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Sweet potato (*Ipomoea batatas* L. Lam) nutritional potential and social relevance: a review

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ABSTRACT
Sweet potato (*Ipomoea batatas* (L.) Lam) is a dicotyledonous angiosperm plant which belongs to the Convolvulaceae family and its capable of producing nutritious tuberous roots eaten worldwide. Its origin, as well as the circumstances related to its worldwide dispersion, are pertinent questions and intrigue researchers till nowadays. China is the main sweet potato producing country, and the Asian continent has the largest share of world production. In Brazil, sweet potatoes are specially grown by small farmers and used to domestic market supply. The sweet potato arouses huge interest when considering its nutritional qualities, mainly because it is rich in fibers, micronutrients, and an excellent source of energy for the consumer. The colored pulp cultivars such as yellow, orange, and purple sweet potatoes have in their composition several bioactive compounds such as polyphenols, carotenoids, and anthocyanins. In this regard, the work presents a review of the main aspects related to taxonomy, morphology, history, world production, and Brazilian production, highlighting the nutritional potential and the social relevance of sweet potatoes as a crop.
Keywords – farming, food, production, sweet potato, tuberous root.

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I. INTRODUCTION

The sweet potato (*Ipomoea batatas* L. Lam.) is an admirable plant because it is the only representative of its kind capable of developing nutritious tuberous roots, which are consumed worldwide. Sweet potatoes are part of the set of foods that make up the roots and tubers commodity. This group represents the sixth most important food crop in the world [1, 2, 3].

It should be noted that the sweet potato epithet is used to refer to the set of tuberous roots that are produced by the plant of the same name. Regarding the name, the expression sweet potato can induce a misunderstanding of identity and support dubious comparisons with other food, the potato (*Solanum tuberosum*).

It is certain that the sweet potato is a tuberous root and is part of the Convolvulaceae family. But the potato is a tuber and a member of the Solanaceae family. The word "potato" originates in the Arawak language that was pronounced by ancestral indigenous peoples who inhabited regions of Central and South America and was used by Spaniards to refer to sweet potatoes. "Camote" is another expression used to identify sweet potatoes especially in countries in South America and comes from the Nahuatl language expressed by Aztec and indigenous peoples who inhabited Mexico. It is worth mentioning that "kumara" (word originating in the South American indigenous Quechua language) is the name of the sweet potato in Oceania [4, 5, 6, 7, 8, 9].

The historical roots linked to the origin of the sweet potato and the events involved in its continental spread are controversial topics and intrigue researchers to this day.

The leading theory related to its appearance indicates that sweet potato is a plant that comes from the Americas, particularly from regions that comprise Central America and South America. Fragments of food found in archaeological sites located in Peru reveal the possibility that sweet potatoes were used more than 10,000 years ago [10, 11, 12].

The history of its spread from the Americas to various parts of the world is entangled with significant sailing events and is intertwined with the chronicles of some of the most famous explorers. The arrival of sweet potatoes in Europe is credited to Christopher Columbus, who, during his exploration trip to the New World, collected in Hispaniola (today São Domingos Island) several spoils including samples of sweet potatoes, and transported them to Spain, presenting them in 1493 to the Spain Catholic Monarch Queen Isabella I of Castile and King Ferdinand II of Aragon [13, 14].

Its cosmopolitan existence is due, in part, to the fact that sweet potatoes are an agricultural crop capable of growing and producing nutritious food abundantly in marginal soils, with low investment in inputs and water resources. This characteristic has contributed to the fact that currently, sweet potatoes are grown in more than 100 countries [2, 15, 16].

Among the countries that produce sweet potatoes, China occupies the first position, followed by countries that make up the African and Asian continent, such as Malawi, Nigeria, Ethiopia, India, Angola, Uganda, among others [2].

In underdeveloped countries, mainly in Asia, Africa and Latin America, sweet potatoes are essential food for supplying the domestic market. In areas in Central and Sub-Saharan Africa, orange-fleshed sweet potatoes are widely used to combat hypovitaminosis A, one of the most severe malnutrition problems faced by vulnerable populations [17, 18].

In Brazil, the productive potential of sweet potatoes is still mitigated due to the low added value that this food has, and most of the harvest is traded through the retail trade of staple foods. In contrast, Brazilian agricultural research centers, such as the Brazilian Agricultural Research Corporation (EMBRAPA), invest in genetic improvement programs for sweet potato cultivars intending to obtain plants suitable for cultivation in Brazilian soil, which have productive characteristics satisfactory and nutritional [19, 20].

From a nutritional point of view, sweet potatoes are a food rich in fiber, vitamins, and minerals, besides to be a great source of energy. The colored potato sweet potato cultivars, especially the yellow, orange, and purple pulp tuber roots, present in their composition bioactive compounds that contribute positively to the health of their consumers [21].

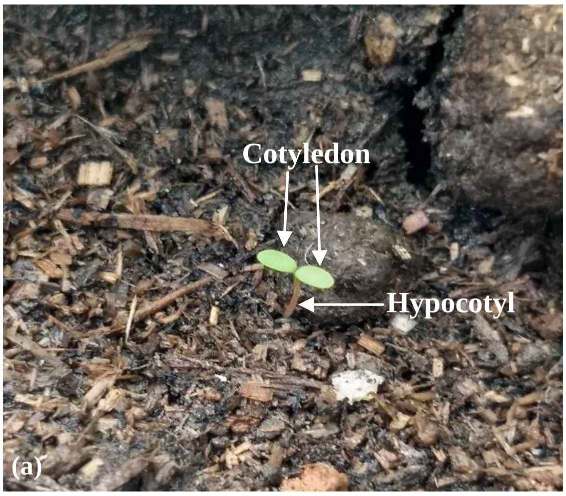
It is worth noting that sweet potatoes can also be used as raw material for the development or incorporation into food products such as, for example, bakery products, sweets, starch, pasta, fermented preserves, nutritional drinks, alcoholic drinks, soy sauce, dairy products, among many others [16]. Furthermore, sweet potatoes can also be used to produce biofuel [22].

The purpose of the work is to fill the gap about the nutritional importance of sweet potatoes and to highlight the relevance that this food has in the social context. This review paper presents a series of information related to aspects of taxonomy, morphology, origin and history, propagation events, world production data, Brazilian agronomic production and research, and the nutritional potential combined with the presence of bioactive compounds in sweet potatoes.

II. SWEET POTATO TAXONOMY AND MORPHOLOGY

The sweet potato is a perennial plant, belonging to the Convolvulaceae family, recognized mainly for generating tuberous roots that are used all over the world, for the most diverse purposes. It is a dicotyledonous angiosperm because, during the germination period and the beginning of its growth, the sweet potato presents the formation of two cotyledons (Fig.1a), which assist in the generation and storage of the energy necessary for the development of the plant [1, 23].

The study of plant taxonomy is old and extensive. To classify the various plant specimens, the work of many researchers culminated in different nomenclature systems, for example, Species Plantarum [24], the Hutchinson system [25], the Takhtajan system [26], Angiosperm Phylogeny Group (APG) [27, 28, 29, 30], Wu Zhengyi [31], the Thorne system [32, 33, 34, 35], et cetera.



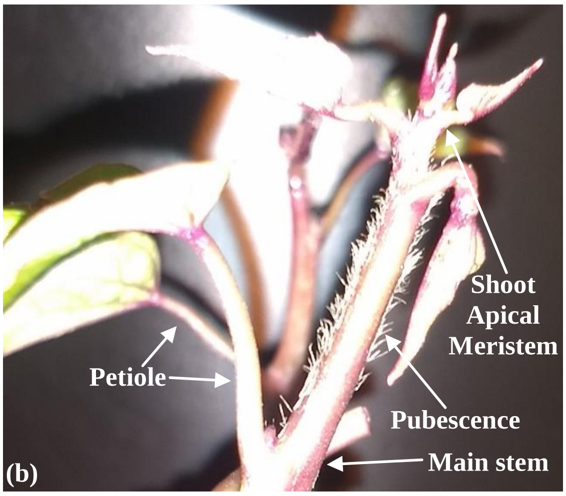


Figure 1: Sweet potatoes growth: (a) Two cotyledons development; (b) Initial petioles and stem with slight pubescence.

According to the APG system, which describes the updated classification of clades, orders and families associated with the group of angiosperm plants, the taxonomy of sweet potatoes originates from the Angiosperms clade and dismembers together with the Eudicot, Superasterids and Asterids clades, which in turn branches the class Lamiids, which groups the order Solanales that hold the family Convolvulaceae [29, 30].

The Convolvulaceae family is broad and cosmopolitan. It is commonly known as The Morning Glory Family because of its floral pattern. The plants that belong to this family are, in the vast majority, reptiles, vines or shrubs, generate roots and rhizomes, and some species produce latex and alkaloids. Its flowers exhibit a gamma petal configuration (five joined petals) in an infundibuliform shape, and a chalice with five separate sepals. This family has about 59 genera distributed in more than 1600 specimens [36, 37].

Among several genera that make up the Convolvulaceae family, the Ipomoea genus is the most expressive, which aggregates more than 500 specimens [37].

It is worth mentioning that sweet potato is the leading representative of the genus Ipomoea, as it is the only plant of the genus capable of producing nutritious tuber roots and of high economic expression. The tuberous roots of sweet potatoes are widely consumed as food, handled, and commercialized worldwide.

During the growth of the plant, the stem develops in a crawling way, prostrate to the ground, manifesting repetitive sprouting, being able to generate roots in the points where the internodes present contact with the soil. The stem is tender and flexible, consisting of the epidermis, the cortex, and the vascular system. It has a cylindrical shape and slightly flattened with a predominance of green color, and may also have a purple, violet or purple depending on the type of cultivar [38, 39, 40].

The stem epidermis may be glabrous or slightly pubescent (Fig.1b), consisting of a thin band of cells and stomata to establish transpiration and gas exchange processes in the plant. The cortex has cell layers that accumulate chlorophyll, in addition to latex-producing ducts, which are also present throughout the stem structure. A thin layer of endoderm separates the cortex from vascular bundles, composed of tissues such as phloem and xylem, which act in the conduction of sap and nutrients. The central region of the stem is formed by the medulla that is composed of parenchyma cells [41, 42].

The length of the stem can vary from 1 to 5 m, and the thickness between 3 to 10 mm. Internodes can develop from 2 to 20 cm apart along the stem [39, 43, 44].

The petiole that is born from the stem can measure up to 30 cm in length and be glabrous or pubescent, in which the sweet potato leaves develop. The stems and petioles have nutrients which can be used for animal feed mainly in the creation of pigs and cattle either in natura or in the form of silage [45, 46].

The leaves are simple, glabrous, or slightly pubescent, with an aspect that varies between ovate, orbicular, sagittal, cordiform or elliptical, and grows petiolate with the entire edges, with the corded base being its main characteristic (Fig.2). The growth of the leaves along the stem presents a spiral configuration of a pentamer pattern or phyllotaxis 2/5, that is, the genetic spiral completes two turns that group five leaves, with the sixth leaf developing relatively above the first leaf [47, 48, 49, 50].

Figure 2: Sweet potato main stem, petioles and leaves in a spiral configuration with 2/5 phyllotaxis.

The plant develops a root system with a pivotal, branched, and diffuse characteristic, consisting of the main root, secondary and tertiary roots, reaching up to 90 cm in depth (Fig.3). The development of the roots follows the characteristics of dicotyledonous plants, with the formation of an axial root (storage root) qualified as a tuberous root that is an elongated, round or fusiform shape, highlighted by the high thickness, and the absorbent roots (pencil and fibrous roots), which are abundant and branched and work on the extraction and transportation of water and nutrients from the soil to the plant [1, 44, 45, 51].

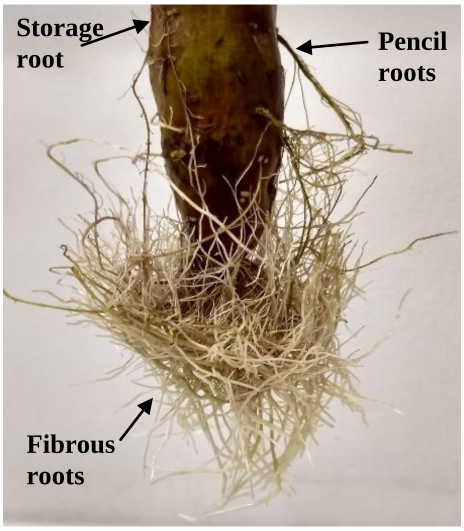


Figure 3: Sweet potato pivoting root system.

Absorbent roots are formed from tissues that have meristematic cells. The exchange rate meristem is responsible for the formation of absorbent roots. The axial root develops from the intense activity of primary, secondary, and tertiary meristematic cells, together with the action of conduction tissues xylem and phloem [1, 44, 52].

Tuberous roots can vary both in length and diameter, as well as in the color of the skin and color of the pulp depending on the type of cultivar. The roots that develop from the internodes are called adventitious roots and are relatively thicker than the basal roots due to the intense activity of cells in the lateral meristem. The same cultivar can show variation in morphology, and the number of roots between different plants also between plants originated from clones [1, 44, 45, 51].

The development of the thickness of the tuberous roots occurs due to the activity of cambial cells of the secondary meristem particularly the cork cambium the vascular cambium and the anomalous cambium. The cork cambium is a lateral meristem that acts in the generation of outer layers of cork cells, forming mainly the periderm that contributes to the protection of the root. The vascular cambium has thick walls that form a circular structure at the root, generating secondary phloem on the outside and parenchyma cells on the inside. Anomalous cambium is a term used to designate cells of the secondary meristem with atypical growth [52, 53, 54].

The primary tissues that constitute the tuberous roots are the periderm, vascular bundles, the tracheids, the sieve cells (especially the sieve-tube members located in the phloem) and the laticifers. The constitution of the tuberous root is varied and heterogeneous, also including the xylem and phloem tissues, reserve parenchyma, external protective epidermis, and secondary periderm, among other tissues [52, 53, 55].

The sweet potato peel is about two millimetres thick and consists of a small number of cell layers. The outer part of the bark is called the skin and is more easily detached from the root. However, the exclusive removal of the peel portion is not straightforward because the boundary between the peel and the upper pulp threshold is not always evident, thus causing part of the pulp to detach from the peel [52].

The surface of the tuberous root bark is generally smooth, but it can present horizontal and vertical constrictions depending on the cultivar and the management of cultivation. The peel can vary in color from purple, white, cream, yellow, orange, brown, and even reddish peel. The pulp may be white, cream, yellow, orange, or purple, depending on the cultivar. The color variation of the pulp is due to the presence of bioactive compounds with a pigment characteristic, such as anthocyanins and carotenoids [1, 44, 56, 57, 58].

III. HISTORICAL ASPECTS

The legitimate geographical origin alluding to the appearance of sweet potatoes is unknown. This topic is current, relevant, and controversial.

The central hypothesis indicates that the plant comes from the Americas, along regions that cover part of Central America and South America. Archaeological studies and the analysis of food fragments present in ancient caves and archaeological sites in Chilca, Peru, indicate the probable presence of sweet potato in this region, still in the Neolithic period, about 8,000 years B.C. [10, 12, 44, 59, 60, 61, 62, 63, 64, 65, 66].

According to Austin[11] the evolution of sweet potatoes is linked to the development of peoples that inhabited the Yucatán Peninsula in southeastern Mexico and the mouth of the Orinoco River which has a large part in the Delta Amacuro state northwest of Venezuela around 5,000 BC. Records show that sweet potatoes were present in the group of foods produced by inhabitants of Peru, around 750 A.D., employing subsistence agriculture [66, 67, 68].

Seeking to understand the origins of the evolution of sweet potatoes, Srisuwan, Sihachakr and Siljak-Yakovlev[64] studied the organization of plant chromosomes *Ipomoea* spp., and describe that the probable origin of sweet potatoes stems from the crossing between wild *Ipomoea*, *Ipomoea trifida* showed greater genetic proximity to *Ipomoea batatas*. Likewise, Roullier et al.[69] analyzed the genetics of sweet potato cultivars from regions in Mexico to Peru and observed that the genetic evolution of accessions of Ipomoea potatoes results from the crossing of the species with another Ipomoea spp.

This hypothesis was corroborated by the work of Yang et al.[70] which used computational algorithms and techniques for gene synthesis from sequences between Ipomoea potatoes and Ipomoea nil. It was able to solve more than 75% of the sequential genomic assembly of the sweet potato, developing a pioneer model with 15 pseudo-chromosomes. The authors raise the hypothesis that the hexaploid domesticated sweet potato ($B_1B_1B_2B_2B_2B_2$), arose from the cross between a diploid wild parent (*Ipomoea trifida*) and a tetraploid wild parent (*Ipomoea batatas*), followed by two duplication events of the entire genome that probably occurred in the period between 800 and 500 thousand years B.C.

Srivastava, Mehrotra and Dilcher[71] analyzed leaf fossils found in archaeological sites in Meghalaya, in eastern India, which were dated to the Paleocene period, around 57 million years B.C. During this period, the Meghalaya region was part of the supercontinent East Gondwana. The researchers identified that the fossils refer to leaves of plants of the family Convolvulaceae, and have similar morphology to leaves of plants of Ipomoea spp. The study presents a hypothesis that the genus Ipomoea may have originated in Asia and that, probably, sweet potatoes may have evolved from this region, and not from the Americas.

On the other hand, another controversial topic involving the sweet potato's history concerns its emergence and dispersion throughout Oceania.

In the Polynesian region, the cultivation of sweet potatoes was already practiced by ancient inhabitants even before the arrival of western explorers. A hypothesis for the arrival of sweet potatoes in the Polynesian region says that Polynesian navigators crossed the Pacific Ocean to the Americas and that, probably, during their return, they transported seed branches or tuberous roots in the budding stage which were distributed to several islands in the region such as the Cook Islands, Northern Mariana Islands, New Zealand, Hawaii, Rapa-Nui (Easter Island) [7, 12, 52, 72, 73, 74, 75, 76, 77, 78].

Evidence revealed the presence of sweet potatoes in the diet of ancestral peoples who inhabited the remote Easter Island. The analysis of the dental calculus of human fossils, recovered from archaeological sites present on the island[79] revealed the deposition of starch granules as the analysis of these starch granules showed compatibility with the starch present in tuberous sweet potato roots [80, 81].

Molecular studies are also carried out to clarify the casualties concerning the global dispersion of sweet potatoes, based on the evaluation of the genetic relationship that exists between species that occupy different regions.

In recent work, Muñoz-Rodríguez et al.[82] studied the phylogenetic evolution of sweet potatoes from the genome analysis of 199 samples, one of which is from the Society Islands (French Polynesia), collected in 1769 by members of the expeditionary corps of the illustrious British explorer James Cook. The researchers shared the perspective that sweet potato strains from the Americas and Polynesia separated at least 100,000 years BC. This theory supports the possibility that sweet potatoes arose in the Polynesian region even before humans.

Miryeganeh and collaborators[83] studied the dispersion over long distances of a plant of the family Convolvulaceae and genus Ipomoea, of which sweet potatoes are part. The authors raise the hypothesis that the cosmopolitan presence of plants of this genus is due to branches and seeds that, possibly, were carried by sea currents and were deposited in the coastal region of different parts of the world, also highlighting the importance of pollen dissemination for angiosperms grouped in this family and genus

IV. SWEET POTATOES WORLD PRODUCTION

Sweet potato is a rustic food crop, capable of growing and producing tuberous roots in poor soils and with low investment in agricultural inputs. The high productive yield is due, in part, to the plant's efficiency in converting energy per unit area, per unit time. This characteristic contributes to its cultivation being carried out in more than 100 countries, mainly in underdeveloped countries where agriculture lacks technology [12, 51, 84].

In countries in Asia, Africa and the Americas, sweet potatoes have fundamental importance as a staple food, used to supply the domestic market and widely used as a food supplement in the diet of several inhabitants [85, 86].

According to data made available by the Food and Agriculture Organization (FAO), in 2018, more than 91 million tons of sweet potatoes were produced worldwide, with a harvest area of around 8 million hectares[2], indicating that the global production of sweet potatoes showed an average yield of about 11 tons per hectare.

Regarding the continents that produce sweet potatoes, Asia has the largest productive share, with the generation of 66% of the total harvest of 2018. Africa is also a continent that shows a large production of sweet potatoes, representing 28.3% of the total produced in that year. The Americas produced approximately 4.6%, Oceania 1% and Europe 0.1% [2].

It is worth mentioning that sweet potato production in Europe tends to be impaired due to the low temperatures that predominate in most countries that make up the continent. Sweet potato is a crop produced on a large scale in the tropics, including countries located in warm temperate zones. For the optimal development of the plant, it is recommended that the cultivation soil has a temperature between 15°C to 29°C, and the environment has a temperature variation between 24°C to 30°C [87].

Among the countries that grow sweet potatoes, China (Central China) stands out as the largest producer, followed by countries located on the African and Asian continents [2]. Table 1 shows the ten countries that most produced sweet potatoes in 2018.

China leads, since 1961 (beginning of the available historical series) to the present day the world production of sweet potatoes [2]. According to information made available in the Statistical Yearbook of China, in 2018, the per capita consumption of tubers by the country's population was about 2.6 kg [88, 89, 90].

China uses a large part of its sweet potato crop as a raw material for animal feed production, starch production and pasta production. Sweet potato branches and leaves are also used for animal feed, especially in pig farming [16, 91].

Table 1 - The ten countries that most produced sweet potatoes in the world in 2018

Countries	Production (t)
Central China	53,009,345
Malawi	5,668,543
Nigeria	4,029,909
United Republic of Tanzania	3,834,779
Ethiopia	1,834,619
Indonesia	1,806,389
Uganda	1,529,608
India	1,400,281
Viet Nam	1,374,664
Angola	1,274,871

Source: [2].

Malawi is a country located on the African continent and, like China, it also shows high production of sweet potatoes. According to Table 1, considering the number of sweet potatoes produced in 2018 in a harvest area of around 283,187 hectares[2], Malawi shows average productivity of around 20 tons per hectare, exceeding the world average.

In Malawi, sweet potatoes are commonly grown using crop rotation techniques with maize and beans. The main crop is ploughed during the period between October and March since the second crop is usually produced in mid-July to September [92, 93].

The significant production of sweet potatoes in Malawi reflects the spread of programs aimed at the development of local agriculture. In the early 1990s, the country was afflicted with a severe drought, which caused insufficient propagating material. Thus, starting in 1992, public agents concentrated their efforts on projects aimed at the distribution of cassava and sweet potato seeds among farmers. As a result, between 1994 and 1995, the sweet potato cultivation area grew by 63%, and production increased by 92% [94, 95].

Agricultural development programs in Malawi provided support to boost food production in the country while contributing to increasing farmers' incomes and combating malnutrition. Thus, sweet potato has become a significant crop for the country's food security [94, 96, 97].

In Latin America, the sweet potato crop is fundamental to the composition of the population's base food group. Regarding sweet potato production in the American continent, the major countries that produced sweet potatoes in 2018 were: United States of America (USA), Brazil, Haiti, Cuba, Argentina, Peru, Uruguay, Mexico, Dominican Republic and Paraguay, respectively [2].

It is worth mentioning that Brazil is the second major sweet potato producer in the Americas.

V. AGRICULTURAL RESEARCH AND SWEET POTATOES PRODUCTION IN BRAZIL

According to data provided by the Brazilian Institute of Geography and Statistics (IBGE), Brazil produced, in 2018, more than 741 thousand tons of sweet potatoes [98].

Table 2 shows the results of Brazilian sweet potato production from the beginning of the historical series to the most recent data.

Table 2 - Brazilian sweet potato production between 1988 to 2018

Year	Production (t)
1988	677,240
1989	682,152
1990	636,691
1991	622,432
1992	603,347
1993	575,872
1994	655,613
1995	619,186
1996	414,283
1997	490,087
1998	444,925
1999	472,422
2000	484,443
2001	484,719
2002	498,046
2003	533,165
2004	538,503
2005	513,646
2006	518,541
2007	529,531
2008	548,438
2009	477,472
2010	495,182
2011	544,820
2012	479,425
2013	505,350
2014	525,814
2015	595,977
2016	672,866
2017	780,461
2018	741,203

Source: [98].

According to Table 2, it is possible to identify that, in 2017, the Brazilian sweet potato crop reached the peak of production compared to the historical series. Considering the numbers between 2012 and 2017, Brazil sweet potato productivity growth more than 38%. However, there was a slight decrease of 5% between the 2017-2018 Brazilian sweet potato production.

Perhaps, the recent growth of Brazilian sweet potato production was directly driven by consumer demand. The sale of tuberous roots occurs mainly in fresh conditions, and most of the flow of the national harvest is carried out through the retail food trade in State Supply Centers (CEASAs), grocery and horticultural markets [99, 100].

On the other hand, agronomic research that seeks to improve production management and available sweet potato cultivars can contribute substantially to leverage productivity indexes, strengthen the production chain and boost the implantation of commercial crops of economic expression, stimulating greater commercial product availability [101].

In 1975, the State Research Execution Unit (UEPAE) in the city of Brasília, initiated research work aimed at improving vegetables. In 1981, UEPAE-Brasília became the National Center for Research on Vegetables and promoted, between 1982-1983, preliminary research aimed at improving sweet potatoes. Later, UEPAE-Brasília would become EMBRAPA-Hortaliças [102].

In 1978, UEPAE-Manaus began researching sweet potatoes to assess the productive potential of the crop for the state of Amazonas. The pioneering work carried out by UEPAE-Manaus sought to establish the cultivation consortium between sweet potatoes and guarana to provide good soil coverage and ensure higher profitability for the local farmer [103, 104].

Guedes[105] studied the cultivation characteristics and the production potential of six sweet potato cultivars in firm lands in the state of Amazonas. Two cultivation experiments were implemented at different times of the year (May and September), with the planting the slips on rows spaced 1 m apart, and 0.50 m between plants, with the application of fertilizer. The May experiment was harvested after 90 days, and the experiment started in September was harvested after 120 days, which showed higher yield and ranged from 16,520 to 32,900 kg/ha. The researcher pointed out that the cultivation of sweet potatoes in Amazonas arouses great interest when considering the generation of raw material to produce flour [106], as well as to produce alcohol.

The Agronomic Institute of Paraná (IAPAR) has also been conducting agronomic research since the 1980s for the improvement and introduction of sweet potato cultivars that are suitable for cultivation in the state of Paraná [107].

Souza[108], evaluated the potential of seven sweet potato genotypes for the city of Ponta Grossa/Paraná, which were cultivated in low fertility soil between 1993-1994. Sweet potatoes were evaluated based on agronomic, commercial, and culinary characteristics. The author comments that the productive yield of the genotypes varied between 13.7 to 21.7 t / ha, while the commercial yield of the tuberous roots varied between 43 to 83% of the total production.

Since 1975, the Santa Catarina Agricultural Research Corporation (EMPASC) has been carrying out research and rural extension work to strengthen the agricultural chain. Later, EMPASC became the Agricultural Research and Rural Extension Corporation of Santa Catarina (EPAGRI). EPAGRI owns the Sweet Potato Germplasm Active Bank (BAG-sweet potato), which was created in 1984, with the collection of cultivars from Santa Catarina and subsequent introduction of cultivars from other countries such as Argentina and Peru, enabling new crosses and obtaining genetically improved cultivars [109].

The cultivars obtained through genetic improvement are oriented to cultivation in Brazilian soil with agronomic benefits such as higher resistance to pests, tolerance to water scarcity, stability in the propagation material and high productivity, together with the biofortification of nutrients (Fig.3). These characteristics contribute to making the sweet potato crop attractive to the producer and the consumer [110, 111, 112, 113].

Figure 3: Sweet potato propagation material example: sprouted tuberous root.

Montes et al.[114] published a case study in the city of São Paulo and reported that the cultivation of sweet potatoes has great importance in the generation of jobs in the field due to the need for labor during mining. In this study, the use of machinery stands out as the main cost item for the producer.

Nunes et al.[115], evaluated the productivity index of sweet potato genotypes with potential for biofortification, from cultivars that stood out in previous research[116], which come from the germplasm bank of Embrapa-Tabuleiros Costeiros in Sergipe. Among the 17 genotypes evaluated in shallow and low fertility soil, 15 showed good productivity of tuberous roots.

The Ministry of Agriculture, Livestock and Supply (MAPA) acts, through the National Registry of Cultivars (RNC), to control the production and commercialization of seeds and seedlings of new plants obtained in agricultural research (MAPA, 2020).

The new cultivars registered with the RNC are authorized to sell seeds and seedlings for cultivation. Table 3 shows the 29 Brazilian sweet potato cultivars.

Table 3 - Brazilian sweet potato cultivars

Cultivar	Holder*	Register
Amanda	UFT	22593
Ana Clara	UFT	22594
Barbara	UFT	22595
Beatriz	UFT	22596
Beauregard	EMBRAPA	26934
Brazlândia branca	EMBRAPA	07840
Brazlândia rosada	EMBRAPA	07841
Brazlândia roxa	EMBRAPA	07852
BRS Amélia	EMBRAPA	27313
BRS Cuia	EMBRAPA	27315
BRS Fepagro viola	EMBRAPA	33889
BRS Gaita	EMBRAPA	33890
BRS Rubissol	EMBRAPA	27314
Carolina Vitoria	EMBRAPA	22597
Coquinho	EMBRAPA	07849
Duda	UFT	22598
Iapar 69	IAPAR	02322
Iapar 70	IAPAR	02323
Izabela	UFT	22600
Julia	UFT	22599
Livia	UFT	22591
Marcela	UFT	22592
Princesa	EMBRAPA	06495
SCS367 Favorita	EPAGRI	27465
SCS368 Ituporanga	EPAGRI	27464
SCS369 Águas Negras	EPAGRI	27463
SCS370 Luiza	EPAGRI	32952
SCS371 Katiy	EPAGRI	32953
SCS372 Marina	EPAGRI	32954

***** UFT: Federal University of Tocantins; EMBRAPA: Brazilian Agricultural Research Corporation; IAPAR: Paraná Agronomic Institute; EPAGRI: Santa Catarina Agricultural Research and Extension Company
Source: [117].

Azevedo et al.[118] analyzed 65 genotypes of sweet potatoes from the germplasm bank of the Federal University of Jequitinhonha and Mucuri Valley (UFVJM) according to the agronomic performance of the plants, mainly regarding the total root productivity, a factor of greater importance under the view of commercial production. The authors point out that the genotypes showed improvements in agronomic performance. However, crop management and environmental effects can directly influence the productivity of tuberous roots.

Reddy et al.[119] evaluated the morphological characteristics of plants from 15 sweet potato cultivars, cultivated in clayey and silty soil, with pH 6.8 and a 120-day production cycle. The authors observed that the yield of tuberous roots has a positive correlation with the morphological characteristics of the plant, such as plant length, number of leaves and shoots. Furthermore, the plants with the highest yield produced tuberous roots with white and cream pulp, while the plants with the lowest yield generated roots with purple and orange pulp.

It is worth mentioning that the research for genetic improvement of sweet potatoes that seek to obtain new cultivars with excellent productive and nutritional performance can contribute to improving the interest of the rural producer in planting the crop inducing an increase in the commercial availability of sweet potatoes.

VI. SWEET POTATO NUTRITIONAL QUALITY AND SOCIAL RELEVANCE

Sweet potato is a food of high nutritional value and consumed worldwide. It is rich in vitamin C and vitamin A (orange-fleshed sweet potato), and a source of energy, fiber, vitamin B5 (pantothenic acid), vitamin B6 (pyridoxine), and potassium. Colored-fleshed sweet potatoes also have bioactive compounds that help to maintain consumer health [120, 121].

The United States Department of Agriculture (USDA) provides information about the nutritional composition of various types of food, including their primary means of consumption, through the database called FoodData [122].

Table 4 presents the sweet potato nutritional composition data provided by USDA-FoodData, under the circumstances of raw and cooked food, highlighting only the nutrients available in the tuberous roots.

Table 4 – Sweet potato raw and cooked with skin nutritional composition

Composition*	**Sweet potato raw (100g)**	**Sweet potato cooked/skin (100g)**
Water	77.28 g	75.78 g
Energy	86 kcal	90 kcal
Protein	1.57 g	2.01 g
Total lipid (fat)	0.05 g	0.15 g
Ash	0.99 g	1.35 g
Carbohydrate	20.12 g	20.71 g
Fiber, total dietary	3.0 g	3.3 g
Sugars	4.18 g	6.48 g
Sucrose	2.52 g	2.28 g
Glucose (dextrose)	0.96 g	0.57 g
Fructose	0.7 g	0.5 g
Maltose	0 g	3.12 g
Starch	12.65 g	7.05 g
Calcium, Ca	30 mg	38 mg
Iron, Fe	0.61 mg	0.69 mg
Magnesium, Mg	25 mg	27 mg
Phosphorus, P	47 mg	54 mg
Potassium, K	337 mg	475 mg
Sodium, Na	55 mg	36 mg
Zinc, Zn	0.3 mg	0.32 mg
Copper, Cu	0.151 mg	0.161 mg
Manganese, Mn	0.258 mg	0.497 mg
Selenium, Se	0.6 µg	0.2 µg
Vitamin C	2.4 mg	19.6 mg
Thiamin	0.078 mg	0.107 mg
Riboflavin	0.061 mg	0.106 mg
Niacin	0.557 mg	1.487 mg
Pantothenic acid	0.8 mg	0.884 mg
Vitamin B-6	0.209 mg	0.286 mg
Folate, total	11 µg	6 µg
Choline, total	12.3 mg	13.1 mg
Betaine	0 mg	34.6 mg
Vitamin A	709 µg	961 µg
β-Carotene	8509 µg	11509 µg
α-Carotene	7 µg	43 µg
Vitamin E	0.26 mg	0.71 mg
β-Tocopherol	0.01 mg	0.01 mg
α-Tocotrienol	0.01 mg	0.02 mg
Vitamin K	1.8 µg	2.3 µg
FAS*	0.018 g	0.052 g
FAM*	0.001 g	0.002 g
FAP*	0.014 g	0.092 g
Tryptophan	0.031 g	0.04 g
Threonine	0.083 g	0.107 g
Isoleucine	0.055 g	0.07 g
Leucine	0.092 g	0.118 g
Lysine	0.066 g	0.084 g
Methionine	0.029 g	0.037 g
Cystine	0.022 g	0.028 g
Phenylalanine	0.089 g	0.114 g
Tyrosine	0.034 g	0.044 g
Valine	0.086 g	0.11 g
Arginine	0.055 g	0.07 g
Histidine	0.031 g	0.039 g
Alanine	0.077 g	0.099 g
Aspartic acid	0.382 g	0.488 g
Glutamic acid	0.155 g	0.198 g
Glycine	0.063 g	0.081 g
Proline	0.052 g	0.067 g
Serine	0.088 g	0.113 g

***** FAS: Fatty acids, total saturated; FAM: Fatty acids, total monounsaturated; FAP: Fatty acids, total polyunsaturated
Note: g = grams; mg = milligrams; µg = micrograms.
Source: [122].

It is noteworthy that the sweet potato is a nutritious food and of high energy value. The natural tuberous roots have a high content of starch, complex carbohydrates, and fibers, as well as minerals and vitamins. When sweet potatoes are cooked, there is a variation in micronutrient density, with an increase in the content of some minerals and vitamin C.

The predominant component of sweet potato on a dry basis is starch, which can vary between 65% to 89% of the composition in different cultivars. Starch is a type of carbohydrate made up of glycosidic chains, which form two portions of polysaccharides called amylose and amylopectin. Starch is considered as the primary energy reserve of plants. The sweet potato starch provides energy to the body, especially when the tuberous roots are subjected to cooking, as the starch chains are transformed into maltose (Table 4), which increases the glycemic index of this food [123, 124, 125, 126].

Sweet potato leaves and branches also have several micronutrients and bioactive compounds. The physicochemical composition of the leaves reveals the presence of several nutrients such as vitamins and minerals, in addition to fibers and bioactive compounds. Sweet potato leaves are consumed as food, especially by inhabitants of countries in the African continent, Asia, and Pacific Ocean islands [127]. The branches and leaves also have a suitable fermentation profile to be used in the production of silage for animal feed [46].

Sun et al.[128], evaluated the nutritional composition of leaves of 40 Chinese sweet potato cultivars and identified a high content of protein, sodium, potassium, and polyphenols. The authors suggest that the consumption of sweet potato leaves may help to combat malnutrition problems in underdeveloped countries.

The tremendous social relevance of sweet potatoes becomes evident when considering the nutritional requirement of the human being combined with the commitment to food production. Sweet potatoes are a convenient food to be used as a nutritional supplement in the diet of vulnerable people.

Countries and international institutions invest in public policies and social projects to aid populations that have problems related to malnutrition, mainly for the group of women, pregnant women, lactating women, and children. The projects seek to promote improvements in the diet by encouraging the production and consumption of nutritious foods, which can prove to guarantee positive effects for the consumer's health [129].

In this sense, sweet potato is a food capable of filling the deficiency of important nutrients for the maintenance of metabolism, as is the case of retinol, also known as vitamin A.

Hypovitaminosis A is considered a severe health problem in several countries that make up the region known as Sub-Saharan Africa. This public health problem encouraged the design of proposals aimed at promoting cultivation and encouraging the consumption of orange-fleshed sweet potatoes, a food rich in β-carotene, a substance considered pro-vitamin A [18, 130].

Williams et al.[86], reported that chronic pathologies resulting from malnutrition, mainly related to hypovitaminosis A, figure as a significant problem for Timor-Leste. The authors evaluated the introduction of three sweet potato cultivars for cultivation by local farmers in the seasons 2006-2007 and 2007-2008, and report that at least one cultivar had production potential under the conditions of local agriculture, combined with the necessary nutritional quality to mitigate the demand for vitamin A by the country's vulnerable population.

Laurie et al.[85], evaluated 57 South African sweet potato cultivars for morphological characteristics and genetic diversity, which come from research to improve native cultivars. Its results showed some sweet potato cultivars with better flavor, longer storage time, and high production capacity with tolerance to dry soils. The authors emphasize the results that are useful for the advancement of cultivation improvement studies, as well as for nutrition programs, for example, the Sweetpotato Action for Security and Health in Africa (SASHA), which acts to stimulate the increase in potato consumption of orange pulp in Africa.

The Helen Keller International institution promoted the project The Reaching Agents of Change (RAC) that worked in Tanzania, Mozambique, Nigeria, Ghana, and Burkina Faso. The project generated political and social changes in the different countries by ensuring the cultivation and supply of orange-fleshed sweet potatoes, making this a significant food for local populations [131].

VII. SWEET POTATO BIOACTIVE COMPOUNDS

The colored flesh sweet potato cultivars have in their composition a wide variety of bioactive compounds such as polyphenols, phenolic acids, carotenoids, and anthocyanins [132, 133, 134]. These compounds can act in various biochemical reactions in the body, contributing positively to the maintenance of consumer health [135, 136].

Several studies seek to quantify[137], extract[138], analyze the stability[139] of bioactive compounds present in sweet potatoes, in addition to assessing their intake and performance for the biological maintenance of the consumer's organism, especially regarding the level of metabolism substances and the consequent increase after the consumption of sweet potatoes [134, 140].

Purple-fleshed sweet potatoes have significant amounts of polyphenols and anthocyanins, which makes regular consumption interesting [86, 134, 141, 142]. Anthocyanins also arouse great interest on the part of the industry in terms of their application as natural coloring [143].

Jie et al.[141] identified and evaluated the thermal stability of purple-fleshed sweet potato anthocyanins (Chinese cultivar Jihei), and reported that thirteen types of anthocyanins were identified, especially cyanidin and peonidin, acylated with p-phenolic acids hydroxybenzoic acid, ferulic acid and caffeic acid. The authors point out that anthocyanins present in purple-fleshed sweet potatoes have the potential for application in various products in the food industry.

Xu et al.[142], characterized the anthocyanins present in the purple-fleshed sweet potato cultivar P40 and evaluated the stability under cooking conditions. The authors report that this cultivar has a high anthocyanin content (14 mg / g on a dry basis), with the identification of 12 acylated anthocyanins. Deacylated anthocyanins showed higher resistance to cooking, highlighting that these compounds can also be used in the development of functional products.

Another bioactive compound present in some sweet potato cultivars that arouses great interest is β-carotene. Champagne et al.[144] characterized the carotenoids present in 10 different tuber and tuberous root cultivars are grown in Vanuatu. In particular, the authors evaluated 33 sweet potato tuber roots and reported a high concentration of trans-β-carotene for orange pulp cultivars.

Ginting[145] evaluated the extraction of carotenoids from orange-fleshed sweet potatoes and their application as a natural color in foods. The author reports that extracts were obtained ranging from 12.49 to 235.94 µg / mL for β-carotene, noting that the extracts showed color stability after one month stored in the dark.

Hussein et al. [146], quantified the presence of sweet potato carotenoids grown in Malaysia and observed that orange pulp cultivars have a higher content of the substance compared to other cultivars, with the variable post-harvest storage time directly influencing the concentration and stability of these compounds. The author also points out that the availability of cultivation throughout the year, associated with the low cost of production, makes orange-fleshed sweet potatoes an interesting source of carotenoids.

VIII. CONCLUSION

The sweet potato taxonomy study provides significant informations related with hierarchical traits of the crop, and that is vital for understanding the morphological and biological properties of its species. However, the historical evolution of the sweet potato, as well as its worldwide dissemination along with its rise in Oceania, are inconclusive themes. In fact, sweet potato is a nutritious food. It has fiber, vitamins, and minerals despite to be a great source of energy. Colorful-fleshed sweet potato cultivars have bioactive compounds such as polyphenols, anthocyanins, and carotenoids, which makes them attractive to consumers looking to eat health-beneficial foods. The major sweet potato producer in the world is China (Central China), flowed by African and Asian countries. Brazilian sweet potato production revealed that the country is far below when compared to the leading world producers which indicates that sweet potato productive and technological potential is still little explored. From that perspective, agricultural research companies have a fundamental role in the improvement of cultivars that present high productive and nutritional performance combined with biofortification and adaptation for the different Brazilian regions. It is noteworthy that further studies should be conducted, aiming at the application of sweet potatoes in different industrial segments in Brazil.

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