





Review

# Sweet Potato (*Ipomoea batatas* L.) Phenotypes: From Agroindustry to Health Effects

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**Citation:** Escobar-Puentes, A.A.; Palomo, I.; Rodríguez, L.; Fuentes, E.; Villegas-Ochoa, M.A.; González-Aguilar, G.A.; Olivas-Aguirre, F.J.; Wall-Medrano, A. Sweet Potato (*Ipomoea batatas* L.) Phenotypes: From Agroindustry to Health Effects. *Foods* **2022**, *11*, 1058. <https://doi.org/10.3390/foods11071058>

Academic Editors: Marcello Iriti and Sara Vitalini

Received: 14 March 2022

Accepted: 3 April 2022

Published: 6 April 2022

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**Abstract:** Sweet potato (SP; *Ipomoea batatas* (L.) Lam) is an edible tuber native to America and the sixth most important food crop worldwide. China leads its production in a global market of USD 45 trillion. SP domesticated varieties differ in specific phenotypic/genotypic traits, yet all of them are rich in sugars, slow digestible/resistant starch, vitamins, minerals, bioactive proteins and lipids, carotenoids, polyphenols, ascorbic acid, alkaloids, coumarins, and saponins, in a genotype-dependent manner. Individually or synergistically, SP's phytochemicals help to prevent many illnesses, including certain types of cancers and cardiovascular disorders. These and other topics, including the production and market diversification of raw SP and its products, and SP's starch as a functional ingredient, are briefly discussed in this review.

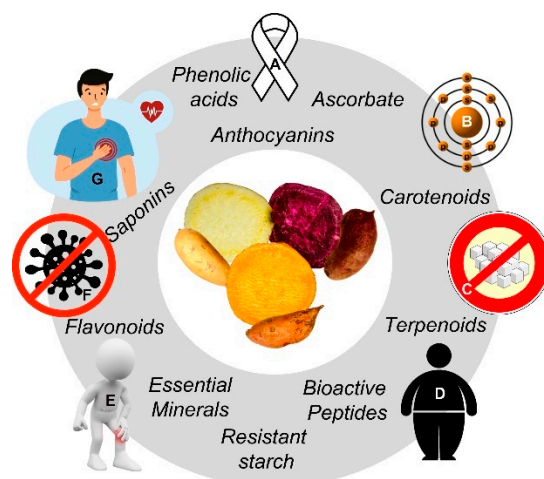
**Keywords:** antioxidants; sweet potato; *Ipomoea batatas*; cancer; carotenoids; phenolic compounds

## 1. Introduction

The study of edible roots and tubers (R&T) has attracted the attention of researchers worldwide. Research published to date ranges from their economic and cultural dimensions to their nutritional/functional value as staple foods for certain countries [1–4]. Among R&T, sweet potato (SP; *I. batatas* (L.) Lam; also known as 'boniato', 'moniato', 'caiaipo', 'kumara' or 'kumera') with its >1600 species, has been a major staple food for certain ancient populations for centuries [1,2]. In fact, archaeobotanical and epigraphic evidence allows us to affirm that SP was and continues to be an ingredient widely used to make different drinks and foods, both sweet and salty, in populations of diverse cultures [3,4].

The genus *Ipomoea* belongs to the *Convolvulaceae* family, and 600–800 species have been identified by cytogenetics [5,6]. Most of them exhibit health-promoting bioactivities, such as those related to their phytochemical profile: anti-inflammatory (*I. cairica*), anti-constipation (*I. digitata*), analgesic (*I. stans*), antidiabetic and hypotensive (*I. aquatica*, *I. batatas*), hemostatic and vasoconstrictor (*I. tricolor*), psychotomimetic (*I. muelleri*, *I. violacea*) and anti-cancer (*I. horsfalliae*, *I. turpethum*) activities [7]. Sweet potato (SP; *I. batatas* (L.) Lam),

contains a wide range of nutrients and xenobiotic phytochemicals with antioxidant, anti-nyctalopia/xerophthalmia, hepatoprotective/spasmolytic, anticoagulant/anti-HIV antibacterial, and antidiabetic potential. Particularly, specific anticancer bioactives (e.g., phenolic acids, carotenoids, and peptides) present in the aerial (leaves, stems, tubers) and non-aerial (storage roots) parts of SP suggest phenotype/variety-specific benefits [8–12]. It is noteworthy that certain phenotypic traits of SP genotypes are closely related to their functional/nutraceutical value: the peel and flesh (central parenchyma) pigmentation, going from white-creamy to dark purple (Figure 1) is related to their phenolic and carotenoid content [13–16].



**Figure 1.** Sweet potato (SP; *Ipomoea batatas* L.) group of phytochemicals with associated health-promoting effects. Preventive actions (clockwise): Immunocompromise (A), prooxidant (B), diabetes (C), adiposity (D), inflammatory (E), infection (F), cardiovascular (G) diseases/metabolic rearrangements. Source: The authors (CC (by/nc/sa)-licensed clip art).

However, food processing and preservation [13,14,17–19] and the gastrointestinal fate of its phytochemicals [20–22] may hinder the health-promoting potential of SP. The aim of this narrative review is to provide an update on SP’s botany/molecular phylogeny, agroindustry, and product commercialization/technological diversification, as well as the nutritional/functional value of SP’s major genotypes (by flesh color) and certain health effects (cancer chemoprevention and cardiovascular health promotion). Certain physiological considerations to ensure SP’s health benefits are discussed shortly.

### 1.1. Botany and Molecular Phylogeny

SP is a member of the bindweed or morning-glory (*Convolvulaceae*) family that groups ~60 genera and >1650 species. This perennial herbaceous vine is a dicotyledonous initially described by Linnaeus in 1753 as *Convolvulus batatas* and further reclassified by Jean-Baptiste Lamarck in 1791 within the genus *Ipomoea*, based on its stigma shape and pollen grain surface. The systematic botany, based on the phenotypical features of a typical SP plant, was previously reported by Huamán [23], who described that storage roots—the commercial edible fraction mistakenly known as a tuber—differ in size, color of rind, skin (peel), flesh (central parenchyma) and shape [24]. Currently, one out of three *Ipomoea* accessions deposited in recognized gene banks (e.g., GenBank®) is *I. batatas* [25]; most of them are commercialized in regional markets.

The origin, timing, and geographic location(s) of cultivated SP have been disentangled recently with the advent of molecular phylogenetics [11,25]. Domesticated SP initially diverged from two non-edible ancestors: the wild SP (polyploid; “pencil-shaped” roots); and *I. trifida* (diploid; no root-forming). These evolved spontaneously to other tetraploids or hexaploid [26–28] progenitors with much thicker tuberous storage roots. Their subsequent clonal propagation, under a pre-existing environmental trait and complex (yet unknown) growing factors, resulted in wild edible storage roots that preceded the domestic cultivation

of current SP genotypes. Nowadays, it is widely accepted that SP are native to South-Central America (domesticated >5000 years ago) and were introduced to Spain and Europe (by Columbus), Africa, India, Southeast Asia, and the Philippines (by Portuguese explorers) between the 14th and 16th century, and that its intensive cultivation began ~630 years ago in Asia and in the 1960s in Africa [29]. It is noteworthy, that the Quechua and Polynesian names for SP ('kuumala' and 'kumara/cumal'), and further DNA genotyping support the Peruvian origin and human transfer of the Polynesian SP [30,31].

A successful breeding program for SP implies a careful selection of germplasms (genetic diversity) and the systematic evaluation of phenotypic traits (ideotypes) sensitive to environmental stressors and crop agronomic performance indicators [32–34]. It is noteworthy that genetic breeding programs aiming to produce new SP varieties remain challenged since it is an allohexaploid crop [5,26–28] with a large chromosome number ( $2n = 6x = 90$ ), a complex sporophytic self- and cross-incompatibility and a high degree of genomic duplication [35,36]. Besides genetic diversity, SP varieties phenotypically differ in flesh/skin colors, size, shape, texture, and taste of the storage root, all intrinsically related to a variety-specific activation/regulation of key biosynthetic routes, such as the methylerythritol-4-phosphate (for carotenoids) and phenylpropanoid (for anthocyanins) pathways [24]. New hexaploidy cultigens with agronomical and nutritional profiles have been produced by genetic engineering. SP phenotypes with higher Fe/Zn bioaccessibility, better carotenoid (IbOr), anthocyanin (IbMYB1, IbDFR), or starch (GBSSI) profiles as well as climate-resilient (e.g., 'Radiance'), and 'dual-purpose' varieties, are some examples [14,25,37–41].

## 1.2. Agroindustry and Phytochemistry

Roots and tubers (R&T) are the third most important food crop after cereals and legumes. R&T with the highest production value are cassava (*Manihot esculenta*), potato (*Solanum tuberosum*), yam (*Dioscorea alata*), and SP [42]. SP can grow in many soils and environmental conditions and demand few agricultural resources, and grow rapidly (3–5 months), depending on the genotype-by-environment interaction [14,43,44]. SP does not tolerate cold weather, but neutral/alkaline and humus-free soils are essential for obtaining high-quality storage roots [45]. SP is not as perishable as climacteric fruits and vegetables, yet post-harvest losses due to physical, physiological (malformed shape), and pathological (microbial spoilage) damage can be important, affecting the SP's shelf life and consumer preference for SP [46,47]. Recommendations for a successful SP harvest are beyond the scope and purpose of this review, but they have been discussed in depth by other authors [13,14].

The global harvested area ( $\text{Ha} \times 10^6$ ) of SP between 1961 and 2010 fell from 13.4 to 8.1, yet a positive production ( $0.98$  to  $1.10 \text{ tons} \times 10^8$ ) and yield ( $\text{hg}/\text{Ha} \times 10^4$ ) trend was recently reported [46]. However, the global SP production did not change much between 1999–2019 (Tables 1 and S1). According to FAO [47], the average harvested area ( $\text{Ha} \times 10^6$ ), annual production ( $\text{tons} \times 10^8$ ), and yield ( $\text{hg}/\text{Ha} \times 10^4$ ) were 9.7, 1.5, and 8.9 in 1999, 7.8, 1.0, and 10.0 in 2009, and 7.8, 0.9, and 11.0 in 2019, respectively (Table 1a). According to FAO, SP is currently cultivated in 112 countries (Table S1), China and Nigeria contributing to 69.4%/ 87.4% (1999), 55.5%/ 76.1% (2009), and 52.7%/ 61.1% (2019) of the global harvest area (Ha)/production (tons) of this tuber, with the current market value at nearly USD 45 trillion. It is noteworthy that China's and Nigeria's crop yields ( $\text{Hg}/\text{Ha}$ ) were not as good as those of other small producers ( $\leq 14, 615 \text{ Ha}$ ), such as Senegal, Australia, Egypt, and the Cook Islands in the same years (Table 1b). A reduction in harvest area was also documented in China and Africa between 1961–2010 [47].

Global crop yields ( $\text{hg}/\text{Ha}$ ) had a slight decline in 1999 (16.5%), 2009 (12.8%), 2019 (11.8%), a fact closely associated with a country (United States of America (USA), China (Ch)), continent (Africa (Af), America (Am), Asia (As)), and worldwide (W) reduction in the total harvested area (Figure S1;  $R^2 = 0.84$ ).

**Table 1.** Agricultural performance of sweet potatoes in two decades <sup>1</sup>.

(a)	Global	China	Nigeria		
		1999			
Area (Ha)	9,749,117	5,945,975			817,000
Production (tons)	147,214,978	126,143,701			2,354,000
Yield (Hg/Ha)	89,239 ± 63,996	212,150			43,673
		2009			
Area (Ha)	7,848,391	3,253,056			1,100,000
Production (tons)	96,424,362	70,040,593			3,300,000
Yield (Hg/Ha)	100,364 ± 73,753	215,307			30,000
		2019			
Area (Ha)	7,769,851	2,373,737			1,717,659
Production (tons)	91,820,732	51,992,156			4,145,488
Yield (Hg/Ha)	110,770 ± 82,415	219,031			24,135
(b)	1999	2009	2019	ΔYield/y	R <sup>2</sup>
Senegal	87,469	400,000	385,997	15,396	0.69
Australia	275,000	250,797	363,976	4805	0.59
Egypt	240,545	285,425	320,537	4197	0.99
Cook Islands	263,478	266,667	291,667	1502	0.86

<sup>1</sup> Source: FAO statistical databases [47]. Agronomic performance indicators for large (a) and small (b) SP producers, average yield change/year ( $\Delta$ Yield/y), and linear trend (R<sup>2</sup>).

Nevertheless, China (21.2–21.5–21.9), Asia (19.6–19.4–20.2) and Africa to a lesser extent (6.3–5.5–5.3) maintained their yields despite reducing their harvested area and net production (Tables 1 and S1). On the other hand, in Latin American countries (8.8–9.7–14.9) and the United States of America (16.5–22.5–24.4), crop yields increased significantly even with a lower harvestable area, compared to Asian countries. As documented by other authors [48,49], between 1961–2010, Brazil, Cuba, and Haiti were major producers ( $5.2 \pm 2.0 \times 10^4$  Ha/ $3.9 \pm 2.3 \times 10^5$  tons; Table S1). Success stories in novel agricultural practices (e.g., poly-cross nurseries) have been documented in other Latin American countries, such as Peru and Bolivia, where SP is a part of their culinary history [50–52].

Moreover, root and tuber crops that provide both food and energy with a low environmental cost (such as SP) are particularly beneficial for the economic progress of small farmers—a mandatory action to achieve the Global Sustainable Development Goals (SDGs) 1.0, 2.0, and 7.0 [43]. However, many specific market reports clearly indicate an increasing trend in the importation and regional production of SP, jointly driven by the international consumer demand, novel retailing, and distribution channels, but mostly a climbing market share pushed by China as the leading producer [46–49].

### 1.2.1. Market Insights

SP is an attractive crop for alleviating many of the world's nutritional problems, such as chronic malnutrition (energy), and hidden hunger (micro deficiencies) [31,53,54]. For centuries, SP has been considered a major staple food in certain middle and low-income countries, unfairly labeled as a “poor person's”, “orphan”, “subsistence” or “famine relief” crop [49,51], despite other health benefits [8,9,12] not related to its energetic value ( $\sim 390$  kcal·100 g<sup>-1</sup>). In fact, SP produces more edible energy/Ha than any other R&T crop (see caloric content in Table S2), and in African countries, the daily consumption of SP and other R&T represents one-third of the daily energy intake [55]. This “food security” demand for fresh SP has contributed to a seemingly stable current regional market [13,14] that drove a global market growth (million USD) from 48,629 in 2019 to 58,470 in 2027 (Compound Annual Growth Rate (CAGR) = 2.1%), with the Asia-Pacific region holding the largest market share (China 80–83%) due to their own domestic consumption and total imports from other countries (e.g., the USA and Uganda) to fulfill that need [41].

The current food and beverage industry of SP-based products is segmented by application, form, type, and by end-use, besides the obvious geographic segmentation. According

to Innova Market Insights [56], global launches of SP-based products increased at a CAGR of 21% between 2015 and 2018 and were: baby foods (14%), cakes, pastries, frozen vegetables, ready-to-eat meals, and confectionary, the latter because of the unique color of certain varieties. Moreover, people's awareness of the health risks associated with wheat gluten prompted a new market niche for SP chips and fries that will grow at a 5.1% CAGR between 2022 and 2030 [57]. It is noteworthy, however, that most of these food developments are based on orange-fleshed SPs while white-creamy or purple ones are on their way.

Lastly, the diversification of SP-based ingredients or products by processing technologies will improve their market penetration even more so, generating new revenues [43]. Some alternative food technologies to home cooking include freezing (cubes, chunks, strips), canning (juices, purees, jams, jellies), thermal and non-thermal dehydration (flours, flakes), frying and baking (chips, strips), and microbial fermentation (beverages, vinegar, pickle, curd, yogurt) technologies or their sub-fractionation to obtain starches, sugars, alcohol, natural (food) colorants and/or semi-purified extracts [14]. As expected, such food developments partially depend on the cultivar genotype, since each one has its own physicochemical [58] and sensorial [59] signature. A detailed description of these processing technologies (advantages and limitations) has been reported by others [13,14].

### 1.2.2. Nutritional Value

The raw chemical composition of representative white, yellow, orange and purple-fleshed SP is reported in Table 2.

**Table 2.** Nutrient composition of SP of different flesh colors <sup>1</sup>.

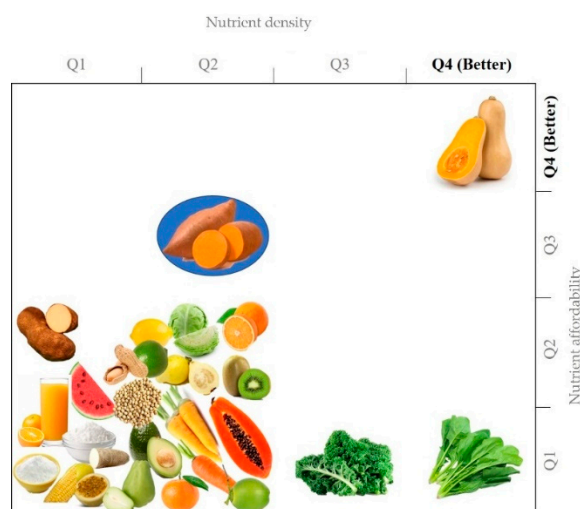
Component	White	Yellow	Orange	Purple
Total carbohydrates	85.3–87.3	81.3–85.7	83.1–87.0	84.5–85.0
Digestible starch	54.6–64.1	51.2–61.1	42.3–60.0	53.4–54.8
Sucrose	5.0–12.9	7.7–11.6	4.7–16.5	5.8–8.1
Protein	4.1–5.8	5.1–5.9	4.3–6.2	5.4–5.8
Resistant starch	2.5–3.7	1.6–4.3	0.6–3.8	1.8–2.7
Ash	2.3–3.4	2.6–2.8	3.3–4.5	1.5–2.9
Crude fiber	1.6–2.6	1.3–1.4	1.9–3.3	1.1–1.5
Fructose	0.5–4.5	0.8–4.3	0.9–6.6	1.9–2.4
Glucose	0.6–4.8	0.9–1.3	1.0–6.5	1.8–2.3
Fat	1.3–1.7	1.8–2.1	1.3–2.2	1.3–1.8

<sup>1</sup> Range (min–max) content (g·100 g<sup>-1</sup>, dry weight basis). Data source: [7–10,12–17].

As indicated by other authors [7–10,12–17], SPs mainly consist of carbohydrates (sugars + starch) and protein, crude fiber, fat, and ash in graded order. Although food processing [10,18–21] and genetic improvements [5,35–37,43,51,52] modify the content of specific components, the overall ratio often remains intact. Moreover, like many other R&Ts, SPs are rich in essential minerals (e.g., Mg, Mn, Fe, P, Zn, Cu Ca) and vitamins, such as  $\alpha/\beta$ -carotene, lutein, vitamin B1, B2, B6, pantothenic acid, niacin, biotin ascorbate, and tocols [10,60,61].

The total/specific content of carotenoids (provitamin A) in SP varies substantially by plant part, varietal (genotype/phenotype), and food processing. In general, SP is recognized as an excellent source of provitamin A ( $\beta > \alpha$  carotenes, 829–43200 IU) [20,21,32,60]. Orange-fleshed SP (OFSP; Figure 1) stands as the best SP source of  $\beta$ -carotene and total carotenoids, and certain varieties, such as Tomlins, Owori, Bechoff, Menya, and Westby varieties rank higher (20–364  $\mu\text{g}/\text{g}$  DW) than other recognized  $\beta$ -carotene sources such as carrots (43.5–88.4  $\mu\text{g}\cdot\text{g}^{-1}$  dw) or mango (10.9–12.1  $\mu\text{g}\cdot\text{g}^{-1}$  dw) [61]. This phenomenon supports the relationship between organoleptic properties, such as the visual and sensory acceptance by consumers as well as the position of multiple researchers who have recommended SP consumption as an appropriate strategy to combat global problems, such as food safety and deficit syndromes such as xerophthalmia or night blindness [62].

The *Nutrient Rich Foods Index* (NRF9.3) has been proposed as a valid and comprehensive index to select individual foods based on their nutrient density (richness), allowing the identification of foods rich in essential nutrients (protein, fiber, vitamins A, C, E, calcium, iron, magnesium, and potassium) while limiting those unhealthy ones, such as saturated fats, added sugars and sodium [60]. OFSP's NRF9.3, canned and/or mashed (925.2), raw (298.9), boiled (166.9), and chips (147.2) rank higher than more than two hundred vegetables (e.g., carrot= 102.0), three hundred fruits (e.g., apple = 47.1), sixty beans, nuts, and seeds (~23.1) and SP leaves/fries/confections (<24.4). Moreover, when considering nutrient density (as NRF9.3) vs. nutrient affordability (as  $\text{NRF9.3} \cdot \text{price}^{-1} \cdot 100 \text{ kcal}^{-1}$ ; higher (Q1) to lower (Q2) cost), raw OFSP (NDP No. 11507) also stands out as a plant food with the highest nutritional value at a lower lowest cost (Figure 2).



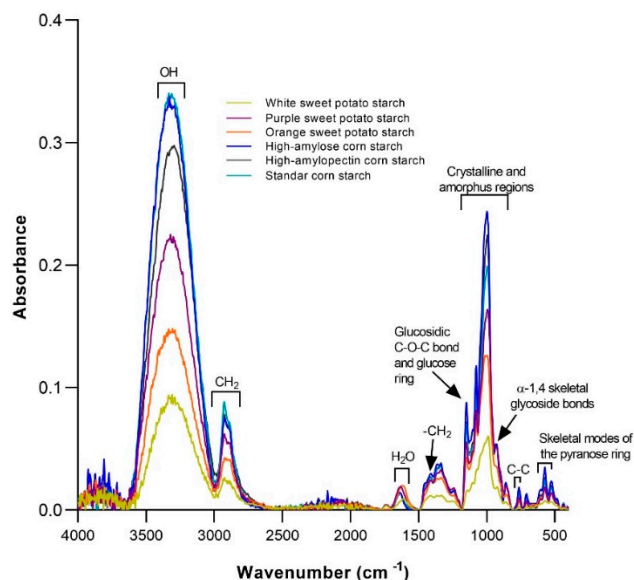
**Figure 2.** Nutrient density and affordability of SP-based foods as compared to common fruits and vegetables. Nutrient density (*Nutrient Rich Foods index* (NRF9.3), see references [60,61] for calculation details) vs. nutrient affordability ( $\text{NRF9.3} \cdot \text{price}^{-1} \cdot 100 \text{ kcal}^{-1}$ ; higher (Q1) to lower (Q2) cost) plot.

It is noteworthy, however, that major contributors to such a favorable NRF9.3 come from OFSP's provitamin A content and the lower simple (sugars)-to-complex (starch and dietary fiber) carbohydrate ratio (Table 2). In this sense, starch is the major complex carbohydrate for SP and its content differs among varieties (58–73% dry matter) [63] while the total content of sucrose, fructose, and glucose—although presented in a lesser amount when compared to starch—is responsible for the sweet taste of most SP varieties. However, SP's peel or flesh (central parenchyma) are not rich sources of crude dietary fiber (Table 2), although they are of slow-fermentable, digestible, and resistant starch, which from the point of view of functional nutrition, is very convenient for the formulation of food for people with glycemic and gastrointestinal disorders [64,65].

The nutritional and nutraceutical properties of natural sources of complex carbohydrates are highly influenced by their GI digestion patterns. Particularly, natural starches are classified according to their hydrolyzing rate under simulated GI conditions as rapid (RDS, 0–20 min), slow (SDS; 21–120 min) and resistant (RS) starch fractions, and the latter is considered mostly fermentable by resident colonic microflora (prebiotic effect) *in vivo* or under simulated colonic conditions [21,63]. RS fermentation produces metabolites (e.g., short-chain fatty acids) related to the prevention of carcinogenesis, the improvement of insulin resistance and the prevention of diseases related to metabolic syndrome [8,10,41].

Total starch and RS content in SP differ upon phenotypes, pre/post-harvest practices, and geographic location, among other factors. SP's RS content varies between 3–68  $\text{g} \cdot 100 \text{ g}^{-1}$  [66–69], being purple (6.2–38), red, OFSP (15–25) and white (6–10) [9,70,71]. In contrast, some authors have reported that the RS content does not vary (24–25%) significantly in starch in different varieties of SP (yellow, white, and purple) [72]; these differences in SP's RS content are explained by the differences in their amylose/amylopectin ratio.

Quantitative Structure-Activity Relationship (QSAR) refers to the process by which a chemical structure (e.g., a given SP phytochemical) is quantitatively correlated with a well-defined biological (e.g., molecular docking with a cell receptor or enzyme), chemical (e.g., the molecular affinity of one molecule to another) and technological (e.g., Maillard reaction) reactivity and so, mild varietal-specific SP's amylose/amylopectin ratio (Figure 3) may impact both the technological food properties and ultimate bioactivity and chemical behavior along the GI tract.



**Figure 3.** FTIR spectra from white, orange, and purple sweet potato (SP) starches as compared to corn starches (CS: high-amylose, high-amylopectin, and normal). Functional chemical groups in SP are quite like those found in CS, although with a variety-specific intensity. Absorption signals at 1048 and 1022  $\text{cm}^{-1}$  are associated with crystalline and amorphous starch regions, while the intense peak at 1000  $\text{cm}^{-1}$  can be attributed to amylose and amylopectin molecules. Source: The authors.

The prebiotic activity of SP flours or semi-purified SP starches has been demonstrated *in vitro* on *Bifidobacteria animalis*, *Lactobacillus acidophilus*, and *Lactobacillus casei* [9,73]. Several authors have proposed the incorporation of new technologies/treatments to increase the RS content and the functional value of SP. Furthermore, from a technological standpoint, prolonged post-harvest storage [74], autoclaving and enzymatic debranching [75], retrogradation and acetylation [65], annealing [66,72], or heat-moistening [72] is used to improve the RS content in SP flour and/or starch. Moreover, chemically-induced esterification (e.g., by succination) increases substantially (up to ten times) SP's RS content [67,68].

Lastly, the protein contribution of SP is within the range of 1.2–6.2 g/100 g of dry weight (DW). However, the quality of this protein is high as it contains several essential amino acids ( $\text{mg/g}^{-1}$  DW), such as leucine (1.2–2.4), isoleucine (0.7–1.5), lysine (1.1–2.2), methionine (0.2–0.3), phenylalanine (0.9–1.8), threonine (0.08), tryptophan (0.8–1.7) and valine (1.1–2.1), which are necessary for the proper functioning of the human body [76]. As if this were not enough, SP protein hydrolysates have been shown to have an antioxidant capacity that helps prevent oxidative DNA damage [77].

### 1.2.3. Functional Value

In addition to the nutritional benefits previously mentioned, SPs contain a wide range of phytochemicals with antioxidant capacity (flavonoids), anti-nyctalopia/xerophthalmia (carotenoids), hepatoprotective/spasmolytic (scopoletin), and antibacterial (friedelin), among other health benefits extensively documented by others [7,8,12,78]. Although the regulation of these events is surely associated with synergistic activities due to the phytochemicals contained, carotenoids and polyphenolic compounds have received particular interest from the scientific community, derived from their abundance and diversity

in SP. Conventionally, it has been conservatively reported that purple SP varieties possess the highest content phenolic content, followed by OFSP and white varieties (Table 3). It should be noted that content, as well as the diversity of bioactive compounds, is closely related to the color of its flesh [78–80]; however, some phenolic species are common among the varieties.

**Table 3.** Antioxidant phytochemicals reported in SP (*Ipomoea batatas* L.)<sup>1</sup>.

Parameter	White	Yellow	Orange	Purple
Total phenols (mg GAE)	1.4–2.5	3.3–3.5	2.9–4.6	11.5–12.3
Flavonoids (mg QE)	5.8–12.2	27.3–29.6	14.6–29.6	76.2–84.4
DPPH (mg TE)	3.2–17.6	9.5–13.5	7.0–11.8	17.2–17.9
Anthocyanins (mg Cy3GE)	-	-	-	1.4–1.6
Carotenoids (mg)	4.5	16.0	180.0	2.9

<sup>1</sup> Range content (g·100 g<sup>-1</sup>, dry weight basis). Gallic acid (GAE), Quercetin (QE), Trolox (TE) and Cyanidin 3-O-glucoside (Cy3GE) equivalents, negligible content (-). Data source: [78–80].

Nowadays, it is possible to discriminate the metabolic profiles of several SP cultivars through chemometrics, where main phytochemical differences could be targeted to activate/disactivate metabolic pathways either naturally [81–83] or by genetic inbreeding [5,28,35,36,51]. Particularly, high-throughput chromatographic platforms have revealed common and variety-specific phenolic profiles. The body of evidence indicates that SPs have a high content of hydroxycinnamic acids with quinic and caffeic acid derivatives commonly present in various genotypes. Among the most abundant hydroxycinnamic derivatives reported are chlorogenic acid, ferulic acid-o-hexoside, feruoyl quinic acid and 3,5-di-caffeoyl-quinic, while the aglycone forms (e.g., caffeic or ferulic acid) are less abundant [81,82]. As for flavonoids, Wang et al. [81] reported that quercetin is one of the major components belonging to flavan-3-ols in purple SP, while Kampferol is abundant in all the varieties examined. These species, as well as catechin, luteolin, chrysoeriol, and hesperetin, have been consistently reported in other investigations [83]. These structures are not found in isolation but are associated with glucose or galactose with O-glycoside bonds. The glycosylation patterns, in essence, represent a challenge for the identification not only of these but also of species such as anthocyanins.

Anthocyanins are particularly reported in purple SP varieties. This makes sense since they are the molecules responsible for providing the characteristic color to both the peel and the flesh. The main anthocyanins reported in purple SP are cyanidin-3-O-glucoside and peonidin 3-O-glucoside [79–81] in the form of monoacetylation and diacetylation. It is necessary to point out that the analysis of transcripts in the phenylpropanoid pathway has revealed high participation of the genes *IbC4H*, *IbCHS*, *IbCHI*, *IbF3H*, *IbDFR*, *IbANS*, and *IbUGT*, which do not occur equally in white, yellow, or orange varieties [81]. Moreover, as previously mentioned, carotenoids are major non-phenolic antioxidants compounds, and some varieties of SP also have a great diversity of carotenoid pigments and are distributed as follows (µgEβ-carotene/100 g): OFSP (180), yellow (16), white (4.5), and purple (2.9) [84,85]. Phenolic compounds + carotenoids + ascorbate synergistically contribute to SP's antioxidant capacity (mg of Trolox equivalents (TE).100 g<sup>-1</sup>) in a varietal-dependent manner [86]: Purple (17.2–17.9), yellow (9.45–13.45), OFSP (6.98–11.8), and white (3.17–17.6).

Saponins are natural compounds made up of aglycone and oligosaccharide chains, which have active surface properties that have been poorly explored in SP. The extraction, isolation, and identification of saponins is a challenge for the scientific community given the diversity of possible glycosides as well as the absence of comparative standards. However, one of the most relevant studies in the field showed that SP can contain about 200 mg of saponins per 100 g (dw). The saponins reported after chemical hydrolysis were oleanolic acid-3-O-[β-D-glucopyranosyl-(1→2)-β-D-galactopyranosyl-(1→2)-β-D-



glucuronopyranosyl]-28-O-b-D-glucopyranoside (sandrosaponin IX) y oleanolic acid-3-O-[b-D-galactopyranosyl-(1→3)-b-D-glucuronopyranosyl]-28-O-b-D-glucopyranoside; these molecules also possess high antioxidant capacity through both antiradical and reducing properties [87]. Lastly, triterpenoids (e.g., bohemeryl acetates, friedelin,  $\beta$ -amyryn) and coumarins (e.g., aesculetin, scopoletin, and umbelliferone) are minor SP phytochemicals with antioxidant, antimicrobial, antinociceptive, anticoagulant, anti-HIV replication, hepatoprotective, spasmolytic, and anti-acetylcholinesterase activity [12,88].

### 1.3. Health Effects and Metabolic Fate of SP's Phytochemicals

Once the diversity of nutrient and non-nutrient compounds has been examined, it is not surprising to find multiple reviews in the literature highlighting the biological activities attributable to SP in the maintenance of optimal nutritional states, and in the prevention of various diseases [8–16]. SP's antioxidant, antimicrobial, anti-diabetic, anti-cancer, anti-inflammatory, hepatoprotective, neuroprotective, anti-obesity, and GI-health-promoting properties have been extensively reviewed [88–90]. However, the subsequent section focuses on relevant information on the anticancer and anti-cardiovascular disease (CVD), pathologies with the highest morbidity/mortality rates worldwide, in which SP can contribute to conventional clinical treatments as alternative adjuvants.

#### 1.3.1. SP and Cancer

Plant bioactives exert many benefits in cancer chemoprevention; cyto/genotoxicity, cell cycle arrest, pro-apoptosis, intracellular signaling, immunomodulation, and anti-angiogenesis are probably the most studied mechanisms. Specifically, a robust body of evidence indicates that certain antioxidant phytochemicals, such as phenolic compounds, carotenoids, ascorbate, and antioxidant dietary fiber and RS, can halt the progression of certain types of cancer cells in vitro and ex vivo, although their effectiveness under clinical conditions remains uncertain. Personalized nutrition for cancer patients demands a continuous search for newer sources of phytochemicals to be used in complementary and alternative medicine. Several studies carried out in recent years [91–109] have reported multiple control points determining the process of initiation, promotion, or the spread of cancer (Table 4).

In the early stages, the cellular integrity, and in particular the genetic material, can be preserved by various compounds, such as trypsin inhibitors, anthocyanins, protein hydrolysates, or hydroxycinnamic acids present in the various varieties of SP. Damage to genetic material caused by reactive oxygen species ( $\bullet\text{OH}$  o  $\text{H}_2\text{O}_2$ ) o UV/gamma-irradiation can be decreased (if not avoided) after exposure to cells with functional compounds that have a high antioxidant capacity [91]. Additionally, it has been shown that the trypsin inhibitor present in the SP variety Tainong 57 can increase the expression of the protein p53, a nuclear protein known as “the guardian of the genome” due to its role in limiting abnormal cell formation, thus preserving the integrity of the genetic material [92].

If cell integrity is affected, this cell becomes abnormal and must multiply to promote a cancerous process. Cyclins are molecular mediators of the cell cycle; in normal conditions, they require binding with kinases to promote the different phases of cell division. Phenolic extracts of the SP variety Whatle/Loretan can decrease the expression of these proteins and limit complexing with their respective kinases [93]. According to the event and in the case of SP phytochemicals, Huang et al., have demonstrated the potential of trypsin inhibitors present in the Tainong 57 variety to limit cell division after arrest in the early phases ( $G_1$  phase) of altered cells [92].

As might be expected, the regulation of signaling pathways is a common and functional mechanism for the modulation of different tumors. The anthocyanins present in SP have been shown to be effective in negatively regulating the signaling pathway of  $\beta$ -catenin, a protein widely recognized for acting as a permanent coactivator of events, such as cell proliferation and differentiation [94,95]. In addition to the role of anthocyanins, phytosterols such as  $\beta$ -Sitosterol-d-glucoside play important roles in the regulation of

additional pathways.  $\beta$ -Sitosterol-d-glucoside has been shown to be efficient in negatively regulating the PI3K/AKT/mTOR signaling pathway, a key pathway in processes, such as cell proliferation, apoptosis, metabolism, and angiogenesis [96,97]. The adverse systemic effects associated with the cancer process largely depend on tumor formation, its ability to survive, nutrient acquisition, and location, among other issues. Phenomena such as angiogenesis have been related to the capacity present in transformed cells to produce chemical mediators that promote vascularization and, therefore, the growth of tumor cells and their dissemination throughout the body (metastasis). Therefore, bioactives combinations with anti-angiogenic capacity seem essential in limiting processes such as the promotion and spread of cancer [98].

**Table 4.** Bioactive compounds in SP and their role against cancer.

Variety	Phytochemical	Mechanism	Action
Initiation			
Tainong 57	Trypsin inhibitor	DNA damage repair	↑ P53 leukemic cells
–	Polyphenols	↓ ROS	↓ Oxidative damage induced by H <sub>2</sub> O <sub>2</sub> in HepG2 cells.
Mixuan No. 1	Protein hydrolysate	↓ ROS	↑ antioxidant activity, ↓ oxidative damage to DNA
Ayamurasaki	Anthocyanins	↓ ROS	↓ Oxidative damage induced by radiation in thymocytes
Tainong 57	Trypsin inhibitor	Cell cycle arrest	Phase G1 arrest
TU-155	Polyphenols	Cell cycle arrest	↓ cyclin D1, A y E, ↑ Cip1/p21
Promotion			
NING No. 1	Polysaccharides	Anti-inflammatory	↓ IL-1 $\beta$ , IL-6 y TNF- $\alpha$
TNG 73	Anthocyanins	Anti-inflammatory	↓ activation of NF- $\kappa$ $\beta$ in RAW 264.7 cells induced by LPS
–	Caffeic acid and derivates	Inhibition in cell proliferation	$\beta$ -catenin and Tcf-4 pathway suppression
Progression			
Bhu Krishna	Anthocyanins	Cell death induction	Apoptosis—↑ caspases
Diverse	Anthocyanins	Cell death induction	↑ caspase 3 in colonic cells
–	Polyphenols	Angiogenesis inhibition	↓ VEGF165 in a dose-dependent manner
–	BSG	Invasion inhibition	PI3K-Akt signaling pathway suppression
Zhongshu-1	SPG-56 Glycoprotein	Invasion inhibition	Regulation in the expression of proteins (MMP2, MMP9, VEGF, occludin, and claudin) related with metastasis.
TNG 73	Anthocyanins	Invasion inhibition	Cell migration suppression (MCF-7 cells)

Non specified (–),  $\beta$ -Sitosterol-d-glucoside (BSG). Data source: [92–96,100–109].

Chen et al. [99] demonstrated the ability of SP polyphenols to reduce the expression of the Vascular Endothelial Growth Factor (VEGF165) in a dose-dependent manner. Moreover, it has been shown that the glycoprotein SPG-56 present in the SP variety Zhongshu-1 can modulate the expression of essential proteins in cell attachment and adhesion. Dysregulation in the production of proteins, such as claudins or occludins (essential for the formation of tight junctions between cells), has been reported under in vitro conditions [100]. Beyond cancer promotion or progression stages, cell cytotoxicity on its own deserves attention. In all stages, the induction of cell death by apoptosis is a key tool to stop the number of viable cells in a programmed way. This event has already been reported for SP polyphenols.

Particularly, the anthocyanin fractions from SP P40, O'Henry, NC Japanese as well as Bhu Krishna seem to be effective modulators in cell models [101,102].

The multi-target nature of SP's phytochemicals helps to tackle cancer at many stages; however, future research on this matter should consider the SP varietal richness and plant part [88], gastrointestinal bioavailability [20–22,37,50], and pharmacokinetics of a given SP's bioactivity to guarantee the effects observed in vitro/ex vivo conditions.

### 1.3.2. SP and Cardiovascular Diseases (CVD)

CVD are the leading cause of worldwide adult mortality. Prevalent cases of total CVD nearly doubled from 271 (CI<sub>95%</sub> 257–285) to 523 (CI<sub>95%</sub> 497–550) million deaths and 17.7 to 34.4 million disability-adjusted life years (DALYs) between 1990–2019 [110]. Since CVD and other non-communicable chronic diseases are closely related to lifestyle factors (e.g., unhealthy diet and sedentarism), it is necessary to promote the healthy intake of fruits, nuts, seeds, beans, vegetables, whole grains, and R&T [111], including the aerial/non-aerial parts of SP plant [88]. Numerous investigations indicate that the dietary intake of flavonoids (e.g., quercetin) from plant foods such as purple SP, can reduce the risk for CVD [112] while SP's tannins, flavonoids, alkaloids reducing sugars, anthraquinones, and cardiac glycosides reduces serum creatinine and lactate-dehydrogenase activity, favoring cardiovascular health [88].

Consuming SP leaves reduces the risk for CVD by synergistically reducing lipid peroxidation and DNA damage, and regulating blood glucose, insulin, and lipid levels [113,114]. Such metabolic effects are partially explained by the 1: 2 ratio of linoleic/ $\alpha$ -linolenic fatty acids [115], compounds that can protect the cardiovascular system from excessive inflammation and oxidative damage [116]. Moreover, Zhao et al. [114] showed that flavones from an SP leaf powder decreased total cholesterol and triglyceride levels in a dose-dependent manner while its insoluble dietary fiber increased fecal bile acids and cholesterol, reducing serum cholesterol levels [117]. In support of this, a randomized controlled clinical study carried out on 58 humans showed a decrease in circulating cholesterol (7 mg/dL) and triglycerides (2 mg/dL) after the consumption of 132 g of white SP as a meal replacement [118]. Moreover, it has been demonstrated in hamsters that consuming SP leaves increases the presence of favorable biomarkers to reduce the risks for CVD [118] by inducing vascular (aortic) relaxation [119] mediated by nitric oxide (NO) as an inhibitor, in the presence of N $\omega$ -nitro-L-arginine (NOLA), an inhibitor nitric oxide synthase (NOS), or by eliminating it from the endothelium [120]. As for SP root, <3 kDa hydrolyzed peptides (VSAIW, AIWGA, FVIKP, VVMPSTF, and FHDPMLR) from sporomin A and B, display a strong anti-ACE (angiotensin-converting enzyme) activity [88,121], while lactic acid bacteria (LAB)-based fermentation of white (Murasaki), orange (Evangeline) and purple (NIC-413)-fleshed SP varieties increases their anti-ACE/antioxidant activity [122]. Additional evidence on the cardioprotective effects of extracts of SP and/or its pure phytochemicals previously identified by chromatographic techniques is summarized in Table 5.

In conclusion, this evidence suggests that several SP bioactives (leaves/root) may individually and synergistically prevent CVD by exerting many cardioprotective mechanisms. Further investigations on the associated molecular events are needed to support the epidemiological and in vivo and in vitro evidence discussed above.

**Table 5.** SP phytochemicals in cardiovascular diseases (CVD).

Phytochemical	Mechanism	Action
Heart		
Anthocyanins	↓ Malondialdehyde	Antioxidant ↓ Lipid peroxidation
Flavonoids/ anthocyanin	Vasodilation induction/ ↓ endothelin—1	Antihypertensive
Tannins/saponins/ Flavonoids/terpenoids	↓ Creatine kinase ↓ Lactate dehydrogenase	Prevention in ischemic damage
Vascular		
Aqueous extracts	↑ Telomerase activity preventing cell senescence	Prevention of coronary artery disease
Anthocyanins	Inhibition of PDGF receptor-β	Regulation of platelet aggregation
Chlorogenic acid	ACE Inhibition	Antihypertensive
Anthocyanins/ethanolic extract	↓ VCAM	Prevention of atherosclerosis
SP leaves	Elongate arterial occlusion time ↓ cyclooxygenase-2, ↓ inducible nitric oxide synthase ↓ tumor necrosis factor-α	Prevention of thrombotic events
Purple SP extract		↓ Inflammation
Brain and Kidney		
Anthocyanins	↑ BDNF	Neuroprotection after ischemic stroke
Flavonoids/ acetylated anthocyanins	Blocking VEGFR2/ROS/NLRP3 signaling	↓ Kidney damage

Angiotensin-converting enzyme (ACE), brain-Derived Nuclear Factor (BDNF), NLR family pyrin domain containing 3 (NLRP3), reactive oxygen species (ROS), platelet-derived growth factor (PDGF), sweet potato (SP), vascular cell adhesion molecule (VCAM), vascular endothelial growth factors receptor 2 (VEGFR2). Data source: [123–134].

## 2. Final Remarks

SP is a common staple food in certain middle/low-income countries with great nutritional and functional potential. Its health benefits are not limited to its nutrients but also to other xenobiotics, including resistant starch [64,65], antioxidants [19,78–84,111], terpenoids [12,88], phytosterols [96,97], bioactive peptides [88,121,122] and many other phytochemicals that modulate key metabolic processes, reducing the odds for chronic illnesses including, yet not restricted to certain types of cancer [92,94,96,100,102–110] and CVD. Further research should focus on understanding the physiological mechanisms and metabolic biotransformation of raw/processed SP's bioactives whose intrinsic functionalities (e.g., anti-inflammatory, antioxidant, enzyme-inhibitory activity) target multiple target organs [88–90].

**Supplementary Materials:** The following are available online at <https://www.mdpi.com/article/10.3390/foods11071058/s1>, Figure S1: Agronomic profitability of sweet potato: Crop yield [production (tons × 10<sup>8</sup>) vs. area (Ha × 10<sup>6</sup>)], Table S1: Agricultural outlook 1999–2019: Sweet Potatoes (Complete FAOSTAT Data), Table S2: Nutrient data for raw/processed sweet potatoes and other edible roots and tubers.

**Author Contributions:** Conceptualization, F.J.O.-A. and A.W.-M.; formal analysis, E.F. and M.A.V.-O.; writing—original draft preparation, F.J.O.-A., A.A.E.-P. and L.R.; writing—review and editing, A.A.E.-P., F.J.O.-A. and A.W.-M.; supervision, I.P. and G.A.G.-A.; project administration, A.W.-M.; funding acquisition, A.W.-M. and G.A.G.-A. All authors have read and agreed to the published version of the manuscript.

**Funding:** National Council of Science and Technology (CONACyT) through the Basic Science project called “Antioxidants of fruits and vegetables in cancer: Are their bioaccessibility, bioavailability or structural synergism responsible for their ineffectiveness?” (CB2015-254063).

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** The authors express their gratitude for the funding granted by the and the school scholarship awarded to the first author.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

- Guadarrama, L.M.; López, J.H. Patrones culinarios asociados al camote (*Ipomoea batatas*) y la yuca (*Manihot esculenta*) entre los mayas yucatecos, ch'oles y huastecos. *Estud. Cult. Maya* **2018**, *52*, 193–226. [CrossRef]
- Motsa, N.M.; Modi, A.T.; Mabhaudhi, T. Sweet potato (*Ipomoea batatas* L.) as a drought tolerant and food security crop. *S. Afr. J. Sci.* **2015**, *111*, 1–8. [CrossRef]
- Rodriguez-Bonilla, L.; Cuevas, H.E.; Montero-Rojas, M.; Bird-Pico, F.; Luciano-Rosario, D.; Siritunga, D. Assessment of genetic diversity of sweet potato in Puerto Rico. *PLoS ONE* **2014**, *9*, e116184. [CrossRef] [PubMed]
- Cartabiano-Leite, C.E.; Porcu, O.M.; de Casas, A.F. Sweet potato (*Ipomoea batatas* L. Lam) nutritional potential and social relevance: A review. *History* **2020**, *11*, 23–40. [CrossRef]
- Mwanga, R.O.; Andrade, M.I.; Carey, E.E.; Low, J.W.; Yencho, G.C.; Grüneberg, W.J. Sweetpotato (*Ipomoea batatas* L.). In *Genetic Improvement of Tropical Crops*; Campos, H., Caligari, P.D.S., Eds.; Springer: Cham, Switzerland, 2017; pp. 181–218. [CrossRef]
- Xiao, S.; Xu, P.; Deng, Y.; Dai, X.; Zhao, L.; Heider, B.; Zhang, A.; Zhou, Z.; Cao, Q. Comparative analysis of chloroplast genomes of cultivars and wild species of sweetpotato (*Ipomoea batatas* [L.] Lam). *BMC Genom.* **2021**, *22*, 262. [CrossRef]
- Meira, M.; Da Silva, E.P.; David, J.M.; David, J.P. Review of the genus *Ipomoea*: Traditional uses, chemistry, and biological activities. *Rev. Bras. Farmacogn.* **2012**, *22*, 682–713. [CrossRef]
- de Albuquerque, T.M.R.; Sampaio, K.B.; de Souza, E.L. Sweet potato roots: Unrevealing an old food as a source of health promoting bioactive compounds—A review. *Trends Food Sci. Technol.* **2019**, *85*, 277–286. [CrossRef]
- de Albuquerque, T.M.R.; Borges, C.W.P.; Cavalcanti, M.T.; Lima, M.; Magnani, M.; de Souza, E.L. Potential prebiotic properties of flours from different varieties of sweet potato (*Ipomoea batatas* L.) roots cultivated in Northeastern Brazil. *Food Biosci.* **2020**, *36*, 100614. [CrossRef]
- Wang, S.; Nie, S.; Zhu, F. Chemical constituents and health effects of sweet potato. *Food Res. Int.* **2016**, *89*, 90–116. [CrossRef]
- Khoury, C.K.; Heider, B.; Castañeda-Álvarez, N.P.; Achicanoy, H.A.; Sosa, C.C.; Miller, R.E.; Scotland, R.W.; Wood, J.R.I.; Rossel, G.; Eserman, L.A.; et al. Distributions, ex situ conservation priorities, and genetic resource potential of crop wild relatives of sweetpotato [*Ipomoea batatas* (L.) Lam., I. series Batatas]. *Front. Plant Sci.* **2015**, *6*, 251. [CrossRef]
- Mohanraj, R.; Sivasankar, S. Sweet Potato (*Ipomoea batatas* [L.] Lam)—A valuable medicinal food: A review. *J. Med. Food* **2014**, *17*, 733–741. [CrossRef] [PubMed]
- Mu, T.H.; Singh, J. Sweet potato: Chemistry, processing, and nutrition—An introduction. In *Sweet Potato*; Mu, T.H., Singh, J., Eds.; Academic Press: Cambridge, MA, USA, 2019; pp. 1–4. [CrossRef]
- Truong, V.D.; Avula, R.Y.; Pecota KYencho, G. Handbook of Vegetables and Vegetable Processing. In *Handbook of Vegetables and Vegetable Processing*; Siddiq, M., Uebersax, M.A., Eds.; Wiley-Blackwell Publishing Co.: Ames, IA, USA, 2018. Available online: <https://www.ars.usda.gov/ARSUserFiles/60701000/Sweetpotato%20Publications/s158.pdf> (accessed on 5 March 2022).
- Cartier, A.; Woods, J.; Sismour, E.; Allen, J.; Ford, E.; Githinji, L.; Xu, Y. Physiochemical, nutritional and antioxidant properties of fourteen Virginia-grown sweet potato varieties. *J. Food Meas. Charact.* **2017**, *11*, 1333–1341. [CrossRef]
- Kim, J.M.; Park, S.J.; Lee, C.S.; Ren, C.; Kim, S.S.; Shin, M. Functional properties of different Korean sweet potato varieties. *Food Sci. Biotechnol.* **2011**, *20*, 1501–1507. [CrossRef]
- Anchundia, M.Á.; Pérez, E.; Torres, F. Composición química, perfil de aminoácidos y contenido de vitaminas de harinas de batata tratadas térmicamente. *Rev. Chil. Nutr.* **2019**, *46*, 137–143. [CrossRef]
- Kourouma, V.; Mu, T.H.; Zhang, M.; Sun, H.N. Effects of cooking process on carotenoids and antioxidant activity of orange-fleshed sweet potato. *LWT* **2019**, *104*, 134–141. [CrossRef]
- Failla, M.L.; Thakkar, S.K.; Kim, J.Y. In vitro bioaccessibility of  $\beta$ -carotene in orange fleshed sweet potato (*Ipomoea batatas*, Lam.). *J. Agric. Food Chem.* **2009**, *57*, 10922–10927. [CrossRef]
- Rios-Romero, E.A.; Ochoa-Martínez, L.A.; Bello-Pérez, L.A.; Morales-Castro, J.; Quintero-Ramos, A.; Gallegos-Infante, J.A. Effect of ultrasound and steam treatments on bioaccessibility of  $\beta$ -carotene and physicochemical parameters in orange-fleshed sweet potato juice. *Heliyon* **2021**, *7*, e06632. [CrossRef]
- Mbogo, D.; Muzhingiri, T.; Janaswamy, S. Starch digestibility and  $\beta$ -carotene bioaccessibility in the orange-fleshed sweet potato puree-wheat bread. *J. Food Sci.* **2021**, *86*, 901–906. [CrossRef]
- Yang, Z.W.; Tang, C.E.; Zhang, J.L.; Zhou, Q.; Zhang, Z.C. Stability and antioxidant activity of anthocyanins from purple sweet potato (*Ipomoea batatas* L. cultivar Eshu No. 8) subjected to simulated *in vitro* gastrointestinal digestion. *Int. J. Food Sci. Technol.* **2019**, *54*, 2604–2614. [CrossRef]

23. Huamán, Z. Botánica Sistemática y Morfología De La Planta De Batata o Camote. International Potato Center. 1992. Available online: <https://docplayer.es/24188174-Botanica-sistemática-y-morfología-de-la-planta-de-batata-o-camote.html> (accessed on 5 March 2022).
24. Amoanimaa-Dede, H.; Su, C.; Yeboah, A.; Chen, C.; Yang, S.; Zhu, H.; Chen, M. Flesh color diversity of sweet potato: An overview of the composition, functions, biosynthesis, and gene regulation of the major pigments. *Phyton* **2020**, *89*, 805–833. [CrossRef]
25. Laurie, S.M.; Calitz, F.J.; Adebola, P.O.; Lezar, A. Characterization and evaluation of South African sweet potato (*Ipomoea batatas* (L.) LAM) land races. *S. Afr. J. Bot.* **2013**, *85*, 10–16. [CrossRef]
26. Yang, J.; Moeinzadeh, M.-H.; Kuhl, H.; Helmuth, J.; Xiao, P.; Haas, S.; Liu, G.; Zheng, J.; Sun, Z.; Fan, W.; et al. Haplotype-resolved sweet potato genome traces back its hexaploidization history. *Nat. Plants* **2017**, *3*, 696–703. [CrossRef] [PubMed]
27. Muñoz-Rodríguez, P.; Carruthers, T.; Wood, J.R.; Williams, B.R.; Weitemier, K.; Kronmiller, B.; Goodwin, Z.; Sumadijaya, A.; Anglin, N.; Filer, D.; et al. A taxonomic monograph of *Ipomoea* integrated across phylogenetic scales. *Nat. Plants* **2019**, *5*, 1136–1144. [CrossRef] [PubMed]
28. Gemenet, D.C.; da Silva Pereira, G.; De Boeck, B.; Wood, J.C.; Mollinari, M.; Olukolu, B.A.; Buell, C.R. Quantitative trait loci and differential gene expression analyses reveal the genetic basis for negatively associated  $\beta$ -carotene and starch content in hexaploid sweetpotato [*Ipomoea batatas* (L.) Lam.]. *Theor. Appl. Genet.* **2020**, *133*, 23–36. [CrossRef] [PubMed]
29. Roullier, C.; Benoit, L.; McKey, D.B.; Lebot, V. Historical collections reveal patterns of diffusion of sweet potato in Oceania obscured by modern plant movements and recombination. *Proc. Natl. Acad. Sci. USA* **2013**, *110*, 2205–2210. [CrossRef]
30. Loebenstein, G. Origin, Distribution and Economic Importance. In *The Sweetpotato*; Loebenstein, G., Thottappilly, G., Eds.; Springer: Dordrecht, The Netherlands, 2009. [CrossRef]
31. Samiyarsih, S.; Azizah, E.; Herawati, W. Anatomical profile and genetic variability of sweet potato (*Ipomoea batatas*) cultivars in Banyumas, Central Java, based on RAPD markers. *Biodiversitas J. Biol. Divers.* **2020**, *21*, 1755–1766. [CrossRef]
32. Otoboni, M.E.F.; De Oliveira, D.J.L.S.F.; Vargas, P.F.; Pavan, B.E.; Andrade, M.I. Genetic parameters and gain from selection in sweet potato genotypes with high beta-carotene content. *Crop Breed. Appl. Biotechnol.* **2020**, *20*, e31632038. [CrossRef]
33. Rahajeng, W.; Rahayuningsih, S.A. Agronomic performance, variance component, and diversity of sixty-two sweet potato accessions. *Biodiversitas* **2017**, *18*, 95–100. [CrossRef]
34. Low, J.W.; Ortiz, R.; Vandamme, E.; Andrade, M.; Biazin, B.; Grüneberg, W.J. Nutrient-dense orange-fleshed sweetpotato: Advances in drought-tolerance breeding and understanding of management practices for sustainable next-generation cropping systems in sub-Saharan Africa. *Front. Sustain. Food Syst.* **2020**, *4*, 50. [CrossRef]
35. Tanaka, M.; Ishiguro, K.; Oki, T.; Okuno, S. Functional components in sweetpotato and their genetic improvement. *Breed. Sci.* **2017**, *67*, 52–61. [CrossRef]
36. Kim, H.S.; Wang, W.; Kang, L.; Kim, S.-E.; Lee, C.-J.; Park, S.-C.; Park, W.S.; Ahn, M.-J.; Kwak, S.-S. Metabolic engineering of low-molecular-weight antioxidants in sweetpotato. *Plant Biotechnol. Rep.* **2020**, *14*, 193–205. [CrossRef]
37. Andre, C.M.; Burgos, G.; Ziebel, J.; Guignard, C.; Hausman, J.-F.; Felde, T.Z. *In vitro* iron bioaccessibility and uptake from orange-fleshed sweet potato (*Ipomoea batatas* (L.) Lam.) clones grown in Peru. *J. Food Compos. Anal.* **2018**, *68*, 79–86. [CrossRef]
38. Shumbusha, D.; Shimelis, H.; Laing, M.; Rukundo, P. Gene action and heritability of yield components of dual-purpose sweetpotato clones. *Euphytica* **2019**, *215*, 122. [CrossRef]
39. Transparency Market Research. Sweet Potatoes Market—Global Industry Analysis, Sice, Share, Growth, Trends and Forecast 2016–2024. 2020. Available online: <https://www.transparencymarketresearch.com/sweet-potatoes-market.html> (accessed on 5 March 2022).
40. The Insight Partners. Sweet potato Market to 2027—Global Analysis and Forecasts. 2019. Available online: <https://www.theinsightpartners.com/reports/sweet-potato-market> (accessed on 5 March 2022).
41. Chandrasekara, A.; Josheph Kumar, T. Roots and tuber crops as functional foods: A review on phytochemical constituents and their potential health benefits. *Int. J. Food Sci.* **2016**, *2016*, 3631647. [CrossRef]
42. Afzal, N.; Afionis, S.; Stringer, L.; Favretto, N.; Sakai, M.; Sakai, P. Benefits and trade-offs of smallholder sweet potato cultivation as a pathway toward achieving the sustainable development goals. *Sustainability* **2021**, *13*, 552. [CrossRef]
43. Rukundo, P.; Shimelis, H.; Laing, M.; Mashilo, J. Genotype-by-environment interaction for dual-purpose traits in sweetpotato. *J. Crop Improv.* **2020**, *34*, 800–823. [CrossRef]
44. Laxminarayana, K.; Mishra, S.; Soumya, S. Good agricultural practices in tropical root and tuber crops (Chapter 4). In *Tropical Roots and Tubers: Production, Processing and Technology*; Sharma, H.K., Njintang, N.Y., Singhal, R.S., Kaushal, P., Eds.; John Wiley Sons, Ltd.: West Sussex, UK, 2016; pp. 183–224. [CrossRef]
45. Kihurani, A.W.; Kaushal, P. Storage techniques and commercialization (Chapter 6). In *Tropical Roots and Tubers: Production, Processing and Technology*; Sharma, H.K., Njintang, N.Y., Singhal, R.S., Kaushal, P., Eds.; John Wiley Sons, Ltd.: West Sussex, UK, 2016; pp. 281–300. [CrossRef]
46. Tavva, S.; Nedunchezhiyan, M. Global status of sweet potato cultivation. *Fruit Veg. Cereal Sci. Biotechnol.* **2012**, *6*, 143–147. Available online: [http://www.globalsciencebooks.info/Online/GSBOOnline/images/2012/FVCSB\\_6\(SI1\)/FVCSB\\_6\(SI1\)143-147o.pdf](http://www.globalsciencebooks.info/Online/GSBOOnline/images/2012/FVCSB_6(SI1)/FVCSB_6(SI1)143-147o.pdf) (accessed on 8 March 2022).
47. FAO. FAOSTAT Database. Available online: [www.fao.org/faostat/en/#data/QC](http://www.fao.org/faostat/en/#data/QC) (accessed on 5 March 2022).
48. Mello, A.F.S.; Silva, G.O.D.; Nunes, M.U.C.; Celestino Filho, P.; Silva, W.B.; Moita, A.W.; de Carvalho, J.L.V.; Nuti, M.R. Performance of sweet potato genotypes in Brazilian regions. *Sci. Agric.* **2022**, *79*, e20210082. [CrossRef]

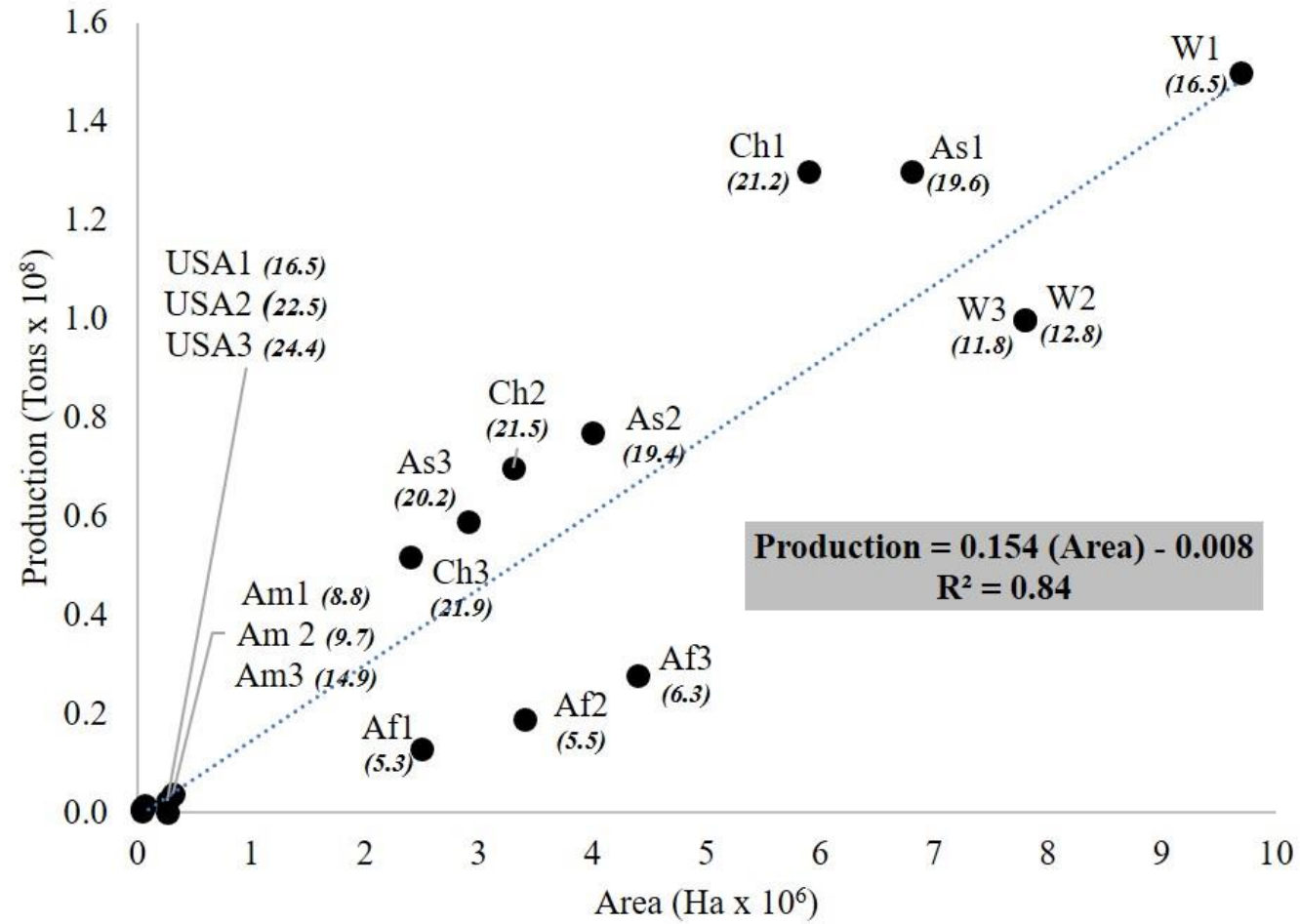
49. Scott, G.J.; Maldonado, L. *Sweetpotato for the New Millennium: Trends in Production and Utilization in Developing Countries*; Program Report 1997–1998; Centro Internacional de la Papa (CIP): Lima, Peru, 1999; pp. 329–335. Available online: <http://www.sweetpotatoknowledge.org/wp-content/uploads/2016/04/Sweetpotato-for-the-New-Millennium-Trends-in-Production-and-Utilization-in-Developing-Countries.pdf> (accessed on 8 March 2022).
50. Choquechambi, L.A.; Callisaya, I.R.; Ramos, A.; Bosque, H.; Mújica, A.; Jacobsen, S.E.; Sørensen, M.; Leidi, E.O. Assessing the nutritional value of root and tuber crops from Bolivia and Peru. *Foods* **2019**, *8*, 526. [[CrossRef](#)]
51. Livia-Tacza, C.; Sánchez, G. Soil arthropods associated with sweetpotato crop (*Ipomoea batata* L.) in La Molina, Lima, Peru. *Peruv. J. Agron.* **2020**, *4*, 1–9. [[CrossRef](#)]
52. Torquato-Tavares, A.; Nascimento, I.R.D.; Pascual-Reyes, I.D.; Santana, W.R.D.; Silveira, M.A.D. Potencial de cruzas simples de camote (*Ipomoea batatas* (L.) Lam.) para mejorar la producción de etanol. *Revista Chapingo. Ser. Hortic.* **2017**, *23*, 59–74. [[CrossRef](#)]
53. Kim, H.S.; Lee, C.-J.; Kim, S.-E.; Ji, C.Y.; Kim, S.-T.; Kim, J.-S.; Kim, S.; Kwak, S.-S. Current status on global sweetpotato cultivation and its prior tasks of mass production. *J. Plant Biotechnol.* **2018**, *45*, 190–195. [[CrossRef](#)]
54. Prakash, P.; Kishore, A.; Roy, D.; Behura, D.; Immanuel, S. Biofortification for reducing hidden hunger: A value chain analysis of sweet potato. *Agric. Econ. Res. Rev.* **2017**, *30*, 201–211. [[CrossRef](#)]
55. Nanbol, K.; Namu, O. The Contribution of Root and Tuber Crops to Food Security: A Review. *J. Agric. Sci. Technol. B* **2019**, *9*. [[CrossRef](#)]
56. Food Navigator—USA.com. Sweet Potatoes Destined for Further Market Penetration, Says Innova Market Insights. Available online: <https://www.foodnavigator-usa.com/Article/2019/05/07/Sweet-potatoes-destined-for-further-market-penetration-says-Innova-Market-Insights#> (accessed on 5 March 2022).
57. PMR. Sweet Potato Fries Market. 2020. Available online: [www.persistencemarketresearch.com/market-research/sweet-potato-fries-market.asp](http://www.persistencemarketresearch.com/market-research/sweet-potato-fries-market.asp) (accessed on 8 March 2022).
58. Laryea, D.; Koomson, D.; Oduro, I.; Carey, E. Evaluation of 10 genotypes of sweetpotato for fries. *Food Sci. Nutr.* **2019**, *7*, 589–598. [[CrossRef](#)]
59. Leksrisompong, P.P.; Whitson, M.E.; Truong, V.D.; Drake, M.A. Sensory attributes and consumer acceptance of sweet potato cultivars with varying flesh colors. *J. Sens. Stud.* **2012**, *27*, 59–69. [[CrossRef](#)]
60. Drewnowski, A. The nutrient rich foods index helps to identify healthy, affordable foods. *Am. J. Clin. Nutr.* **2010**, *91*, 1095S–1101S. [[CrossRef](#)]
61. USDA. Sweet Potato, Raw, Unprepared. Available online: <https://fdc.nal.usda.gov/fdc-app.html#/food-details/168482/nutrients> (accessed on 8 March 2022).
62. Neela, S.; Fanta, S.W. Review on nutritional composition of orange-fleshed sweet potato and its role in management of vitamin A deficiency. *Food Sci. Nutr.* **2019**, *7*, 1920–1945. [[CrossRef](#)]
63. Brabet, C.; Reynoso, D.; Dufour, D.; Mestres, C.; Arredondo, J.; Scott, G. *Starch Content and Properties of 106 Sweetpotato Clones from the World Germplasm Collection Held at CIP, Peru*; CIP Program Report 1997–1998; CIP: Lima, Peru, 2013; pp. 279–286. Available online: <http://www.sweetpotatoknowledge.org/wp-content/uploads/2015/10/Starch-Content-and-Properties-of-106-Sweetpotato-Clones-From-The-World-Germplasm-Collection-Held-at-CIP-Peru.pdf> (accessed on 8 March 2022).
64. Sun, J.; Chen, H.; Kan, J.; Gou, Y.; Liu, J.; Zhang, X.; Wu, X.; Tang, S.; Sun, R.; Qian, C.; et al. Anti-inflammatory properties and gut microbiota modulation of an alkali-soluble polysaccharide from purple sweet potato in DSS-induced colitis mice. *Int. J. Biol. Macromol.* **2020**, *153*, 708–722. [[CrossRef](#)]
65. Lu, H.; Gui, Y.; Guo, T.; Wang, Q.; Liu, X. Effect of the particle size of cellulose from sweet potato residues on lipid metabolism and cecal conditions in ovariectomized rats. *Food Funct.* **2015**, *6*, 1185–1193. [[CrossRef](#)]
66. Song, H.Y.; Lee, S.Y.; Choi, S.J.; Kim, K.M.; Kim, J.S.; Han, G.J.; Moon, T.W. Digestibility and physicochemical properties of granular sweet potato starch as affected by annealing. *Food Sci. Biotechnol.* **2014**, *23*, 23–31. [[CrossRef](#)]
67. Lv, Q.Q.; Li, G.Y.; Xie, Q.T.; Zhang, B.; Li, X.M.; Pan, Y.; Chen, H.Q. Evaluation studies on the combined effect of hydrothermal treatment and octenyl succinylation on the physico-chemical, structural and digestibility characteristics of sweet potato starch. *Food Chem.* **2018**, *256*, 413–418. [[CrossRef](#)] [[PubMed](#)]
68. Remya, R.; Jyothi, A.N.; Sreekumar, J. Morphological, structural and digestibility properties of RS4 enriched octenyl succinylated sweet potato, banana and lentil starches. *Food Hydrocoll.* **2018**, *82*, 219–229. [[CrossRef](#)]
69. Kwon, C.; Kim, H.R.; Moon, T.W.; Lee, S.H.; Lee, C.J. Structural and physicochemical characteristics of granular malic acid-treated sweet potato starch containing heat-stable resistant starch. *J. Chem.* **2019**, *2019*, 2903252. [[CrossRef](#)]
70. Yu, S.X.; Mu, T.H.; Zhang, M.; Ma, M.M.; Zhao, Z.K. Effects of retrogradation and further acetylation on the digestibility and physicochemical properties of purple sweet potato flour and starch. *Starch-Stärke* **2015**, *67*, 892–902. [[CrossRef](#)]
71. Cui, R.; Zhu, F. Physicochemical properties and bioactive compounds of different varieties of sweet potato flour treated with high hydrostatic pressure. *Food Chem.* **2019**, *299*, 125129. [[CrossRef](#)]
72. Trung, P.T.B.; Ngoc, L.B.B.; Hoa, P.N.; Tien, N.N.T.; Van Hung, P. Impact of heat-moisture and annealing treatments on physicochemical properties and digestibility of starches from different colored sweet potato varieties. *Int. J. Biol. Macromol.* **2017**, *105*, 1071–1078. [[CrossRef](#)]
73. Zheng, Y.; Wang, Q.; Li, B.; Lin, L.; Tundis, R.; Loizzo, M.R.; Zheng, B.; Xiao, J. Characterization and prebiotic effect of the resistant starch from purple sweet potato. *Molecules* **2016**, *21*, 932. [[CrossRef](#)]

74. Lu, P.; Li, X.; Janaswamy, S.; Chi, C.; Chen, L.; Wu, Y.; Liang, Y. Insights on the structure and digestibility of sweet potato starch: Effect of postharvest storage of sweet potato roots. *Int. J. Biol. Macromol.* **2020**, *145*, 694–700. [CrossRef]
75. Babu, A.S.; Parimalavalli, R. Effect of pullulanase debranching and storage temperatures on structural characteristics and digestibility of sweet potato starch. *J. Saudi Soc. Agric. Sci.* **2018**, *17*, 208–216. [CrossRef]
76. Mu, T.H.; Tan, S.S.; Xue, Y.L. The amino acid composition, solubility and emulsifying properties of sweet potato protein. *Food Chem.* **2009**, *112*, 1002–1005. [CrossRef]
77. Zhang, M.; Mu, T.H.; Sun, M.J. Sweet potato protein hydrolysates: Antioxidant activity and protective effects on oxidative DNA damage. *Int. J. Food Sci. Technol.* **2012**, *47*, 2304–2310. [CrossRef]
78. Petropoulos, S.A.; Sampaio, S.L.; Di Gioia, F.; Tzortzakis, N.; Rouphael, Y.; Kyriacou, M.C.; Ferreira, I. Grown to be blue—Antioxidant properties and health effects of colored vegetables. Part I: Root vegetables. *Antioxidants* **2019**, *8*, 617. [CrossRef]
79. Dong, J.U.; Mu, T.H.; Sun, H.N. Sweet potato and potato residual flours as potential nutritional and healthy food material. *J. Integr. Agric.* **2017**, *16*, 2632–2645. [CrossRef]
80. Teow, C.C.; Truong, V.D.; McFeeters, R.F.; Thompson, R.L.; Pecota, K.V.; Yencho, G.C. Antioxidant activities, phenolic and  $\beta$ -carotene contents of sweet potato genotypes with varying flesh colours. *Food Chem.* **2007**, *103*, 829–838. [CrossRef]
81. Wang, A.; Li, R.; Ren, L.; Gao, X.; Zhang, Y.; Ma, Z.; Ma, D.; Luo, Y. A comparative metabolomics study of flavonoids in sweet potato with different flesh colors (*Ipomoea batatas* (L.) Lam). *Food Chem.* **2018**, *260*, 124–134. [CrossRef] [PubMed]
82. Padda, M.; Picha, D. Quantification of phenolic acids and antioxidant activity in sweetpotato genotypes. *Sci. Hortic.* **2008**, *119*, 17–20. [CrossRef]
83. Park, S.-Y.; Lee, S.Y.; Yang, J.W.; Lee, J.-S.; Oh, S.-D.; Oh, S.; Lee, S.M.; Lim, M.-H.; Park, S.K.; Jang, J.-S.; et al. Comparative analysis of phytochemicals and polar metabolites from colored sweet potato (*Ipomoea batatas* L.) tubers. *Food Sci. Biotechnol.* **2016**, *25*, 283–291. [CrossRef] [PubMed]
84. Tang, Y.; Cai, W.; Xu, B. Profiles of phenolics, carotenoids and antioxidative capacities of thermal processed white, yellow, orange, and purple sweet potatoes grown in Guilin, China. *Food Sci. Hum. Wellness* **2015**, *4*, 123–132. [CrossRef]
85. Kammona, S.; Othman, R.; Jaswir, I.; Jamal, P. Characterisation of carotenoid content in diverse local sweet potato (*Ipomoea batatas*) flesh tubers. *Int. J. Pharm. Pharm. Sci.* **2015**, *2*, 347–351.
86. Makori, S.I.; Mu, T.H.; Sun, H.N. Total polyphenol content, antioxidant activity, and individual phenolic composition of different edible parts of 4 sweet potato cultivars. *Nat. Prod. Commun.* **2020**, *15*, 1934578X20936931. [CrossRef]
87. Dini, I.; Tenore, G.C.; Dini, A. Saponins in *Ipomoea batatas* tubers: Isolation, characterization, quantification and antioxidant properties. *Food Chem.* **2009**, *113*, 411–419. [CrossRef]
88. Alam, M.K. A comprehensive review of sweet potato (*Ipomoea batatas* [L.] Lam): Revisiting the associated health benefits. *Trends Food Sci. Technol.* **2021**, *115*, 512–529. [CrossRef]
89. Nguyen, H.C.; Chen, C.C.; Lin, K.H.; Chao, P.Y.; Lin, H.H.; Huang, M.Y. Bioactive compounds, antioxidants, and health benefits of sweet potato leaves. *Molecules* **2021**, *26*, 1820. [CrossRef] [PubMed]
90. Laurie, S.M.; Faber, M.; Claasen, N. Incorporating orange-fleshed sweet potato into the food system as a strategy for improved nutrition: The context of South Africa. *Food Res. Int.* **2018**, *104*, 77–85. [CrossRef]
91. Kocyigit, A.; Guler, E.M.; Dikilitas, M. Role of antioxidant phytochemicals in prevention, formation, and treatment of cancer in Reactive Oxygen Species (ROS) in Living Cells. In *Reactive Oxygen Species (ROS) in Living Cells*; InTech Open: Rijeka, Croatia, 2018; pp. 21–45. [CrossRef]
92. Huang, G.J.; Sheu, M.J.; Chen, H.J.; Chang, Y.S.; Lin, Y.H. Growth inhibition and induction of apoptosis in NB4 promyelocytic leukemia cells by trypsin inhibitor from sweet potato storage roots. *J. Agric. Food Chem.* **2007**, *55*, 2548–2553. [CrossRef]
93. Karna, P.; Gundala, S.R.; Gupta, M.V.; Shamsi, S.A.; Pace, R.D.; Yates, C.; Narayan, S.; Aneja, R. Polyphenol-rich sweet potato greens extract inhibits proliferation and induces apoptosis in prostate cancer cells *in vitro* and *in vivo*. *Carcinogenesis* **2011**, *32*, 1872–1880. [CrossRef]
94. Taira, J.; Uehara, M.; Tsuchida, E.; Ohmine, W. Inhibition of the  $\beta$ -catenin/Tcf signaling by caffeoylquinic acids in sweet potato leaf through down regulation of the Tcf-4 transcription. *J. Agric. Food Chem.* **2014**, *62*, 167–172. [CrossRef]
95. Mantilla, C.; Suárez Mellado, I.; Duque Jaramillo, A.; Navas, M.C. Mecanismos de señalización por  $\beta$ -catenina y su papel en la carcinogénesis. *CES Med.* **2015**, *29*, 109–127. Available online: <http://www.scielo.org.co/pdf/cesm/v29n1/v29n1a10.pdf> (accessed on 8 March 2022).
96. Xu, H.; Li, Y.; Han, B.; Li, Z.; Wang, B.; Jiang, P.; Zhang, J.; Ma, W.; Zhou, D.; Li, X.; et al. Anti-breast-cancer activity exerted by  $\beta$ -sitosterol-D-glucoside from sweet potato via upregulation of microRNA-10a and via the PI3K–Akt signaling pathway. *J. Agric. Food Chem.* **2018**, *66*, 9704–9718. [CrossRef]
97. Patel, K.; Kumar, V.; Verma, A.; Rahman, M.; Patel, D.K.  $\beta$ -sitosterol: Bioactive compounds in foods, their role in health promotion and disease prevention “a concise report of its phytopharmaceutical importance”. *Curr. Tradit. Med.* **2017**, *3*, 168–177. [CrossRef]
98. Rajabi, M.; Mousa, S.A. The role of angiogenesis in cancer treatment. *Biomedicines* **2017**, *5*, 34. [CrossRef] [PubMed]
99. Chen, C.-M.; Li, S.-C.; Au, H.-K.; Shih, C.-K.; Hsu, C.-Y.; Liu, J.-F. Constituents in purple sweet potato leaves inhibit *in vitro* angiogenesis with opposite effects *ex vivo*. *Nutrition* **2011**, *27*, 1177–1182. [CrossRef] [PubMed]
100. Li, Z.; Yu, Y.; Wang, M.; Xu, H.; Han, B.; Jiang, P.; Ma, H.; Li, Y.; Tian, C.; Zhou, D.; et al. Anti-breast cancer activity of SPG-56 from sweet potato in MCF-7 bearing mice *in situ* through promoting apoptosis and inhibiting metastasis. *Sci. Rep.* **2019**, *9*, 146. [CrossRef]



101. Lim, S. *Anthocyanin-Enriched Purple Sweet Potato for Colon Cancer Prevention*; Kansas State University, ProQuest Dissertations Publishing: Ann Arbor, MI, USA, 2012; Available online: <https://www.proquest.com/openview/aac0a1d3911587677e77c25f72859b42/1?pq-origsite=gscholar&cbl=18750> (accessed on 8 March 2022).
102. Vishnu, V.R.; Renjith, R.S.; Mukherjee, A.; Anil, S.R.; Sreekumar, J.; Jyothi, A.N. Comparative study on the chemical structure and in vitro antiproliferative activity of anthocyanins in purple root tubers and leaves of sweet potato (*Ipomoea batatas*). *J. Agric. Food Chem.* **2019**, *67*, 2467–2475. [[CrossRef](#)]
103. Lee, J.H.; Woo, K.S.; Lee, H.-U.; Nam, S.S.; Lee, B.W.; Lee, Y.-Y.; Lee, B.; Kim, H.-J. Intracellular reactive oxygen species (ros) removal and cytoprotection effects of sweet potatoes of various flesh colors and their polyphenols, including anthocyanin. *Prev. Nutr. Food Sci.* **2019**, *24*, 293–298. [[CrossRef](#)]
104. Zhang, M.; Mu, T.H. Contribution of different molecular weight fractions to anticancer effect of sweet potato protein hydrolysates by six proteases on HT-29 colon cancer cells. *Int. J. Food Sci. Technol.* **2018**, *53*, 525–532. [[CrossRef](#)]
105. Han, Y.T.; Chen, X.H.; Xie, J.; Zhan, S.M.; Wang, C.B.; Wang, L.X. Purple sweet potato pigments scavenge ROS, reduce p53 and modulate Bcl-2/Bax to inhibit irradiation-induced apoptosis in murine thymocytes. *Cell. Physiol. Biochem.* **2011**, *28*, 865–872. [[CrossRef](#)]
106. Ayeleso, T.B.; Ramachela, K.; Mukwevho, E. A review of therapeutic potentials of sweet potato: Pharmacological activities and influence of the cultivar. *Trop. J. Pharm. Res.* **2016**, *15*, 2751–2761. [[CrossRef](#)]
107. Jiang, T.; Zhou, J.; Liu, W.; Tao, W.; He, J.; Jin, W.; Guo, H.; Yang, N.; Li, Y. The anti-inflammatory potential of protein-bound anthocyanin compounds from purple sweet potato in LPS-induced RAW264. 7 macrophages. *Food Res. Int.* **2020**, *137*, 109647. [[CrossRef](#)]
108. Sugata, M.; Lin, C.Y.; Shih, Y.C. Anti-inflammatory and anticancer activities of taiwanese purple-fleshed sweet potatoes (*Ipomoea batatas* L. Lam) extracts. *BioMed Res. Int.* **2015**, *2015*, 768093. [[CrossRef](#)] [[PubMed](#)]
109. Lim, S.; Xu, J.; Kim, J.; Chen, T.-Y.; Su, X.; Standard, J.; Carey, E.; Griffin, J.; Herndon, B.; Katz, B.; et al. Role of anthocyanin-enriched purple-fleshed sweet potato p40 in colorectal cancer prevention. *Mol. Nutr. Food Res.* **2013**, *57*, 1908–1917. [[CrossRef](#)] [[PubMed](#)]
110. Roth, G.A.; Mensah, G.A.; Johnson, C.O.; Addolorato, G.; Ammirati, E.; Baddour, L.M.; Barengo, N.C.; Beaton, A.Z.; Benjamin, E.J.; Benziger, C.P.; et al. Global burden of cardiovascular diseases and risk factors, 1990–2019: Update from the GBD 2019 study. *J. Am. Coll. Cardiol.* **2020**, *76*, 2982–3021. [[CrossRef](#)]
111. Lutz, M.; Fuentes, E.; Ávila, F.; Alarcón, M.; Palomo, I. Roles of phenolic compounds in the reduction of risk factors of cardiovascular diseases. *Molecules* **2019**, *24*, 366. [[CrossRef](#)]
112. Sesso, H.D.; Liu, S.; Gaziano, J.M.; Buring, J.E. Dietary lycopene, tomato-based food products and cardiovascular disease in women. *J. Nutr.* **2003**, *133*, 2336–2341. [[CrossRef](#)] [[PubMed](#)]
113. Chen, C.M.; Li, S.C.; Lin, Y.L.; Hsu, C.Y.; Shieh, M.J.; Liu, J.F. Consumption of purple sweet potato leaves modulates human immune response: T-lymphocyte functions, lytic activity of natural killer cell and antibody production. *World J. Gastroenterol.* **2005**, *11*, 5777–5781. [[CrossRef](#)]
114. Zhao, R.; Li, Q.; Long, L.; Li, J.; Yang, R.; Gao, D. Antidiabetic activity of flavone from *Ipomoea batatas* leaf in non-insulin dependent diabetic rats. *Int. J. Food Sci. Technol.* **2007**, *42*, 80–85. [[CrossRef](#)]
115. Johnson, M.; Pace, R.D. Sweet potato leaves: Properties and synergistic interactions that promote health and prevent disease. *Nutr. Rev.* **2010**, *68*, 604–615. [[CrossRef](#)]
116. Torres-Urrutia, C.; Guzmán, L.; Schmeda-Hirschmann, G.; Moore-Carrasco, R.; Alarcón, M.; Astudillo, L.; Gutierrez, M.; Carrasco, G.; Yuri, J.A.; Aranda, E.; et al. Antiplatelet, anticoagulant, and fibrinolytic activity in vitro of extracts from selected fruits and vegetables. *Blood Coagul. Fibrinolysis* **2011**, *22*, 197–205. [[CrossRef](#)]
117. Chen, C.-M.; Lin, Y.-L.; Hsu, C.-Y.; Shieh, M.-J.; Liu, J.-F. Consumption of purple sweet potato leaves decreases lipid peroxidation and DNA damage in humans. *Asia Pac. J. Clin. Nutr.* **2008**, *17*, 408–414. Available online: <https://apjcn.nhri.org.tw/server/APJCN/17/3/408.pdf> (accessed on 5 March 2022). [[PubMed](#)]
118. Shih, C.K.; Chen, C.M.; Hsiao, T.J.; Liu, C.W.; Li, S.C. White sweet potato as meal replacement for overweight white-collar workers: A randomized controlled trial. *Nutrients* **2019**, *11*, 165. [[CrossRef](#)] [[PubMed](#)]
119. Yoon, S.; Pace, R.D.; Dawkins, N.L. The antioxidant potential of sweet potato greens in preventing cardiovascular disease risk in hamster. *FASEB J.* **2007**, *21*, A1091. [[CrossRef](#)]
120. Runnie, I.; Salleh, M.N.; Mohamed, S.; Head, R.J.; Abeywardena, M.Y. Vasorelaxation induced by common edible tropical plant extracts in isolated rat aorta and mesenteric vascular bed. *J. Ethnopharmacol.* **2004**, *92*, 311–316. [[CrossRef](#)] [[PubMed](#)]
121. Nazir, M.A.; Mu, T.H.; Zhang, M. Preparation and identification of angiotensin I-converting enzyme inhibitory peptides from sweet potato protein by enzymatic hydrolysis under high hydrostatic pressure. *Int. J. Food Sci. Technol.* **2020**, *55*, 482–489. [[CrossRef](#)]
122. Chintia, P.; Sarkar, D.; Pecota, K.; Dogramaci, M.; Shetty, K. Improving Phenolic Bioactive-Linked Functional Qualities of Sweet Potatoes Using Beneficial Lactic Acid Bacteria-Based Biotransformation Strategy. *Horticulturae* **2021**, *7*, 367. [[CrossRef](#)]
123. Jawi, I.M.; Mahendra, A.N.; Subawa, A.A.N.; Yasa, I.S.; Gunawan, W.G. Comparison of antihypertensive and antioxidative effect of Mahogany (*Swietenia Mahagoni* (L.) Jacq.) seed extract and purple sweet potato (*Ipomoea batatas*) tuber extract on rodent model of hypertension. *Biomed. Pharmacol. J.* **2017**, *10*, 577–582. [[CrossRef](#)]

124. Herawati, E.R.N.; Santosa, U.; Sentana, S.; Ariani, D. Protective effects of anthocyanin extract from purple sweet potato (*Ipomoea batatas* L.) on blood MDA levels, liver and renal activity, and blood pressure of hyperglycemic rats. *Prev. Nutr. Food Sci.* **2020**, *25*, 375–379. [[CrossRef](#)]
125. Suastika, L.; Oktaviono, Y.; Soemantri, D.; Sandra, F. Purple sweet potato extract and vitamin C increase the proliferation of endothelial progenitor cells from stable coronary artery disease patients. *Bali Med. J.* **2021**, *10*, 243–248. [[CrossRef](#)]
126. Choi, J.H.; Hwang, Y.P.; Park, B.H.; Choi, C.Y.; Chung, Y.C.; Jeong, H.G. Anthocyanins isolated from the purple-fleshed sweet potato attenuate the proliferation of hepatic stellate cells by blocking the PDGF receptor. *Environ. Toxicol. Pharmacol.* **2011**, *31*, 212–219. [[CrossRef](#)]
127. Satriyasa, B.K. Purple sweet potato ethanolic extract reduces aortic VCAM expression in rabbit with high-cholesterol diet. *Bali Med. J.* **2017**, *6*, S26–S28. [[CrossRef](#)]
128. Rahmawati, E.; Sasangka Prasetyawan, C.M.; Srihardyastutie, A.; Adnyana, M.O. Potential of Purple Sweet Potato (*Ipomoea batatas* L.) To Increase BDNF Level and VEGF Expression in The Cerebellum of Ischemic Stroke Rats. *J. Pure Appl. Chem. Res.* **2018**, *7*, 45–52. [[CrossRef](#)]
129. Rahmawati, I.S.; Soetjipto, S.; Adi, A.C.; Aulanni'am, A.A. The effectiveness of ethanol extract of purple sweet potato var. Ayamurasaki as a natural antihypertensive mitigator in deoxycorticosterone acetate-salt hypertensive rats. *Drug Invent. Today* **2019**, *11*, 3179–3193.
130. Zheng, G.-H.; Shan, Q.; Mu, J.-J.; Wang, Y.-J.; Zhang, Z.-F.; Fan, S.-H.; Hu, B.; Li, M.-Q.; Xie, J.; Chen, P.; et al. Purple sweet potato color attenuates kidney damage by blocking VEGFR2/ROS/NLRP3 signaling in high-fat diet-treated mice. *Oxidative Med. Cell. Longev.* **2019**, *2019*, 5189819. [[CrossRef](#)] [[PubMed](#)]
131. Shafe, M.; Eze, E.; Ubhenin, A.; Tende, J. Effects of Aqueous Tuber Extract of Ipomea batatas on Cardiac Enzymes, Lipid Profile and Organ Weights in Wistar Rats. *J. Basic Appl. Res. Biomed.* **2016**, *2*, 414–417.
132. Chang, H.H.; Lan, Y.C.; Chung, S.D.; Chien, C.T. Sweet potato leaf feeding decreases cholesterol, oxidative stress and thrombosis formation in syrian hamsters with a high-cholesterol diet. *Life* **2021**, *11*, 802. [[CrossRef](#)] [[PubMed](#)]
133. Osuntokun, O.T.; Yusuf-Babatunde, M.A.; Fasila, O.O. Components and Bioactivity of *Ipomoea batatas* (L.)(Sweet Potato) Ethanolic Leaf Extract. *Asian J. Adv. Res. Rep.* **2020**, *10*, 10–26. [[CrossRef](#)]
134. Li, J.; Shi, Z.; Mi, Y. Purple sweet potato color attenuates high fat-induced neuroinflammation in mouse brain by inhibiting MAPK and NF- $\kappa$ B activation. *Mol. Med. Rep.* **2018**, *17*, 4823–4831. [[CrossRef](#)]



**Figure S1.** Agronomic profitability of sweet potato  
 Crop yield [production (tons 10<sup>8</sup>) vs. area (Ha 10<sup>6</sup>)]. 1999 (1), 2009(2), 2019 (3)  
 data for Africa (Af), America (Am), China (Ch), United States of America (USA) and  
 world (W).

Supplementary Material (Table S1) - Agricultural outlook 1999-2019: Sweet Potatoes (Complete FAOSTAT Data)

Country	1999			2009			2019		
	A (Ha)	P (Tons)	Yield (Hg/Ha)	A (Ha)	P (Tons)	Yield (Hg/Ha)	A (Ha)	P (Tons)	Yield (Hg/Ha)
Réunion	15	300	200,000	--	--	--	--	--	--
Martinique	120	1,170	97,500	--	--	--	--	--	--
Guadeloupe	390	4,267	109,410	--	--	--	--	--	--
Greece	339	6,250	184,366	173	3,522	203,584	--	--	--
Italy	1,275	10,231	80,243	439	7,771	177,016	--	--	--
Spain	1,267	20,364	160,726	1,443	24,838	172,128	--	--	--
Portugal	2,668	23,687	88,782	1,758	23,490	133,618	--	--	--
Bhutan	--	--	--	104	105	10,096	25	48	19,200
Botswana	--	--	--	--	--	--	300	3,000	100,000
Malawi	--	--	--	--	--	--	368,927	5,908,989	160,167
Niue	14	247	176,429	15	251	167,333	16	251	156,875
Suriname	16	196	122,500	7	98	140,000	66	888	134,545
Belize	25	107	42,800	4	32	80,000	18	86	47,778
Antigua and Barbuda	26	153	58,846	43	269	62,558	44	289	65,582
Maldives	29	48	16,552	15	12	8,000	2	2	10,000
Guatemala	30	200	66,667	10	65	65,000	17	109	64,118
Yemen	33	318	96,364	45	407	90,444	42	352	83,810
Brunei Darussalam	35	180	51,429	41	252	61,463	36	284	78,889
Trinidad and Tobago	35	222	63,429	138	271	19,638	314	967	30,796
Mauritius	35	400	114,286	77	950	123,377	40	414	103,500
Cook Islands	46	1,212	263,478	18	480	266,667	6	175	291,667
Costa Rica	50	150	30,000	85	250	29,412	201	601	29,900
Saint Kitts and Nevis	50	170	34,000	26	230	88,462	40	306	76,500
Saint Lucia	50	480	96,000	42	397	94,534	23	330	230,435
Bahamas	68	259	38,088	386	1,332	34,508	592	2,080	35,135
Grenada	72	200	27,778	46	128	27,826	2,821	7,886	27,955
El Salvador	83	525	63,253	104	636	61,154	132	760	57,576
Honduras	120	763	63,583	1,090	7,000	64,220	2,843	16,984	59,740
New Caledonia	167	490	29,341	595	689	11,580	626	626	10,000
Palestine	167	5,037	301,617	95	2,500	263,158	67	1,832	273,433
Barbados	220	3,500	159,091	41	888	216,585	91	2,093	230,000
Tonga	249	3,080	123,695	572	6,352	111,049	651	6,483	99,585
Puerto Rico	320	2,526	78,938	298	2,633	88,356	487	58	84,828
Ecuador	337	1,913	56,766	1,900	3,600	18,947	2,240	3,922	17,508
Dominica	436	1,787	40,986	410	2,086	50,878	380	2,385	62,763
Fiji	477	5,224	109,518	357	4,894	137,087	901	9,053	100,477
Micronesia (Federated States of)	530	3,075	58,019	543	3,094	56,980	561	3,108	55,401
Somalia	540	5,400	100,000	772	7,608	98,549	868	8,626	99,378
Morocco	545	7,290	133,761	695	11,882	170,964	457	9,366	204,945
Cabo Verde	720	3,800	52,778	450	7,700	171,111	195	3,395	174,103
Australia	800	22,000	275,000	1,693	42,460	250,797	2,168	78,910	363,976
Pakistan	825	9,268	112,339	1,046	11,951	114,254	1,688	15,963	94,568
Israel	894	8,600	96,197	3,444	32,237	93,603	2,417	33,032	144,940
New Zealand	1,000	17,000	170,000	1,036	12,400	119,691	1,202	12,050	100,250
Chile	1,077	7,382	68,542	1,303	11,303	86,746	1,410	18,436	130,752
Eswatini	1,264	2,300	18,196	1,358	2,500	18,409	1,285	2,458	19,128
Congo	1,350	9,000	66,667	976	6,853	70,215	1,306	9,395	71,937
Guyana	1,354	2,990	22,083	93	2,310	248,387	511	14,151	276,928
Saint Vincent and the Grenadines	1,363	2,181	16,001	2,300	2,800	12,174	253	2,500	98,814
Venezuela (Bolivarian Republic of)	1,530	13,928	91,033	750	8,000	106,667	1,665	17,336	104,120
Jamaica	1,543	24,970	161,828	2,004	34,229	170,803	2,456	43,188	175,847
Gabon	1,600	2,800	17,500	1,665	3,124	18,763	2,119	4,227	19,948
Liberia	1,800	18,000	100,000	2,016	20,895	103,646	2,136	24,455	114,490
Togo	2,036	9,201	45,634	597	3,989	66,817	2,375	9,862	36,514
Burkina Faso	2,058	17,294	84,033	6,419	81,499	126,965	5,907	66,383	112,380
Mauritania	2,077	2,066	9,947	2,301	2,573	11,182	2,826	5,081	17,979
Zimbabwe	2,202	4,813	21,857	9,235	23,285	25,214	12,512	35,400	28,293
Comoros	2,284	5,141	22,509	2,807	6,503	23,167	3,394	8,001	23,574
Malaysia	2,300	25,000	108,696	1,309	13,495	103,094	3,317	56,323	169,801
Niger	2,400	49,500	206,250	3,042	48,742	160,230	6,233	173,171	277,829
Mexico	2,458	47,465	193,104	2,313	44,052	190,454	3,104	59,358	191,231
Senegal	3,034	26,538	87,469	1,500	60,000	400,000	2,316	89,397	385,997
Bolivia (Plurinational State of)	3,100	13,600	43,871	1,616	7,551	46,726	1,070	4,487	41,935
Timor-Leste	3,500	14,000	40,000	4,807	12,790	26,607	1,375	2,862	20,815
Mali	4,407	46,779	106,147	12,381	236,759	191,228	19,807	312,477	157,761
Solomon Islands	5,200	74,000	142,308	6,700	96,000	143,284	7,614	107,894	141,705
Sudan (former)	5,400	116,000	214,815	9,660	216,000	223,602	25,130	253,628	100,926
Myanmar	5,414	30,585	56,492	7,200	59,000	81,944	6,537	62,631	95,810
Uruguay	6,000	60,000	100,000	7,600	72,000	94,737	8,805	80,444	91,362
Sierra Leone	7,547	34,200	45,316	38,724	176,969	45,700	18,675	178,753	95,718
Sri Lanka	8,380	51,600	61,575	6,000	47,270	78,783	3,255	35,607	109,392
Dominican Republic	8,558	52,952	61,874	6,086	47,147	77,468	6,914	54,714	79,135
Cambodia	9,322	32,516	34,881	9,283	78,891	84,984	8,063	42,473	52,676
Paraguay	10,085	79,365	78,696	5,120	44,511	86,936	5,087	50,520	99,312
Egypt	10,520	253,053	240,545	12,517	357,266	285,425	14,165	454,041	320,537
Benin	10,885	68,847	63,249	11,471	63,695	55,527	10,279	68,323	66,469
Equatorial Guinea	11,735	36,000	30,677	17,582	81,244	46,209	19,829	124,115	62,593
Lao People's Democratic Republic	13,050	80,600	61,762	18,131	171,147	94,395	5,720	114,885	200,848
Peru	14,552	244,671	168,136	16,006	262,724	164,141	16,764	301,344	179,757
South Africa	14,774	52,000	35,197	21,000	63,022	30,010	32,112	88,692	27,620
Argentina	17,000	244,784	143,991	21,596	327,132	151,478	22,671	337,487	148,863
Republic of Korea	20,109	428,085	212,882	20,918	350,661	167,636	21,775	309,211	142,003
Angola	22,000	182,303	82,865	147,813	982,588	66,475	178,272	1,680,146	94,246
Côte d'Ivoire	23,639	50,824	21,500	24,434	18,654	28,981	45,212	32,023	18,023
Chad	24,000	62,000	25,833	4,982	28,856	57,921	32,635	217,324	66,592
Ethiopia	24,702	220,000	89,062	53,431	450,697	84,351	52,406	1,755,855	335,048
Cameroon	27,054	178,272	65,895	49,012	266,078	54,288	85,953	495,177	57,610
United States of America	33,590	554,335	165,030	39,214	883,100	225,200	59,370	1,450,250	244,273
Democratic People's Republic of Korea	36,500	490,000	134,247	29,000	390,000	134,483	41,148	561,796	136,531
Zambia	37,000	52,000	14,054	60,638	200,450	33,057	27,341	109,336	39,990
Bangladesh	41,278	383,000	92,786	31,697	305,025	96,232	23,014	235,881	102,495
Guinea	42,695	162,760	38,122	25,000	82,194	32,878	55,014	281,700	51,205
Brazil	43,158	472,422	109,463	42,241	477,472	113,035	57,290	805,412	140,585
Japan	44,500	1,008,000	226,517	40,500	1,026,000	253,333	34,300	740,700	218,280
Democratic Republic of the Congo	49,092	246,000	50,110	48,585	243,460	50,110	108,211	542,686	50,151
Kenya	51,320	543,089	105,824	77,821	1,034,204	132,895	65,973	893,656	135,458
Cuba	53,075	261,000	49,176	78,496	437,100	55,684	54,176	555,078	102,458
Mozambique	55,000	400,000	72,727	86,300	900,000	104,287	33,970	451,204	132,824
Haiti	58,000	172,000	29,655	75,000	294,172	39,223	9,333	42,002	45,004
Ghana	65,000	90,000	13,846	72,249	117,879	16,316	73,621	154,260	20,953
Madagascar	92,000	520,000	56,522	127,000	910,857	71,721	132,579	1,113,142	83,961
Papua New Guinea	102,000	480,000	47,059	120,000	595,000	49,583	145,077	743,735	51,265
Burundi	112,000	734,172	65,551	138,000	926,319	67,125	93,578	1,023,458	109,370
Philippines	132,349	557,386	42,115	114,300	560,516	49,005	63,338	525,862	63,100
India	134,400	1,152,400	85,744	124,300	1,119,700	90,000	110,000	1,156,000	105,091
Indonesia	172,243	1,665,547	96,698	183,874	2,057,913	111,920	86,360	1,806,339	209,164
Rwanda	179,941	862,562	47,936	123,386	803,228	65,099	183,889	1,247,584	67,844
Viet Nam	270,200	1,744,600	64,567	146,600	1,211,300	82,626	116,698	1,402,350	120,169
United Republic of Tanzania	282,020	565,220	20,042	651,940	1,417,390	21,741	539,513	3,921,590	72,688
Uganda	539,000	2,354,000	43,673	463,000	1,943,000	41,965	463,568	1,949,476	42,054
Nigeria	817,000	2,451,000	30,000	1,100,000	3,300,000	30,000	1,717,659	4,145,488	24,135
China	5,945,975	126,143,701	212,150	3,253,056	70,400,593	215,307	2,373,737	51,992,156	219,031

Country	1999			2009			2019		
	A (Ha)	P (Tons)	Yield (Hg/Ha)	A (Ha)	P (Tons)	Yield (Hg/Ha)	A (Ha)	P (Tons)	Yield (Hg/Ha)
World	9,743,043	147,348,709	7,844,474	96,364,636	7,309,599	85,908,695	111,289		

Supplementary Material (Table S2) - Nutrient data for raw/processed sweet potatoes and other edible roots & tubers

	Potatoes	Cassava	Yams	Orange-fleshed sweet potato (OFSP)							
	Raw	Raw	Raw	Raw	Leaves	Canned	Canned/mashed	Candy	Chips	Boiled	Fries
<i>NDB # / FDC Id.</i>	<i>11352</i>	<i>11134</i>	<i>11601</i>	<i>11507</i>	<i>11505</i>	<i>1103254</i>	<i>11514</i>	<i>1103252</i>	<i>1103258</i>	<i>1103247</i>	<i>1103257</i>
Water (g)	79.3	59.7	69.6	77.0	86.8	75.7	73.9	57.5	4.5	79.8	44.5
Energy (Kcal)	77	160	118	86	42	91	101	178	529	76	259
Energy (KJ)	322	667	494	359	175	380	422	743	2207	317	1081
Protein (g)	2.1	1.4	1.5	1.6	2.5	1.6	2.0	1.0	2.9	1.4	2.1
Fat (g)	0.1	0.3	0.2	0.1	0.5	0.2	0.2	3.3	32.2	0.1	18.1
Carbohydrates (by difference)	17.5	38.1	27.9	20.0	8.8	21.0	23.2	37.5	56.5	17.7	34.1
Sugars (g)	0.8	1.7	0.5	4.2	0.0	5.0	5.5	29.0	8.8	5.7	12.3
Total dietary fiber (TDF, g)	2.1	1.8	4.1	3.0	5.3	1.8	1.7	1.8	8.8	2.5	5.5
Ca (mg)	12.0	16.0	17.0	30.0	78.0	22.0	30.0	20.0	59.0	27.0	50.0
Fe (mg)	0.8	0.3	0.5	0.6	1.0	0.9	1.3	0.5	2.1	0.7	0.8
Mg (mg)	23.0	21.0	21.0	25.0	70.0	22.0	24.0	13.0	65.0	18.0	25.0
P (mg)	57.0	27.0	55.0	47.0	81.0	49.0	52.0	23.0	144.0	32.0	56.0
K (mg)	425.0	271.0	816.0	337.0	508.0	311.0	210.0	165.0	920.0	229.0	391.0
Na (mg)	6.0	14.0	9.0	55.0	6.0	207.0	75.0	142.0	227.0	181.0	140.0
Zn (mg)	0.30	0.34	0.24	0.30	0.90	0.18	0.21	0.15	0.53	0.20	0.36
Cu (mg)	0.11	0.10	0.18	0.15		0.14	0.28	0.07	0.41	0.09	0.17
Se (µg)	0.40	0.70	0.70	0.60	0.90	0.70	0.80	0.30	2.10	0.20	0.40
Ascorbate (C, mg)	19.70	20.60	17.10	2.40	11.00	26.30	5.20	9.10	0.00	12.70	6.80
Tiamin (B1, mg)	0.08	0.09	0.11	0.08	0.16	0.04	0.03	0.04	0.09	0.06	0.08
Riboflavin (B2, mg)	0.03	0.05	0.03	0.06	0.35	0.06	0.09	0.04	0.16	0.05	0.09
Niacin (B3, mg)	1.06	0.85	0.55	0.56	1.13	0.74	0.96	0.38	2.10	0.54	
Piridoxine (B6, mg)	0.30	0.09	0.29	0.21	0.19	0.19	0.24	0.14	0.53	0.16	0.17
Folic acid (B9, µg)	15.00	27.00	23.00	11.00	1.00	17.00	11.00	4.00	37.00	6.00	29.00
Choline (mg)	12.10	23.70	16.50	12.30		12.90		8.00	36.00	10.80	24.90
A (IU)	2.00	13.0	138.0	14187.0	3778.0	7951.7	8698.3	11221.7	23556.7	1576.7	8300.0
A (RAE, µg)	0.00	1.0	7.0	709.0	0.22	397.0	435.0	574.0	1178.0	784.0	45.0
β-carotene (µg)	1.00	8.0	83.0	8509.0	2217.0	4771.0	5219.0	6733.0	14134.0	9406.0	4980.0
α-carotene (µg)	0.0	0.0	0.0	7.0	42.0	0.0	0.0	0.0	0.0	0.0	0.0
β-criptoxanthin (µg)	0.0	0.0	0.0	0.0	58.0	0.0	0.0	0.0	0.0	0.0	0.0
α-tocopherol (E, mg)	0.01	0.19	0.35	0.26		1.00	1.10	1.03	9.77	0.94	0.00
Phylloquinone (K, µg)	2.00	1.90	2.30	1.80	302.20	0.00	2.40	4.40	24.40	2.10	15.70
Saturated fatty acids (g)	0.025	0.074	0.037	0.018	0.110	0.041	0.040	0.906	2.930	0.030	2.420
16:0 (g)	0.016	0.069	0.034	0.018	0.100	0.040	0.040	0.477	1.390	0.030	1.710
18:0 (g)	0.004	0.005	0.004	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000
Monounsaturated fatty acids (g)	0.002	0.075	0.006	0.001	0.020	0.008	0.008	1.143	9.100	0.000	7.550
18:1 (g)	0.001	0.075	0.006	0.001	0.020	0.008	0.008	1.116	8.800	0.000	7.380
Polyunsaturated fatty acids (g)	0.042	0.048	0.076	0.014	0.228	0.084	0.080	0.994	12.160	0.060	6.680
18:2 (g)	0.032	0.032	0.064	0.013	0.192	0.071	0.070	0.882	11.020	0.060	5.874
18:3 (g)	0.010	0.017	0.012	0.000	0.000	0.013	0.000	0.112	1.140	0.000	0.796

USDA Nutrient Data Bank: <https://fdc.nal.usda.gov/>; Storage root or tuber (R/T)