a growing population (between 5% and 5.5% between 2013 and 2014. Gbetoenonmon, 2013) [11]. Agricultural technologies capable of producing nutritious and marketable foods in agro-ecological zones and important socio-economic contexts are extremely urgent. Roots and tubers, including cassava, sweet potato, potato and yam, are the main food crops for human consumption in Africa (Huat *et al*., 1999, Nteranya and Mbabu 2015) [13, 21]. The importance of tubers in the consumption of populations has led root and tuber operators to adopt new conservation techniques in order to guarantee the availability of products throughout the year. Sweet potato provides strategic opportunities to improve nutrition and rural incomes in several countries and regions affected by micronutrient deficiencies. Sweet potato is already an important part of African cropping systems, due to its robustness, which allows production under difficult conditions. Sweet potato is a tuberized root crop that is of great economic importance in tropical, subtropical and mild temperate regions (Sihachakr *et al*., 1997) [28]. Sweet potatoes are grown in most parts of Africa and well established as a food security crop in many high-population countries. It is the seventh most important crop in the world after wheat, rice, maize, potato, barley and cassava because of its high yield, high adaptability and high strength (Yan *et al*., 2014) [31]. Sweet potato is one of the most consumed tubers in production areas, although its processing products are scarce. Indeed, it constitutes a so-called subsistence crop in the production areas, as it does not occupy a prominent place in international trade because of transport and conservation difficulties. (Bell *et al*., 2000) [5].

In Benin, sweet potatoes are grown in the northern and southern regions of the country. They are among the five most important staple crops (cassava, plantain, sweet potato, yam and maize). Compared to other crops, it grows under varied agricultural conditions and adapts well to heat, drought, many diseases and pests, as well as poor and flooded soils. It has broad agronomic adaptability, high productivity, a short development cycle and high nutritional value, making it a particularly important crop for food security in countries with high anthropogenic pressures and vulnerability to climate change. (FAO, 1991) [9].
According to the work of Owori *et al*., (2007) [22]; Ahmed *et al*., (2010) [3], sweet potato is an important source of carbohydrates (96%), in the form of simple carbohydrates and dietary fibers, which play an important role in energy deficiencies. Apart from carbohydrates, sweet potato is a good source of vitamins A compared to other roots and tubers (up to 4000 U.I. per 100 g of fresh tubers, depending on the variety). Its vitamin C content (30 mg / 100 g) is also remarkable (Bell *et al*., 2000) [5]. It also contains vitamins E, B1, B2 and folic acid. It is rich in minerals essential to the proper functioning of the body such as zinc and calcium (32%).
On the scientific level, very few studies have focused on sweet potato, particularly in Benin (Adegbola, 2003) [2]. Thus, this review aims to review the work done on sweet potato in order to highlight its nutritional value and to optimize technological advances in view of its valorization.

1.1 Origin and Expansion of Sweet Potato
The sweet potato, Ipomoea batatas, is known and consumed since prehistoric times. It originated in Central America or Northwestern South America (IITA, 1982) [15]. Randrianarisoa (2005) [25] also mentions two origins of sweet potato: Central America and Latin America. Its precise regional origin remains controversial. Indeed, studies based on the Ipomoea

wildlife complex and their morphological variations in comparison with the cultivated form in the New World suggest a South American origin (northern Ecuador or Peru) or Mesoamerican (Mexico- Venezuela) for domestication. The Mesoamerican hypothesis was raised by a comparative study of genetic diversity in the South American and Mesoamerican zone (Roullier, 2010) [26]. However, archaeological excavations carried out in Peruvian sites (where the oldest remains date from 8,000 years before our era) indicate that it is originally from South America (Anonymous 2)

Contrary to the history of the origin of the sweet potato, that of its expansion abounds with a common point of view. Indeed, the sweet potato was first introduced in Europe by the Spanish and Portuguese colonists. However, it was first introduced into the Polynesian islands where it is named Kumara (Bell *et al*., 2000) [5]. In Europe, sweet potato was introduced for the first time in Germany by Christopher Columbus in 1942 (Bell *et al*., 2000) [5]. During the sixteenth century, sweet potatoes spread to the Philippines thanks to the Spanish and to Africa, India, Southern Asia and Indonesia thanks to the Portuguese (Roullier, 2010) [26]. Today sweet potato is widespread in all countries and the largest producers are China, Indonesia, Vietnam, Uganda, Japan and India.

2. Characteristics and Botanical Description of the Plant

Sweet potato (Ipomoea batatas L. Lam.) Is a perennial plant belonging to the Convolvulaceae family (Yan *et al*., 2014) [31]. There are more than 50 genera belonging to this family including "Ipomoea" with more than 1000 species including Ipomoea batatas (Randrianarisoa, 2005) [25]. The most common varieties are white fleshed varieties and varieties with purple or orange flesh. These varieties include several cultivars in them. The stems of the sweet potato, herbaceous and creeping, bear leaves of variable shape, generally lobed, sometimes cut (depending on the variety) and long petiolated "5 to 30 cm long" (Mathieu-Daudé *et al*., 2001) [20]. As for its flowers, they are white or violet in color and grouped along the stem. As far as the fruiting of the plant is concerned, it is rarely observed in cultivation. As for the tubers, they are roots that can go down to 2 m underground and extremely variable: globular or elongated. The skin color of its tubers may be brownish, orange, purple / carmine, light brown / beige or yellowish / ocher. As for the flesh of the tuber, according to Bell *et al*. (2000) [5], its tint may be purple, red / vermilion, orange, yellow-red, pinkish, whitish / milky white or beige. According to Zhao *et al*. (2014), sweet potatoes are usually orange in color, but they may also be violet in color (Zhao *et al*., 2014). This coloration is due in particular to the presence of red anthocyanins and their linked glucosides. Conversely, the sweet potato whose color is orange, owes it to its content of carotenoids (Donado-Pestana *et al*., 2012) [9]. Each plant produces a few tubercles (about 10). These tubers weigh between 0.1 and more than 1 kg and contain a sticky white latex (Mathieu-Daudé *et al*., 2001) [20]. However, from a nutritional point of view, the orange flesh variety is recommended. It has a very interesting nutritional composition compared to white flesh varieties. Its content of β-carotenes and antioxidants exceeds that of the white-fleshed variety. Sweet potato is a plant that adapts well to different types of climate. Indeed, it can be grown both in temperate climates and in tropical and equatorial climates (Mathieu-Daudé *et al*., 2001) [20]. According to Randrianarisoa (2005) [25], sweet potato is a photoperiodic plant (faster tuberization in day less than 12 h and inhibited in day greater than 14 h). In addition, sweet potato is a plant that adapts well to heat, drought and many diseases and pests, as well as to poor and flooded soils (Gura, 1991) [12]. In summary, the conditions required for optimum development combine temperatures between 22 and 33 ° C, high luminous intensity, short days, precipitation of water greater than 200 mm and requiring 120 to 210 days to close the cycle (Mathieu-Daudé *et al*., 2001, and Gura, 1991) [20, 12].

3. Composition and Uses of Sweet Potato

3.1 The Leaves

Sweet potato leaves contain 4.6% protein, 0.2% lipid (Gura, 2001), 9.1% carbohydrate (Bell *et al*., 2000) [5]. They have a calorific capacity in the order of 49 calories, an iron content of 6.2 mg, calcium of 158 mg (Table 1) (Anonymous 1). They also contain anthocyanins and phenolic compounds (Anonymous 2). They are also excellent sources of vitamin A and ascorbic acid. On the diet, sweet potato leaves and shoots are used as condiments. They are used in the preparation of sauces in many regions in Africa, the Philippines (Owori *et al*., 2007) [22]. In animal feed, leaves and sweet potato shoots can be used to feed herbivores or rabbits and livestock; they constitute excellent fodder both in the fresh state and after desiccation (Anonymous 2).

Table 1: Composition of sweet potato leaves per 100 g of edible matter

Nutrient	Levels
Energy	49%
lipids	0,2%
Water	-
protein	4,6%
Calcium	158 mg
Iron	6,2 mg
Vitamin B6	-
fibers	-

not determined

3.2 The Tubers

Sweet potato tubers have a fairly diverse composition. They contain between 0.8 to 2% protein, 0.2 to 0.4% lipid and 25 to 30% carbohydrate (Gura, 2001). The composition of the tubers varies according to the variety, the "temperate or tropical region" and the type of soil (Owori *et al*., 2007) [22]. The sweet potato tubers contain mostly substances of carbohydrate origin (sugars and fibers). Besides carbohydrates, the tubers contain a lot of vitamins (provitamin A and those of group B), minerals (calcium and zinc), some vitamin E (tocopherol). However, the levels of orange flesh in vitamins: thiamine, riboflavin, niacin and ascorbic acid exceed that of the white flesh variety (IITA, 1982) [15].

Sweet potato is an important source of dietary fiber because its pectin content reaches 5% of its fresh weight or 20% of dry matter at the time of harvest (Collons and Walter, 1982). The protein content could vary from 2 to 7.5% depending on the cultivar and the treatment. The sweet potatoes of certain varieties contain many anthocyanins, these small pigments

which give the coloring to the sweet potato. As an integral part of the flavonoid family, anthocyanins possess antioxidant, anti-cancer, anti-inflammatory properties. Nitrogen fertilizer raises the protein content of potatoes but lowers the lysine content and increases aspartic acid and the free amino acids (Hou *et al*., 1982) [14]. Sweet potato flour has much lower levels of certain constituents (Table 2). According to Badila *et al*. (2009) [4], potato flour contains 6.31% protein, 0.90% lipid, 2.13% ash. A large variation in the vitamin A composition exists and may be particularly low in the white flesh variety of tropical areas. In addition orange flesh contains many more carotenoids than white flesh. It should be noted that several modes of preparation of the tuber for consumption (cooking with water, frying etc.), contribute to reduce the content of certain vitamin components. Ascorbic acid has decreased during long-term storage (IITA, 1982) [15]. Sweet potato is of high nutritional value because of the reasonable composition of its proteins in essential amino acids. The tuber skin is richer in protein and other non-carbohydrate compounds than the rest of the tubercle (IITA, 1982) [15].

Table 2: General composition of sweet potato: tubers and flour

Nutritional elements	Tubers (% DM) Salunkhé, 1986	Tubers (as% of PC) www.fao.org	Potato flour (% DM) Badila *et al*., 2009 [4]
Energy (Kcal)	-	105	-
Carbohydrates (in% DM)	96 g	-	-
Protein (in% DM)	4,3 g	1,6 g	6,31 g
Lipids	-	0,3 g	0,90 g
Ashes	-	-	2,13 g
Calcium (mg)	32	22	0,05 g
Phosphorus (mg)	47	1,6	0,59 g
Sodium (mg)	10	-	0,008 g
Iron (mg)	0,7	0,3	0,09 g
Potassium (mg)	243	-	0,07 g
Magnesium (mg)	31	-	0,86 g
Vitamin A (UI)	8800	-	-
Vitamin C (mg)	21	-	-
Thiamine (mg)	0,10	-	-
Niacin (mg)	0,06	-	-
Riboflavin (mg)	0,06	-	-

not determined; MS: Dry Matter; PC: Edible portion

One study found that with the heat treatment of sweet potato, an increase in the concentration of phenolic compounds was observed (Dincer *et al*., 2011) [8]. The main phenolic compounds identified in sweet potato are anthocyanins and phenolic acids, such as caffeic acid, monocaffeoylquinic acid (chlorogenic acid), dicaffeoylquinic acid and tricaffeoylquinic acid. The main anthocyanins are cyanidin rather than peonidine (Karna *et al*., 2011) [16].

The use of sweet potato is mainly culinary in the human diet in various forms. In Benin the tubers of sweet potato are eaten most often cooked with water, or well fried. The flour obtained from the tubers can be used for the preparation of various foods either as is, or in combination with other flours, in particular wheat flour or cereals. The products usually prepared are puree, cakes, drinks, biscuits, etc. (Owori *et al*., 2007) [22].

However, the modern ways of using sweet potato (cakes, biscuits, drinks) are rare in Benin. Nevertheless sweet potato is one of the most consumed tubers, although the processing products are scarce. Indeed according to the investigations of Konkobo *et al*., (2002) [17], 74.4% of households consume and make several traditional uses in Ouagadougou (see figure). These are French fries, the main use in urban areas (47%); potato stew "rare or non-existent in the catering space" used by 29% of households; boiled potato, a traditional form of consumption (20% of households). The other modes of consumption of second importance are direct consumption, that is to say fresh (2%), rice sauce (1%) where it is used as a vegetable and degel %). Among these modes of culinary use of sweet potato, only the degeu is a transformed product. The deguè is made from sweet potato flour.

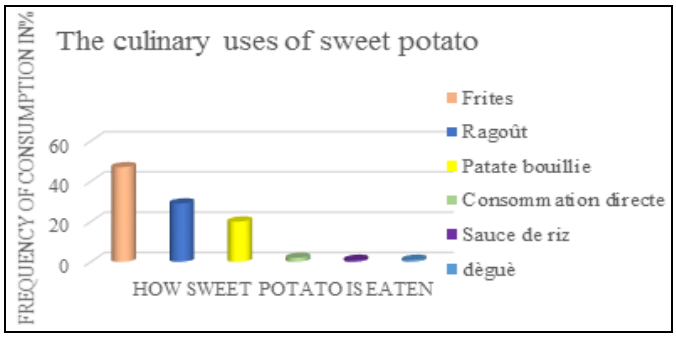

Fig 1: Culinary uses of sweet potato by the population of Ouagadougou (Konkobo *et al*., 2002) [17]

4. Other Uses of Sweet Potato

Globally, sweet potatoes have other non-nutritional interests.

4.1 Medicinal Use

Potato is used in the testing of many diseases. Indeed, studies carried out in vitro (Anonymous 2), and in some animals have shown that sweet potato has a very important pharmacological interest. This is due to the presence of certain compounds such as anthocyanins, carotenoids, phenolic compounds, trypsin inhibitory proteins and arabino-galactone compounds. Researchers have reported that sweet potato extracts (tubers) exert an anti-carcinogenic effect on the prostate, gallbladder,

breasts and lungs. In addition, it was found that sweet potato extracts (leaves and tubers) could have a protective effect against cardiovascular diseases: prevention and reduction of bad cholesterol (LDL), relaxation of the blood vessels (case of the aorta 21). You may be more likely to guard against the oxidation of bad cholesterol (LDL) by consuming sweet potatoes. Containing phenolic compounds and anthocyanins, this food reduces the above oxidation. The vitamin C richness of this food also helps fight heart disease. It has also been shown that extracts of sweet potato (tubers) have a beneficial effect against lesions or liver diseases. Its anti-diabetic effect has also been demonstrated: decreased insulin resistance. Consuming this food is advisable if you suffer from hypertension. Indeed, this tubercle is rich in potassium, a mineral known to lower blood pressure. You will get more potassium by consuming a sweet potato than eating a banana (another food reputed to be rich in potassium). The high fiber content in this food helps the body to maintain the digestive system in good health and to regulate digestion.

4.2 Industrial Use: Production of Alcohol

Sweet potatoes can be used for the production of alcohol. In addition to starch, sweet potato tubers also contain sucrose of the order of 6% (Mathieu-Daudé *et al*., 2001) [20], which can be used for the production of alcohol by fermentation and distillation. The presence of sucrose also makes the tubers suitable for the production of starch, which, mixed with sugar, gives a syrup used in brewing (Mathieu-Daudé *et al*., 2001) [20]. In addition, sweet potato is used in the production of Lactic Acid or Lactic Acid (LPA) used in the manufacture of biodegradable plastics (Adam, 2005) [1].

5. Production of Sweet Potato

In Benin, the area planted with sweet potato compared to other root and tuber crops is only 2.6%. Production decreased from 65,489 tonnes to 57,283 tonnes from 2001 to 2002, resulting in a 13% reduction and a slight increase in yield (0.23%) (Paraïso *et al*., 2010) [24].

6. Toxic Substances and Antinutritional Factors of Sweet Potato

According to FAO, (1991) [5], apart from cassava, which contains cyanogenetic glucosides, the cultivated varieties of the majority of tubers and edible roots do not contain dangerous toxins. As far as sweet potato is concerned, it contains raffinose, one of the sugars responsible for flatulence. Three of the sugars present in plant tissues, raffinose, stachyose and verbascose are not digested in the upper part of the digestive tract. The amount of raffinose present depends on the cultivar. In some parts of Africa, the cultivars used are considered too mild and cause flatulence (Palmer, 1982). Lin and Chen (1985) [19] have established that sweet potato has a trypsin inhibitor activity ranging from 90% inhibition in some varieties to 20% in others. When heated for a few minutes at 90 ° C., the trypsin inhibitors become inactive. Lawrence and Walker (1976) [18] considered the activity of the trypsin inhibitor in potato as a contributing factor to the Enteritis necroticans disease. This conclusion seems doubtful because sweet potato is generally not consumed raw and the activity of the trypsin inhibitor is destroyed by heat.

Potatoes produce metabolites in the event of injury or exposure to infectious agents. This is in response to physiological stimulation or due to exposure of injured tissue to fungal contamination. Some of these compounds, particularly furan terpenoids, are known to be toxic (Uritani, 1967). The fungal contamination of potato tubers by Ceratocystis fimbriata and several species of Fusarium leads to the production of ipomoeamarone, a hepatotoxin, while other metabolites such as 4-ipoméanol are pulmonary toxins. Baking only destroys 40% of these toxins. Catalano *et al*., (1977) reported that it is sufficient to peel the bruised potatoes 3 to 10 mm around the affected area to eliminate almost all toxins.

7. Different Varieties of Sweet Potato

According to the survey carried out by Adegbola in 2003 and recorded in the final report of the analysis of the sweet potato sector in Benin, potato varieties are counted according to the regions and in the national language. The following table gives us the list.

Table 3: sweet potato varieties in Benin

Varieties	Regions
South Valley	Vobodouaho ou Gboado
	Hinkintchin
	Amiwédé
	Zohoukan
	Zohoun
	Sagon
	Hatti
	Fouloba
	Gnohonoudobokonmi
	Kononmagniaton
	Bohounbo
	Hamma
South Plateau	Vobodouaho ou Gboado
	Bohounbo
	Jodoucha
	Hamma
	Massahouin
	Kilonoukon
	Aglansodji
	Sochadoucha
	Houègbo
	Deux couleurs
	Laidékounkan
	Houndrékan
	Sokan
North east	Troidokpan
	Tantikpika
	Houègbo
	Blanche
	Athaina
	Nimpoga
	Naperra
	Rouge
North West	Blanche
	Dococonomper
	Docononwan
	Rouge
	Jaune
	Yeintakagnampera
	Yakokanonpia
	Yakokannon wouapia

Table 4: The varieties identified by IITA include

Variety	Features	Country
Ndargu	Shape: Irregular Main skin color: Violaceae Color of the flesh: Yellow orange Flavor of the pulp: Little sweet Virus resistance: Present	Dakar, Sénégal, 1970
Fanaye	Shape: Irregular Main skin color: White Color of flesh: White Flavor of the pulp: Little sweet Virus resistance: Absent	Dakar, Sénégal, 1970
Ciam	Shape: Oval Main skin color: White Color of flesh: White Flavor of the pulp: Little sweet Virus resistance: Present	IITA, Bénin, 1980
Clone 2	Shape: Oval Main skin color: White Color of flesh: White Flavor of the pulp: Little sweet Virus resistance: Absent	IITA, Bénin, 1980
Clone 29	Shape: Oval Main skin color: White Color of the flesh: Yellow orange Flavor of the pulp: Little sweet Virus resistance: Present	IITA, Bénin, 1980
2532 Tis	Shape: Elliptical Main skin color: Red Color of flesh: Yellow Flavor of the pulp: Little sweet Virus resistance: Present	IITA, Bénin, 1980
2544	Shape: Obovale Main skin color: Red Color of flesh: White Flavor of the pulp: Little sweet Virus resistance: Present	IITA, Bénin, 1980
83-176 Tis	Shape: Oval Main skin color: Red Color of flesh: White Flavor of the pulp: Little sweet Virus resistance: Present	IITA, Bénin, 1980
Walo	Form: Obovale Main skin color: White Color of flesh: White Flavor of the pulp: Little sweet Virus resistance: Present	Dakar, Sénégal, 1970

8. Storage and Conservation of Sweet Potato

Storage of sweet potatoes is usually done in three ways: storage in pits, piles and underground. For storage in pits, the peasants dig a hole whose interior is lined with grass. Then the tubers are placed in the hole and then closed with grass. Occasionally, the tubers are watered to avoid dehydration. For heap storage, the principle is to arrange a place on the farm or at home, to deposit the tubers in piles. This pile is then covered with herbs and then watered at times as in the case of storage in pit. This practice is common in the valley regions. The duration of storage is generally short and varies between one and two months. As far as underground storage is concerned, it is not to harvest the potato even though it is at maturity. In other words, the tubers are kept under ridges or ridges. This technique is mostly encountered on the plateau where flooding is not common. Note that other farmers also store the sweet potato in the room (on the ground), but in this case, the duration does not exceed 7 days. The same is true for storage in the attic.

Without special treatment, sweet potato tubers do not remain long after harvest. They are stored in a dry, cool and ventilated room. After 3 to 6 weeks, their quality deteriorates: they become fibrous, rot and germinate. Some varieties keep longer than others. The storage of tubers can be extended to 5-6 months by storing between 13 and 16 ° C, at a relative humidity of 85-90%. Previously, the tubers will have to undergo curing, which consists of a few days in a hot and humid atmosphere (29 ° C and 90% humidity) (Vernier and Varin, 1994) [30].

9. Conclusion

This review, with the aim of taking stock of research carried out on sweet potato for its valorization, reveals that very few studies have been carried out on this important product. It is therefore necessary to carry out more nutritional, technological and microbiological studies in order to highlight its nutritional value and to optimize technological advances in view of its valorisation.

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