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Series on the Safety of Novel Foods and Feeds No. 20

CONSENSUS DOCUMENT ON COMPOSITIONAL CONSIDERATIONS FOR NEW VARIETIES OF SWEET POTATO [Ipomoea batatas (L.) Lam.]: KEY FOOD AND FEED NUTRIENTS, ANTI-NUTRIENTS, TOXICANTS AND ALLERGENS

English - Or. English

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Series on the Safety of Novel Foods and Feeds

No. 20

Consensus Document on Compositional Considerations for New Varieties of SWEET POTATO [*Ipomoea batatas* (L.) Lam.]: Key Food and Feed Nutrients, Anti-nutrients, Toxicants and Allergens

Environment Directorate

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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FOREWORD

The OECD's Task Force for the Safety of Novel Foods and Feeds decided at its first session, in 1999, to focus its work on the development of science-based ***consensus documents,*** which are mutually acceptable among member countries. These consensus documents contain information for use during the regulatory assessment of a particular food/feed product. In the area of food and feed safety, consensus documents are being published on the nutrients, anti-nutrients or toxicants, information of its use as a food/feed and other relevant information.

This consensus document addresses compositional considerations for new varieties of sweet potato [*Ipomoea batatas* (L.) Lam] by identifying the key food and feed nutrients, anti-nutrients, toxicants and allergens. A general description of these components is provided. As well, there is background material on the production, processing and uses of sweet potato and considerations to be taken into account when assessing new varieties of sweet potato. Constituents to be analysed, related to food use and to feed use, are suggested.

South Africa served as the lead country in the preparation for the document, in collaboration with Japan (co-lead), and the draft has been revised on a number of occasions based on the input from other member countries and stakeholders.

The Task Force endorsed this document, which is published under the responsibility of the Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology of the OECD.

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PREAMBLE

Food and feed products of modern biotechnology are being commercialised and marketed in OECD member countries. The need has been identified for detailed technical work aimed at establishing appropriate approaches to the safety assessment of these products.

At a Workshop held in Aussois, France (OECD, 1997), it was recognised that a consistent approach to the establishment of substantial equivalence might be improved through consensus on the appropriate components (*e.g.*, key nutrients, key toxicants and anti-nutritional compounds) on a crop-by-crop basis, which should be considered in the comparison. It is recognised that the components may differ from crop to crop. The Task Force therefore decided to develop consensus documents on phenotypic characteristics and compositional data. These data are used to identify similarities and differences following a comparative approach as part of a food and feed safety assessment. They should be useful to the development of guidelines, both national and international and to encourage information sharing among OECD member countries.

These documents are a compilation of current information that is important in food and feed safety assessment. They provide a technical tool for regulatory officials as a general guide and reference source, and also for industry and other interested parties and will complement those of the Working Group on Harmonisation of Regulatory Oversight in Biotechnology. They are mutually acceptable to, but not legally binding on, member countries. They are not intended to be a comprehensive description of all issues considered to be necessary for a safety assessment, but a base set for an individual product that supports the comparative approach. In assessing an individual product, additional components may be required depending on the specific case in question.

In order to ensure that scientific and technical developments are taken into account, member countries have agreed that these consensus documents will be reviewed periodically and updated as necessary. Users of these documents are invited to provide the OECD with new scientific and technical information, and to make proposals for additional areas to be considered.

A short, pre-addressed questionnaire is included at the end of this document. The information requested should be sent to the OECD at one of the addresses shown.

THE ROLE OF COMPARATIVE APPROACH AS PART OF A SAFETY ASSESSMENT

In 1990, a joint consultation of the Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO) established that the comparison of a final product with one having an acceptable standard of safety provides an important element of safety assessment (WHO, 1991).

In 1993 the Organisation for Economic Co-operation and Development (OECD) further elaborated this concept and advocated the approach to safety assessment based on substantial equivalence as being the most practical approach to addressing the safety of foods and food components derived through modern biotechnology (as well as other methods of modifying a host genome including tissue culture methods and chemical or radiation induced mutation). In 2000 the Task Force concluded in its report to the G8 that the concept of substantial equivalence will need to be kept under review (OECD, 2000).

The Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology in 2000 concluded that the safety assessment of genetically modified foods requires an integrated and stepwise, case-by-case approach, which can be aided by a structured series of questions. A comparative approach focusing on the determination of similarities and differences between the genetically modified food and its conventional counterpart aids in the identification of potential safety and nutritional issues and is considered the most appropriate strategy for the safety and nutritional assessment of genetically modified foods. The concept of substantial equivalence was developed as a practical approach to the safety assessment of genetically modified foods. It should be seen as a key step in the safety assessment process although it is not a safety assessment in itself; it does not characterise hazard, rather it is used to structure the safety assessment of a genetically modified food relative to a conventional counterpart. The Consultation concluded that the application of the concept of substantial equivalence contributes to a robust safety assessment framework.

A previous Joint FAO/WHO Expert Consultation on Biotechnology and Food Safety (1996) elaborated on compositional comparison as an important element in the determination of substantial equivalence. A comparison of critical components can be carried out at the level of the food source (*i.e.* species) or the specific food product. Critical components are determined by identifying key nutrients, key toxicants and anti-nutrients for the food source in question. The comparison of key nutrients should be between the modified variety and non-modified comparators with an appropriate history of safe use. The data for the non-modified comparator can be the natural ranges published in the literature for commercial varieties or those measured levels in parental or other edible varieties of the species (FAO, 1996). The comparator used to detect unintended effects should ideally be the near isogenic parental line grown under identical conditions. While the comparative approach is useful as part of the safety assessment of foods derived from plants developed using recombinant DNA technology, the approach could, in general, be applied to foods derived from new plant varieties that have been bred by other techniques.

SECTION I – BACKGROUND

A. General description of sweet potato

1. The sweet potato [*Ipomoea batatas* (L.) Lam.] belongs to the *Convolvulaceae* or morning glory family (Jones, 1965; Austin, 1977). It is considered as the only major economically important species of the *Ipomoea* genus (Hall and Phatak, 1993). *Ipomoea batatas* is thought to have originated in Mexico and possibly Central America (Zhang and Corke, 2001). Common names in Latin America are 'batata', 'camote' and 'boniato' (Spanish), 'batata doce' (Portuguese), 'apichu' and 'kumara' (Martin and Jones, 1986; Woolfe, 1992). Indigenous South Americans have probably cultivated sweet potatoes for thousands of years. The crop was spread to other parts of the world such as Polynesia and New Zealand during the 8th century. Introduction into China occurred during the 14th century, probably from the Philippines and into Japan during the 17th century first from England, which was unsuccessful and then from China (Woolfe, 1992). Sweet potato was introduced to the tropical areas of Africa, Europe, China, India, and Indonesia during the 16th century (Janssens, 2001). Along its long-standing domestication process, the crop has developed secondary centres of genetic diversity; many types of sweet potato that are genetically distinct from those found in their area of origin can be found in Papua New Guinea and in other parts of Asia (CIP Website).

2. Sweet potato is a perennial plant, although it is typically cultivated as an annual crop (Janssens, 2001). Despite its name, the sweet potato is not related to the potato (which belongs to the *Solanaceae* family). This herbaceous plant does not develop a tuber (thickened stem), but certain of its roots produce edible storage roots (Jones *et al*., 1986). Nearly half of the sweet potato produced in Asia (the world's largest producing region) is used for animal feed, while the remainder is primarily used for human consumption. In Africa in contrast, most of the crop is cultivated for human consumption. Sweet potato is high in carbohydrates and vitamin A and can produce more edible energy per hectare per day than wheat, rice or cassava. It has an abundance of uses ranging from consumption of fresh roots or leaves to processing into animal feed, starch, flour, candy, and alcohol (CIP Website). Various publications review the crop characteristics, agronomy, and food and feed applications of sweet potato, which is indicative of the interest of the scientific community in this particular crop (Bovell-Benjamin, 2007; Chassy *et al*., 2008; Lebot, 2009; Woolfe, 1992).

B. Production

3. Sweet potato is an important crop in many parts of the world, being cultivated in more than 100 countries. As a world crop, it ranks seventh from the viewpoint of total production after wheat, rice, maize, potato, barley and cassava (Kays, 2005). In monetary terms, it ranks thirteenth globally in the production value of commodities, and is fifth on the list of the developing countries' most valuable food crops (Woolfe, 1992). The annual world production was 110.1 million tonnes (Mt) in 2008 with 84% produced in Asia (92.5 Mt), 12.7% in Africa (14 Mt), 2.6% in Americas (2.6 Mt), 0.7 Mt in Oceania and less than 0.1 Mt in Europe (FAOSTAT 2008, Table 1). Furthermore, the crop accounts for about one-third of the production of root and tuber crops in developing countries. China is by far the largest producer, accounting in 2008 for more than 77% of the world supply, followed by Nigeria, Uganda, Indonesia and Vietnam (Table 1). The global land area under production in 2008 was estimated to reach 8.2 million hectares, with an average yield of 13.5 t/ha (Table 1).

4. Since China contributes the largest portion of sweet potato production in the world, production in one of the Chinese provinces should be mentioned. The Shandong province has an approximate annual production of about 17 million tonnes which is produced on 600 000 ha (Fuglie *et al*., 1999). Compared with the 2008 FAO data, this would account for approximately 20% of China's production and 15% of the world sweet potato production.

5. It is important to note that when compiling a review on the world-wide production of sweet potato, discrepancies in data might occur. Since sweet potato is mainly produced by small farmers on non-contiguous plots, harvested several times a year and not sold through regulated domestic markets, estimating the exact production and trade of this crop is difficult.

Table 1. Sweet potato production figures for selected countries, 2008

Country	**Production** (1000 t)	**Area** (1000 ha)	**Average Yield** (t/ha)
Asia Total	**92 490**	**4 433**	**20.9**
China	*85 213	*3 685	23.1
Indonesia	1 877	174	10.8
Vietnam	1 324	162	8.2
India	1 146	126	9.1
Japan	*968	*41	23.8
Philippines	572	116	4.9
Korea, DPR	380	*28	13.6
Korea, R.	329	19	16.9
Bangladesh	307	32	9.7
Africa Total	**14 013**	**3 312**	**4.2**
Nigeria	3 318	1 106	3.0
Uganda	2 707	599	4.5
Tanzania	*1 322	*505	2.6
Kenya	895	63	14.3
Madagascar	*890	127	7.0
Burundi	*874	*131	6.7
Rwanda	*800	*140	5.7
Angola	*710	*145	4.9
Ethiopia	526	62	8.4
Americas Total	**2 852**	**301**	**9.5**
United States	837	39	21.2
Brazil	*519	*47	10.9
Cuba	375	59	6.4
Argentina	*340	*24	14.2
Oceania	**706**	**125**	**5.6**
Papua New Guinea	*580	*115	5.0
Europe	**67**	**6**	**12**
World Total	***110 128***	***8 178***	***13.5***

Source: FAOSTAT (2008)
* FAO estimate

6. A very small amount of the world production of sweet potato is traded internationally (as unprocessed roots, 0.17% in 2007). The main 2007 exporters were the United States, China, Israel and France, while the main importers were the United Kingdom, Canada, France and Japan (FAOSTAT 2007, Table 2).

Table 2. Sweet potato import and export figures for selected countries, 2007

Importing Country	Import (1000 t)	Exporting Country	Export (1000 t)
Asia	**39.5**	**Asia**	**43.4**
China, Hong Kong SAR	3.2	China	16.0
Japan	14.6	Israel	12.3
Singapore	6.4	Indonesia	8.4
Malaysia	5.6		
Saudi Arabia	3.5		
Africa	**1.2**	**Africa**	**9.7**
		Egypt	7.1
Americas	**44.7**	**Americas**	**67.1**
United States	7.8	United States	38.9
Canada	24.9	Dominican Rep.	8.2
Argentina	7.9	Brazil	5.9
		Honduras	5.4
		Paraguay	3.4
Europe	**93.9**	**Europe**	**25.7**
United Kingdom	37.1	France	10.1
Albania	12.7	Italy	6.8
France	15.6	Netherlands	5.8
Italy	6.0		
Netherlands	12.0		
Oceania	**0.3**	**Oceania**	**0.2**
World Total	***179.6***	***World Total***	***146.0***

Source: FAOSTAT (2007)

C. Processing and uses

7. Sweet potato is an important root crop and, besides human consumption, the roots, stems and leaves are readily eaten by cattle, goats, pigs and poultry as forage for animals.

8. Sweet potato roots can be sliced, dried, and ground in order to produce flour that remains in good condition for a long time. Dried root slices are a suitable means of storage in humid areas. In Indonesia, sweet potato is soaked in salt water for about an hour to inhibit microbial growth before drying. The flour is used as a dough conditioner for bread, biscuit, and cake processing (it may substitute for up to 20% of wheat flour), as well as in gluten-free pancake preparation (Shih *et al*., 2006). Sweet potato flour is used as a stabiliser in the ice-cream industry, and powder made from dehydrated sweet potato is used in instant soups.

9. Mashed sweet potato is used as an ingredient of ice cream, tarts, baking products, and desserts as a substitute for more expensive ingredients. As puree, it is used in pie fillings, sauces (*e.g*. tomato sauce in Uganda), frozen patties, baby foods, and in fruit-flavoured sweet potato jams together with pineapple,

mango, guava and orange. In the United States, sweet potato in whole, halved, chunks or pureed form is canned. Sweet potato can be frozen as cubes, slices, french fries, mash, halves, quarters, or whole roots. In Japan sweet potato slices are steamed and dried to produce *hoshiimo* or *mushikiri* (Woolfe, 1992).

10. Sweet potato is further processed as and sugar-coated or salted crisps for snack foods (Woolfe, 1992). Sweet potato crisps are produced in much the same way as potato and the product is now popular in Asia. The sugar-coated chips are popular in China and the salted variety is popular in the United States.

11. The major industrial use of sweet potato is for the production of starch (Figure 1). Sweet potato starch is produced under alkaline (pH 8.6) conditions by using lime, which helps to flocculate impurities and dissolve the pigments. The uncooked starch of the sweet potatoes is very resistant to the hydrolysis by amylase. When cooked, its susceptibility to the enzyme increases. Thus, after cooking the easily hydrolysable starch fraction of sweet potato increases from 4% to 55% (Cerning-Beroard and Le Dividich, 1976). The starch shows properties intermediate between potato starch and maize/cassava starch, *e.g.* in terms of viscosity. In Japan about 90% of the starch produced from sweet potato is used to manufacture starch syrup, glucose and isomerised glucose syrup (high fructose syrup), lactic acid beverages, bread, as well as other products in the food industry such as distilled spirits called *shochu*. In China the starch is used for making pasta (Singh *et al*., 2004) and for producing alcoholic beverages. Non-alcoholic juices are also made in African countries such as Uganda.

12. In Africa, sweet potato is mainly consumed as food in an array of consumption patterns across production areas (Manrique, 1998; CIP Website). In eastern and southern Africa roots are eaten either just boiled or cooked together with beans, vegetables, and other foods, and sometimes fried as chips. In a few areas the roots are peeled, sliced and dried. In South Africa sweet potato is mainly consumed fresh and the largest portion of the production is sold on the commercial fresh produce markets. Many resource-poor farmers in South Africa grow sweet potato in home gardens. In these cases sweet potato is an important subsistence food crop where resource-poor farmers boil and eat sweet potatoes as part of a hot meal, or cold with tea, and to a lesser extent in stews. At this level, sweet potato processing is limited to occasional drying, freezing, and baking crisps and bread.

13. Sweet potato has potential use in the bio-fuel industry. Some sweet potato varieties have a carbohydrate content that approaches the lower limits of those of sugarcane, the highest-yielding ethanol crop. At this point, sweet potato is not an economically competitive fuel source. It costs more to grow and process sweet potato than many other fuel sources. In addition to ethanol, the ethanol manufacturing process also produces by-products as marketable products. Selling these by-products (*e.g.* residual mash) from this industry to the feed industry is an important economic outlet for ethanol manufacturers (USDA Website, 2008).

14. In South America, the juice of red sweet potatoes is combined with lime juice to make a fabric dye.

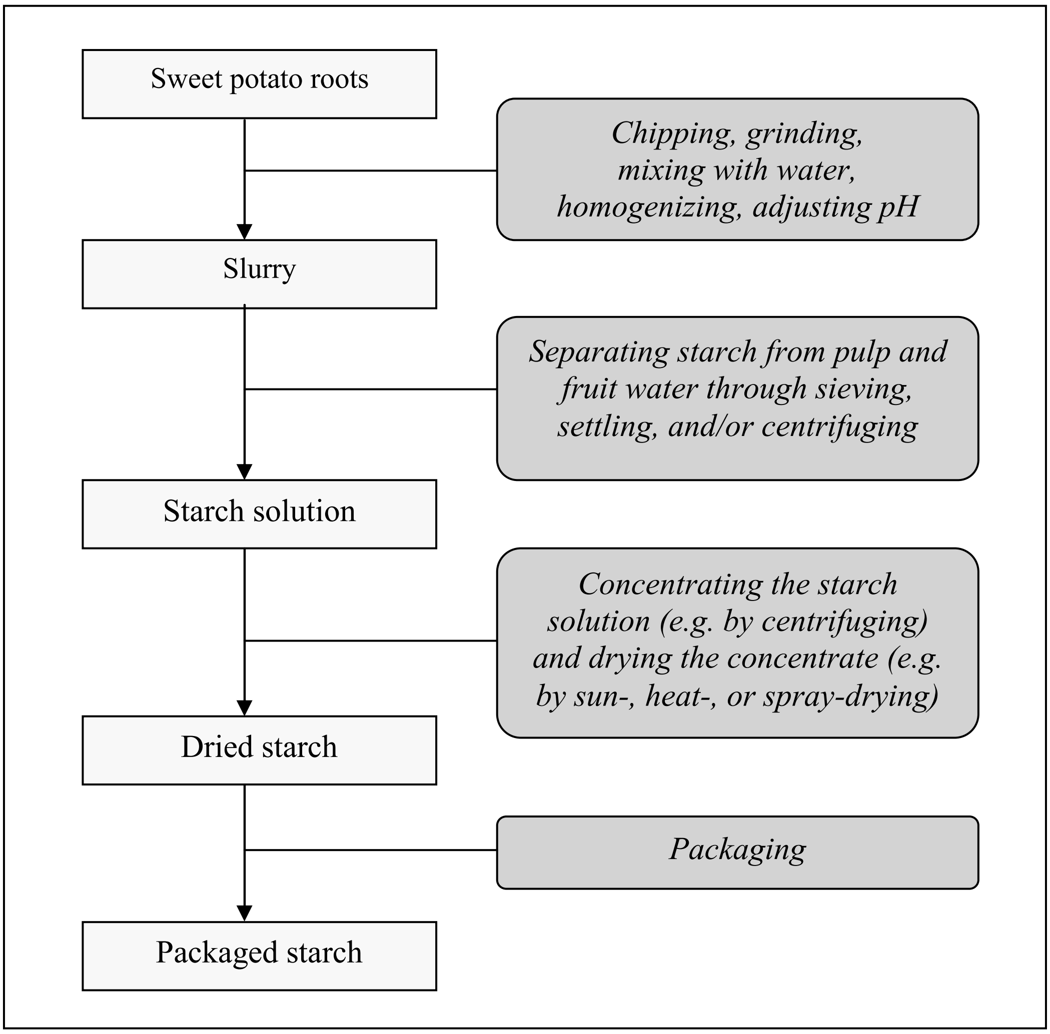

Figure 1: Sweet potato starch production, generalized process scheme

Adapted from: Woolfe (1992) and Bovell-Benjamin (2007)

D. Appropriate comparators for testing new varieties

15. This document suggests parameters that sweet potato breeders should measure when developing new modified varieties. The data obtained in the analysis of a new sweet potato variety should ideally be compared to those obtained from an appropriate near isogenic non-modified variety, grown and harvested under the same conditions.[1] The comparison can also be made between values obtained from new varieties and data available in the literature, or chemical analytical data generated from other commercial sweet potato varieties.

16. Components to be analysed include key nutrients, toxicants and allergens. Key nutrients are those which have a substantial impact in the overall diet of humans (food) and animals (feed). These may be major constituents (fats, proteins, and structural and non-structural carbohydrates) or minor compounds (vitamins and minerals). Similarly, the levels of known anti-nutrients and allergens should be considered. Key toxicants are those toxicologically significant compounds known to be inherently present in the species, whose toxic potency and levels may impact human and animal health. Standardized analytical methods and appropriate types of material should be used, adequately adapted to the use of each product and by-product. The key components analysed are used as indicators of whether unintended effects of the genetic modification influencing plant metabolism has occurred or not.

E. Breeding characteristics screened by developers

17. The major goals of current research and development programmes focusing on the improvement of sweet potato include:

- Improved root yield, dry matter yield, foliage yield, and maturity period.
- Disease and pest resistance, *e.g.* resistance to sweet potato feathery mottle virus (SPFMV) disease (Okada *et al*., 2001), resistance to the sweet potato weevil (*Cylas formicarius*), and tolerance to sweet potato virus disease (SPVD).
- Increased nutritional value focusing on the improvement of the beta-carotene content of sweet potato as part of the Harvest Plus Crop Biofortification Program (HARVESTPLUS, 2004; Nestel *et al.*, 2006). Focusing on cultivars with purple or orange flesh with high levels of anthocyanins (*e.g.* CIP-VITAA Partnership, 2004).
- Taste attributes.
- Processing attributes such as starch quality. New sweet potato lines are being developed having low gelatinization and altered starch structures (Katayama *et al*., 2004, 2006) as a convenient-cooking cultivar.
- Tolerance to abiotic stress including salinity, drought and acid soils.

[1] For additional discussion of appropriate comparators, see the Guideline for the Conduct of Food Safety Assessment of Foods Derived from Recombinant DNA Plants CAC/GL 45/2003 of the Codex Alimentarius Commission (paragraphs 44 and 45).

SECTION II - NUTRIENTS

18. Sweet potato is a staple food source for many indigenous populations in China, Central and South Americas, Ryukyu Islands, Africa, the Caribbean, the Maori people, Hawaiians, and Papua New Guineans. It serves as an important protein source for many world populations (Bovell-Benjamin, 2007) and is an important source of starch and other carbohydrates. The energy value of sweet potato exceeds that of potato, cassava and other known tubers (Janssens, 2001). The carbohydrate content of the storage roots varies from 25% to 30%, while the rest is composed of water (58%-72%). Leaves contain about 3% protein, approximately twice the amount of storage roots (Woolfe, 1992).

19. Sweet potato contains various micro-nutrients. Substantial quantities of vitamin C, moderate quantities of thiamin (vitamin B1), riboflavin (vitamin B2) and niacin, some quantities of panthothenic acid (vitamin B5), pyridoxine (vitamin B6), folic acid and satisfactory quantities of vitamin E are present. Sweet potato also contains some essential minerals and trace elements having especially high quantities of iron. Two other important minerals present are potassium and calcium (Woolfe, 1992). Moderate quantities of zinc, sodium, magnesium and manganese are also present (Antia *et al*., 2006; Suda *et al*., 1999).

20. The major contribution which sweet potato makes to human nutrition is the beta-carotene present in orange-fleshed varieties. Beta-carotene is converted to vitamin A in the human body. Dark-orange varieties can contain up to 20 000 µg beta-carotene per 100 g fresh storage root weight (Woolfe, 1992; Takahata *et al*., 1993; Bovell-Benjamin, 2007; Teow *et al*., 2007). Other crops such as maize, rice and wheat contain very little beta-carotene. Orange-fleshed sweet potato is used in food diversification programs for the alleviation of vitamin A deficiency.

21. A portion (100 g) of sweet potato root may supply the following nutrients required daily for an adult African male (Woolfe, 1992):

- 100% of beta-carotene (dark orange sweet potato)
- 57% of vitamin C
- 6% of thiamin
- 8% of riboflavin
- 3% of niacin
- 6% of folate
- 2-7% of iron

22. Sweet potato leaves have a high value as feed for farm animals with 3 kg of green leaves equivalent to 1 kg of maize with a nutritional value rated at 95%-100% that of maize. Dry leaves have a higher nutritional value when compared with alfalfa hay as forage (Reed, 1976). Dried sweet potato leaves consist of 22% crude protein, 46% crude fibre and 9% total ash. The digestible crude protein is 9% and the total digestible nutrients are 22.4% (Satapathy *et al*., 2006).

23. The nutrient compositions of the sweet potato leaves, roots and processed products as related to proximates, minerals, vitamins, lipids, proteins and some secondary metabolites are presented in Table 3 to Table 10. The refuse values indicated in the tables does not affect the values presented.

Table 3. Proximate composition of raw sweet potato

Nutrient	Storage roots					Leaves		
	With skins	Without skin						
	Raw un-prepared[1]	Raw, frozen un-prepared[2]	Raw[3]	Raw[4]	*Range of mean values – raw without skin*	Raw[5]	Raw[4]	*Range of mean values – raw*
g/100g FW[6]								
Water	77.3	74.9	66.1	68.8–73.3	*66.1–74.9*	88.0	86.7	*86.7–88.0*
g/100g DW[7]								
Protein	6.9	6.8	3.5	3.7–6.1	*3.5–6.8*	33.2	24.1	*24.1–33.2*
Total Fat	0.2	0.7	0.6		*0.6–0.7*	2.5		
Ash	4.4	4.0	2.9	2.6–3.2	*2.6–4.0*	11.3	10.5	*10.5–11.3*
Carbohydrate	88.6	88.5	92.9	91.0–95.0	*88.5–95.0*	53.0	60.2	*53.0–60.2*
Crude Fibre				3.0–3.2	*3.0–3.2*		12.0	*12.0*
Dietary Fibre	13.2	6.8	6.8		*6.8*	16.6		*16.6*
Sugars, total	18.4							
Sucrose	11.1							
Glucose	4.2							
Fructose	3.1							
Starch	55.7							

[1] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11507, Refuse 28% (non-edible parings and trimmings)
[2] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11516, Refuse 0%
[3] Standard Tables of Food Composition in Japan, Fifth Revised and Enlarged Edition (2005)
[4] O'Hair (1984)
[5] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11505, Refuse 6% (tough stems and bruised leaves)
[6] Fresh weight (FW)
[7] Dry weight (DW); for references 1, 2 & 5, values were calculated using reported values for water

Table 4. Proximate composition of processed sweet potato

Nutrient	Storage roots					Leaves
	Baked, frozen, without skin[1]	Boiled, without skin[2]	Cooked[3]	Steamed[4]	Baked[4]	Cooked[5]
g/100g FW[6]						
Moisture	73.7	80.1	72.9	66.4	58.1	88.7
g/100g DW[7]						
Protein	6.5	6.9	6.3	3.6	3.4	20.5
Total fat	0.5	0.7	0.4	0.6	0.5	2.7
Ash	4.1	3.2	0.0	3.0	3.1	12.0
Carbohydrate	89.0	89.2	78.6	92.9	94.0	64.8
Dietary fibre	6.8	12.6	11.1	11.3	8.4	16.81
Sugars total	34.9	28.9				48.0
Sucrose		7.2				
Glucose		2.7				
Fructose		2.2				
Maltose		16.8				
Starch		26.3				

[1] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11507, Refuse 0%
[2] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11510, Refuse 0%
[3] Medical Research Council, South Africa (1998)
[4] Standard Tables of Food Composition in Japan, Fifth Revised and Enlarged Edition (2005)
[5] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11506, Refuse 0%
[6] Fresh weight (FW)
[7] Dry weight (DW) values were calculated using reported values in Table 4 for water

Table 5. Mineral composition of raw sweet potato (per 100 g DW[1])

Mineral (value per 100g)	**Unit**	**Storage roots**					**Leaves Raw[1]**		
		With skin	**Without skin**						
		Raw un-prepared[2]	**Raw, frozen un-prepared[3]**	**Raw[4]**	**Raw[5]**	***Range of mean values - raw without skin***	**Raw[6]**	**Raw[5]**	***Range of mean values***
Calcium	mg	132.0	147.4	118.0	79.0–106.0	*79.0–147.4*	307.3	647.0	*307.3–647*
Iron	mg	2.7	2.1	2.1	3.4–6.4	*2.1–6.4*	8.4	33.8	*8.4–33.8*
Magnesium	mg	110.0	87.6	73.7		*73.7–87.6*	506.6		*506.6*
Phosphorus	mg	206.9	179.2	135.7	142.0–160.0	*135.7–179.2*	780.7	609.0	*609.0–780.7*
Potassium	mg	1483.3	1453.6	1386.4	724.0	*724.0–1453.6*	4302.3		
Sodium	mg	242.1	23.9	11.8	107.0	*11.8–107.0*	74.8		
Zinc	mg	1.3	1.2	0.6		*0.6–1.2*	2.4		
Manganese	mg	1.1	2.7	1.3		*1.3–2.6*	2.1		
Copper	mg	0.7	0.7	0.5		*0.5–0.7*	0.3		
Selenium	mcg	2.6	2.4	-		*2.4*	7.5		

[1] Dry Weight (DW) values were calculated using reported values for water from the respective reference in Table 3
[2] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11507, Refuse 28% (non-edible parings and trimmings)
[3] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11516, Refuse 0%.
[4] Standard Tables of Food Composition in Japan, Fifth Revised and Enlarged Edition (2005)
[5] O'Hair (1984)
[6] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11505, Refuse 6% (tough stems and bruised leaves)

Table 6. Mineral content of processed sweet potato (per 100 g DW[1])

Nutrient	Unit	Storage Roots					Leaves
		Baked frozen without skin[2]	Boiled without skin[2]	Cooked[3]	Steamed[4]	Baked[4]	Cooked[5]
Calcium, Ca	mg	133.1	135.9	103.3	139.9	81.1	212.6
Iron, Fe	mg	2.1	3.6	1.9	1.8	1.7	5.3
Magnesium, Mg	mg	79.8	90.6	73.8	56.6	54.9	540.3
Phosphorus, P	mg	167.3	161.0	203.0	125.0	131.3	531.4
Potassium, K	mg	1433.5	1157.5	1284.1	1458.3	1288.8	4225.0
Sodium, Na	mg	30.4	135.9	36.9	11.9	31.0	115.1
Zinc, Zn	mg	1.1	1.0	1.1	0.6	0.5	2.3
Manganese, Mn	mg	2.5	1.3	-	1.5	0.8	2.0
Copper, Cu	mg	0.7	0.5	-	0.5	0.5	0.3
Selenium, Se	mcg	2.3	1.0	-	-	-	8.0

[1] Dry weight (DW) values were calculated using reported values for water from Table 5 for the respective references
[2] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11510, Refuse 0%
[3] Medical Research Council, South Africa (1998)
[4] Standard Tables of Food Composition in Japan, Fifth Revised and Enlarged Edition (2005)
[5] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11506, Refuse 0%

Table 7. Vitamin composition of raw sweet potato (per 100 g DW[1])

Nutrient (value per 100g)	Unit	Storage roots					Leaves Raw[1]		
		With skins	Without skins						
		Raw un-prepared[2]	Frozen un-prepared[3]	Raw[4]	Raw[5]	*Range*	Raw[6]	Raw[5]	*Range of mean values*
Vitamin c, total	mg	10.56	52.97	29.00	79.00 – 119.00	*29.00–119.00*	91.36	127.80	*91.36–127.80*
Thiamin	mg	0.34	0.27	0.11	0.35	*0.11–0.35*	1.30	0.80	*0.80–1.30*
Riboflavin	mg	0.27	0.20	0.03	0.16	*0.03–0.20*	2.87	1.60	*1.60–2.87*
Niacin	mg	2.45	2.38	0.80	2.40	*0.8–2.38*	9.39	5.30	*5.30–9.39*
Pantothenic acid	mg	3.52	2.05	0.96	-	*0.96–2.05*	1.87	-	
Vitamin B6	mg	0.92	0.70	0.28	-	*0.28–0.70*	1.58	-	
Folate, total	mcg	48.42	83.63	49.00	-	*49.0–83.63*	664.45	-	
Folate, DFE	mcg	48.28	83.63				664.45		
Choline	mg	54.14				-			
Carotene, beta	mcg	37451.58	24771.01						
Carotene, alpha	mcg	30.81				-			
Vitamin A, IU[a]	IU	62 442.78	41 286.34	-	-		8 538.21	-	
Vitamin A, RAE[b]	mcg	3 120.60	2 062.92	-	-		423.59	-	
Vitamin E	mcg	1.14	-	1.60	-		-	-	-
Vitamin K	mcg	7.92	-	-	-	-	-	-	-

[a] IU: International units [b] RAE: retinol activity equivalents

[1] Dry weight (DW) values were calculated using reported values for water from Table 3 for the respective references
[2] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11507, Refuse 28% (non-edible parings and trimmings)
[3] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11516, Refuse 0%
[4] Standard Tables of Food Composition in Japan, Fifth Revised and Enlarged Edition (2005)
[5] O'Hair (1984)
[6] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11505, Refuse 6% (tough stems and bruised leaves)

Table 8. Vitamin composition of processed sweet potato (per 100 g DW[1])

Nutrient	Unit	Storage roots					Leaves
		Baked frozen without skin[2]	Boiled without skin[3]	Cooked[4]	Steamed[5]	Baked[5]	Cooked[6]
Vitamin C, total	mg	34.60	64.42	92.25	59.52	23	13.29
Thiamin	mg	0.25	0.28	0.26	0.30	0.12	0.99
Riboflavin	mg	0.21	0.24	0.48	0.09	0.06	2.36
Niacin	mg	2.11	2.71	2.21	2.08	1.0	8.88
Pantothenic acid	mg	2.13	2.92		2.89	1.30	1.77
Vitamin B6	mg	0.71	0.83	0.89	0.68	0.33	1.42
Folate, total	mcg	83.65	30.20		136.90	47	434.01
Folic acid	mcg	0.00	0.00	84.87		-	0.00
Folate, total	mcg	83.65	30.20			-	434.01
Folate, DFE[a]	mcg	83.65	30.20			-	434.01
Choline	mg	-	54.35				86.01
Carotene, beta	mcg	47520.91	47528.94				4871.57
Carotene, alpha	mcg	178.71	0.00				
Vitamin A, IU[b]	IU	79353.61	79214.90	8051.66		-	8113.37
Vitamin A, RAE[c]	mcg	3965.78	3960.74			-	407.44
Vitamin E	mcg	2.93	4.73		4.46	1.3	8.50
Vitamin K	mcg	9.51	10.57		0.00	0.0	961.91

[a] DFE: dietary folate equivalents [b] IU: International units [c] RAE: retinol activity equivalents

[1] Dry weight (DW) values were calculated using respective reported values for water in Table 4
[2] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11517, Refuse 0%
[3] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11510, Refuse 0%
[4] Medical Research Council, South Africa (1998)
[5] Standard Tables of Food Composition in Japan, Fifth Revised and Enlarged Edition (2005)
[6] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11505, Refuse 6% (tough stems and bruised leaves)

Table 9. Fatty acid composition of sweet potato (per 100 g DW[1])

Fatty Acid	Unit	Storage roots						Leaves	
		With skins	Without skins						
		Raw[2]	Frozen, raw[3]	Raw[4]	*Range of mean values (raw)*	Boiled[5]	Frozen/baked[6]	Raw[7]	Cooked[8]
16:0	g	0.079	0.139	0.068	*0.069–0.139*	0.031	0.084	0.049	0.523
18:0	g	0.004	0.016	0.012	*0.012–0.0162*	0.0	0.011	0.050	0.053
18:1 undifferentiated	g	0.004	0.028	0.006	*0.006–0.028*	0.0	0.019	0.100	0.106
18:2 undifferentiated	g	0.057	0.267	0.150	*0.150–0.267*	0.061	0.160	.0.939	1.001
18:3 undifferentiated	g	0.004	0.052	0.021	*0.021–0.052*	0.0	0.027	0.174	0.186

[1] Dry weight values (DW) were calculated using reported values for water from Tables 3 & 4 for the respective references
[2] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11507, Refuse 28% (non-edible parings and trimmings)
[3] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11516, Refuse 0%
[4] Standard Tables of Food Composition in Japan, Fifth Revised and Enlarged Edition (2005)
[5] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11510, Refuse 0%
[6] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11517, Refuse 0%
[7] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11505, Refuse 6% (tough stems and bruised leaves)
[8] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11506, Refuse 0%

Table 10. Amino acid composition of sweet potato (per 100 g DW[1])

Amino Acid	Unit	Storage roots				Leaves	
		With skins	Without skins				
		Raw[2]	Raw, frozen[3]	Boiled[4]	Baked/frozen[5]	Raw[6]	Cooked[7]
Tryptophan	g	0.136	0.084	0.141	0.08.	0.291	0.177
Threonine	g	0.365	0.339	0.367	0.323		
Isoleucine	g	0.242	0.339	0.242	0.327		
Leucine	g	0.405	0.498	0.408	0.479		
Lysine	g	0.290	0.335	0.292	0.319	1.894	1.169
Methionine	g	0.128	0.167	0.126	0.160	0.714	0.443
Cystine	g	0.097	0.056	0.096	0.053	0.390	0.239
Phenylalanine	g	0.392	0.406	0.393	0.393	-	-
Tyrosine	g	0.150	0.279	0.151	0.266	-	-
Valine	g	0.379	0.446	0.377	0.426	-	-
Arginine	g	0.242	0.315	0.242	0.304	-	-
Histidine	g	0.136	0.127	0.136	0.122	-	-
Alanine	g	0.339	0.370	0.337	0.357	-	-
Aspartic acid	g	1.681	1.163	1.686	1.114	-	-
Glutamic acid	g	0.682	0.665	0.679	0.639	-	-
Glycine	g	0.277	0.307	0.277	0.297	-	-
Proline	g	0.229	0.299	0.232	0.285	-	-
Serine	g	0.387	0.350	0.388	0.338	-	-

[1] Dry weight (DW) values were calculated using reported values for water from Tables 3 & 4 for the respective references
[2] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11507, Refuse 28% (non-edible parings and trimmings)
[3] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11516, Refuse 0%
[4] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11510, Refuse 0%
[5] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11517, Refuse 0%
[6] USDA National Nutrient Database for Standard Reference, Release # 22 (2009, NBD No. 11505, Refuse 6% (Tough stems and bruised leaves)
[7] USDA National Nutrient Database for Standard Reference, Release # 22 (2009), NBD No. 11506, Refuse 0%

SECTION III – OTHER CONSTITUENTS

A. Anti-nutrients

1. Oxalate

24. Oxalate is found in uncooked sweet potato leaves at levels of 73 mg/100 g (Ravindran *et al.,* 1995) to 89 mg/100 g (Lebot, 2009) and levels up to 308 mg/100 g are found in dry matter (Antia *et al*., 2006). A high intake of oxalate reduces the calcium availability, as indicated by the intermediate calcium absorption index of sweet potato roots (0.423 ± 0.0255; Weaver *et al*., 1997). Proper boiling of sweet potato leaves before consumption significantly reduces the total oxalate content (Antia *et al*., 2006) since more than 60% of oxalates are present in water soluble form which leaches out into the water (Holloway *et al.,* 1989). Oxalates, both free and as calcium oxalate, are present in the roots and the total levels are generally similar to those in other root crops (Lebot, 2009; Woolfe, 1992).

2. Trypsin inhibitors

25. The first non-leguminous plant reported to contain a trypsin inhibitor was sweet potato (Sohonie and Bhandarkar, 1954). Strong inhibition of trypsin has been demonstrated *in vitro* and this could indicate interference with protein digestion *in vivo*, thus having nutritional implications in humans (Woolfe, 1992). Since trypsin inhibitors are present in uncooked sweet potato roots this is especially true for those snacking on raw sweet potato. Sporamins, which are the major storage proteins in sweet potato roots, have an inhibiting effect on protein degradation by trypsin and belong to the Kunitz type of trypsin inhibitors, which are also found in various other crops (Shewry, 2003). Trypsin inhibitor activity (TIA) varies considerably between different cultivars. It is suggested that genotypes with high protein content and low TIA, as well as appropriate methods of processing, can improve the utilisation of sweet potato for food as well as feed (Zhang and Corke, 2001). Analysis of 8 sweet potato cultivars and 199 breeding lines indicated the average TIA of the cultivars are 197 U/mg DW (range of 65 to 392 U/mg DW) and the average TIA of the breeding lines are 273 U/mg DW (range of 38 to 944 U/mg DW; Jun *et al*., 2005). Some sweet potato lines of low trypsin inhibitor activity have been bred (Toyama *et al*., 2006). The levels of TIA in sweet potatoes can generally be regarded as low and cooking/microwaving sweet potato tubers at high temperatures (100°C) destroys most TIA (Sasi Kiran and Padmaja, 2003; Ravindran *et al.,* 1995).

3. Polyphenols

26. Sweet potato is a source of polyphenols. These include phenolic acids, such as chlorogenic-, caffeic- and dicaffeoylquinic acids (Padda and Picha, 2007), anthocyanins (cyanidin and peonidin which cause the purple colour found in some sweet potato varieties) (Oki *et al*., 2002) and flavonols such as quercetin and rutin (Guan *et al*., 2006). Polyphenols are known to chelate metals such as iron and zinc and reduce their absorption. Polyphenols may also inhibit some digestive and cellular enzymes (Halliwell, 2007).

4. Phytic acid

27. Phytic acid (myo-inositol 1,2,3,4,5,6-hexakis [dihydrogen phosphate] is present in sweet potato. Phytic acid is estimated to bind 60-75% of the phosphorus in the form of phytate (NAS, 2005). Dilworth *et al*. (2005) found 4.98 X 10^3 mmole/g phytate in uncooked sweet potato roots oven dried at 65°C, and 2.238 X 10^3 mmole/g in cooked roots.

B. Toxicants

28. Sweet potato produces certain metabolites in response to injury and on exposure to infectious agents such as fungi. Some of these metabolites, known as phytoalexins, especially the furano-terpenoids, are known to be toxic (Woolfe, 1992). Fungal contamination of sweet potato roots by *Ceratocystis fimbriata* and several *Fusarium* species, especially *F. solani*, and damage caused by weevils leads sweet potato plants to produce of phytoalexins (Schneider *et al*., 1984), which can also be further converted biochemically by fungi growing on the diseased potato. Phytoalexins produced upon insect damage are produced by the storage roots (Wilson *et al*., 1971), and small amounts can be found in the leaves and stems upon injury (Clark *et al*., 1981). Furano-terpenoids are formed by sweet potato roots in response to stress (*e.g*. mould infection) and then converted to toxic forms by the moulds growing on the roots (Chassy *et al.*, 2008). The furano-terpenoid, 4-ipomeanol (exert cytochrome-P450-mediated toxicity) is produced specifically upon *F. solani* infection and it has been shown to be a major component of “lung oedema factor” (Wilson *et al.*, 1971; Boyd, 1976). The differences among different species of husbandry animals and humans in toxic effects – and target organs – of phytoalexins such as 4-ipomeanol appear to be linked with the differential induction of, and metabolism by, cytochrome P450 isozymes (Lakhanpal *et al.*„ 2001). However, the levels of furano-terpenoids are decreased by baking or cooking and because of the bitter taste of furano-terpenoids, infected sweet potatoes are usually discarded. Levels of furano-terpenoids in non-diseased sweet potatoes may be negligible (Woolfe, 1992).

C. Allergens

29. There have been three reported cases of allergy to sweet potato, with symptoms including generalized urticaria, hypotension, nausea, vomiting and loss of consciousness (Velloso *et al.*, 2004). No other cases have been reported in scientific literature.

D. Other components

1. Raffinose

30. Raffinose is a sugar that is not digested in the upper digestive tract and that is fermented by colon bacteria to yield flatus gases (*e.g*. hydrogen and carbon dioxide; Palmer, 1982). This process is not known to occur in low-sugar cultivars. Therefore, the higher the raffinose content and the sweeter the taste, the higher the probability for flatulence to occur (Martin and Deshpande, 1985). It has been reported that 0.5% of the fresh weight of baked sweet potato consists of raffinose (Palmer, 1982). The level of raffinose depends on the sweet potato cultivar; a study on Taiwanese cultivars indicated that raffinose levels ranged from 0.102% to 1.08% dry weight (Tsou and Yang, 1984).

2. Lutein

31. Sweet potato leaves contain relatively high levels of lutein, a carotenoid. Lutein levels in sweet potato leaves have been found ranging from 0.37 mg/g FW (Ishiguro and Yoshimoto, 2006) to 0.58 mg/g FW (Menelaou *et al.*, 2006).

SECTION IV - SUGGESTED CONSTITUENTS TO BE ANALYSED RELATED TO FOOD USE

32. Sweet potato is an important staple food for large sectors of the world population in the tropics. In many places, sweet potato is a key security food especially during periods when other foods are in short supply (Manrique, 1998). For instance, in Papua New Guinea, sweet potato is the main staple food of the highlands and often supplies 90% of the caloric intake.

33. Although sweet potato is considered to be a low protein food in regions where food is abundant, it serves as an important source of protein in other countries, *e.g.* in East Africa. Protein is evaluated in relationship to its biological value which is markedly influenced by the relative amounts of indispensable (essential) and dispensable (non-essential) amino acids and the form of nitrogen in the diet (WHO, 2007). WHO (2007) and NAS (2005) list the following nine amino acids as indispensable, *i.e.* those having carbon skeletons that cannot be synthesized to meet body needs from simpler molecules: histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. Additionally, NAS (2005) lists six amino acids as "conditionally indispensable", *i.e.* those amino acids requiring a dietary source when endogenous synthesis cannot meet metabolic needs: arginine, cysteine, glutamine, glysine, proline and tyrosine. However, WHO (2007) indicated that the requirement for indispensable amino acids is not an absolute value, and one must consider the total N content of the diet, including the dispensable amino acids particularly at lower levels of N consumption. Worldwide, sweet potato provides significant amounts of carbohydrates, macro-nutrients, as well as substantial quantities of micro-nutrients (Woolfe, 1992). Also potassium and calcium are important minerals to consider for both tubers and leaves. Leaves are a fair source of iron. The vitamins beta-carotene and C are also important. Raw storage roots and leaves also contain trypsin inhibitor and raffinose, two anti-nutrients. Table 11 shows suggested nutritional and compositional parameters to be analysed in sweet potato for food use.

Table 11. Suggested nutritional and compositional parameters to be analysed in sweet potato matrices for food use

Parameter	Storage roots raw	Leaves raw
Moisture [a]	X	X
Crude protein [a]	X	X
Crude fat (ether extractable) [a]	X	X
Ash [a]	X	X
Carbohydrates [b]	X	X
Dietary fibre	X	X
Potassium	X	X
Calcium	X	X
Iron		X
Beta-carotene	X	X
Vitamin C	X	X
Amino acids	X	X
Trypsin inhibitor	X	X
Raffinose	X	X

[a] These components should be measured using a method suitable for the measurement of proximates
[b] Carbohydrates are calculated as follows: 100 - (water + crude protein + total fat + ash) g/100 g fresh weight

SECTION V - SUGGESTED CONSTITUENTS TO BE ANALYSED RELATED TO FEED USE

34. Sweet potato can be fed to all domestic animals, including ruminants and non-ruminants. For instance, in China 40% of sweet potato produced is used as animal feed, in Brazil 35%, and in Madagascar 30% (Woolfe, 1992). Both the roots and leaves can be used in either a fresh or dried form or as silage and fed to cattle. In countries such as China, Japan, and Taiwan where sweet potato is processed into starch and alcohol, their by-products are also used as animal feed.

35. The storage roots serve as a source of energy in animal diets. Peeled sweet potato storage roots can replace up to 75% of maize in the diets of layer chicken without influencing their performance (Agwunobi, 1993). It has been shown that dried sweet potato can replace up to 50% of the maize in pig diets (Dominguez, 1992).

36. Nwokolo (1990) has reviewed the use of sweet potatoes for swine feed and concluded that leaves, stems and roots can be safely fed to swine. Fresh roots contain trypsin inhibitor, which adversely affect swine and thus it is best if sweet potatoes roots are cooked prior to feeding to inactivate the trypsin inhibitor. Cutting and drying fresh roots into chips also improves digestibility and utilization. It has been found that supplementing swine diets containing sweet potato roots with lysine and sulphur amino acid improves the utilization of sweet potatoes.

37. Table 12 shows suggested nutritional and compositional parameters to be analysed in sweet potato for feed use. The constituents of key importance are crude protein, crude fat (ether extractable) ash, carbohydrates, dietary fibre, calcium and phosphorus[2]. Although there are twenty primary amino acids that occur in proteins, only ten or eleven are recognized as essential, *i.e.* a need has been shown to be supplied by the diet (NAS, 2005). According to NAS (2005), the essential amino acids for swine include arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, tryptophan, valine and threonine. There is also a requirement for cystine and tyrosine, but these amino acids can be synthesized from methionine and phenylalanine, respectively. Amino acid content is also important, especially in swine and poultry diets. NAS (2005) lists the same amino acids as essential for poultry, with the addition of lysine.

38. In cattle and sheep, where microbial protein from the rumen has been considered the primary protein source for the animal, there is increased interest in proteins that escape rumen fermentation, particularly in high producing dairy cattle. Thus, nutritionists are taking a closer look at the potential for cattle to also have certain limiting amino acids. Methionine, lysine, phenylalanine, and threonine have been suggested as being limiting amino acids for cattle.

39. Calcium and phosphorus are major minerals in animal feed and should be measured. For swine and poultry, trypsin inhibitor and phytic acid are also important. Oxalate may also be a compound of interest as it also binds minerals making them unavailable for digestion by the animal (Almazan, 1995).

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[2] Analysis of acid detergent fibre (ADF) and neutral detergent fibre (NDF) in sweet potato may be relevant to ruminant nutrition.

Table 12. Suggested nutritional and compositional parameters to be analysed in sweet potato matrices for feed use

Parameter	Storage root raw	Leaves raw
Moisture [a]	X	X
Crude protein [a]	X	X
Crude fat (ether extractable) [a]	X	X
Ash [a]	X	X
Carbohydrates [b]	X	X
Dietary fibre	X	X
Calcium	X	X
Phosphorus	X	X
Amino acids	X	X
Oxalate		X
Trypsin inhibitor	X	

[a] These components should be measured using a method suitable for the measurement of proximates
[b] Carbohydrates are calculated as follows: 100 - (water + crude protein + total fat + ash) g/100 g fresh weight

SECTION VI - REFERENCES

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