Journal of Food Composition and Analysis 23 (2010) 486–498

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Critical Review

Linking biodiversity, food and nutrition: The importance of plant identification and nomenclature

Mark Nesbitt [a,*], Rory P.H. McBurney [a,b], Melanie Broin [c], Henk J. Beentje [a]

[a] *Royal Botanic Gardens, Kew, Richmond, Surrey TW9 3AB, United Kingdom*
[b] *Centre for Biocultural Diversity, Department of Anthropology, Marlowe Building, University of Kent, Canterbury CT2 7NR, United Kingdom*
[c] *Moringanews Network, 11 rue du Faubourg Saint Antoine, 75011 Paris, France*

A R T I C L E I N F O

Article history:
Received 28 March 2008
Received in revised form 20 March 2009
Accepted 25 March 2009

Keywords:
Standards
Food composition
Plant identification
Plant nomenclature
Voucher specimens
Methodology
Taxonomy
Botany
Ethnobotany
Biodiversity
Nutrition

A B S T R A C T

The use of biodiversity for food and nutrition requires accurate, reliable and accessible food composition data. It is essential for users of such data to be certain of the reliability of identification and naming of food plants, which is particularly problematic for lesser-known wild or locally cultivated plants. The aims of this paper are to assess the reliability and quality of botanical information in papers citing quantitative food composition data of wild and locally cultivated species and to make recommendations for minimum standards in publishing botanical information with food composition data. We developed a framework for evaluating sample plant identification and nomenclature, and surveyed 50 papers referring to 502 species sampled ('sample plants'), each associated with one or more nutritional data. We also tested whether or not a botanist was involved in the identification of 'difficult to identify' species. Of 502 sample plants, only 36 followed best practice for plant identification, and 37 followed best practice for plant nomenclature. Overall, 27% of sample plants were listed with names that are not in current use, or are incorrectly spelt, or both. Only 159 sample plants would have been found from a database search of citations and abstracts. Considering the need for food composition data from wild and locally cultivated food species, and the cost of analysis, researchers must identify, name and publish species correctly. Drawing on the fields of ethnobotany and ethnopharmacology, comprehensive recommendations are given for best practice.

1. Introduction

Over the past two decades, there has been an increased recognition of the importance of wild or locally cultivated food plants as sources of micronutrients and plant secondary metabolites (Scoones et al., 1992). More recently, the role of these biologically diverse species in maintaining human and environmental health has been highlighted, particularly in relation to global food security, sustainable development and the United Nations Millennium Development Goals (Frison et al., 2006; Johns and Eyzaguirre, 2006). The generation and review of food composition data from wild or locally cultivated food species is fundamental to the elements and activities of the global 'Cross-Cutting Initiative on Biodiversity for Food and Nutrition' within the framework of the United Nations Convention on Biological Diversity (Convention on Biological Diversity, 2006).

Determining the nutritional value of wild or locally cultivated food species not covered in national food tables commences with a literature review, and if necessary, continues with fieldwork and laboratory studies to generate new data. It culminates with the publication of food composition data and its inclusion into new or revised food tables.

In an earlier study of a single species widely used for food in Africa, the horseradish (or drumstick) tree, *Moringa oleifera* Lam., it became clear that missing, outdated or misspelt botanical names made it difficult to find published nutritional values (McBurney et al., 2004). In light of this, we have reviewed all the botanical names in 50 of the journal articles (the survey papers, see Appendix A) examined in McBurney et al. (2004). These present original food composition data from locally used, mainly wild, species. We found worrying deficiencies in the identification and naming of plant species.

In this paper we review appropriate procedures for recording plant species, drawing on best practice in botanical and ethnobotanical fieldwork, and test compliance with these in published literature on food composition. We also assess the potential impact of non-compliance, and set out simple, easy-to-follow guidelines for botanical fieldwork in food composition

* Corresponding author. Tel.: +44 20 8332 5386; fax: +44 20 8332 3717.
E-mail address: m.nesbitt@kew.org (M. Nesbitt).

0889-1575/$ – see front matter © 2009 Elsevier Inc. All rights reserved.
doi:10.1016/j.jfca.2009.03.001

projects. Although we draw on examples from species used in tropical Africa, a focus of work at the Royal Botanic Gardens, Kew, the lessons from this study are applicable worldwide.

2. The importance of plant names

It is widely accepted that any study of plants that aims to draw on scientific literature, or which aims to put new data into the public domain, must use botanical names. These are binomials, consisting of the Latin genus and species, and must conform to the *International Code of Botanical Nomenclature*. A botanical name is a unique identifier or 'plant passport' to which information can be attached, therefore enabling the movement of data across languages, scientific disciplines, and electronic retrieval systems. When used correctly, botanical names are unambiguous.

Wild or locally cultivated food species present special challenges in identification and naming. They may be less familiar to researchers than major crop plants. Taxa with very different culinary and nutritional properties may look very similar. Furthermore, wild or locally cultivated species tend to be most commonly used in poorer and/or isolated regions which have been studied less by botanists.

The use of common (vernacular) names is no substitute for the botanical identification of a plant. A plant may have several different local names, or one name may be used to describe different species with similar uses or taste. For example, the *Traditional Food Plants of Kenya* (Maundu et al., 1999) gives approximately 3800 common names, of which 10% are used for two or more species, and 2% for species in different genera. Some examples are 'Indian plum' which can be used for *Flacourtia indica* (Burm. f.) Merr. or *Ziziphus mauritiana* Lam. (Maundu et al., 1999: 14) and 'Enkasijoi' in Maasai, which can refer to two *Rumex* species, or to *Oxygonum sinuatum* (Meisn.) Dammer (Maundu et al., 1999: 24). In another example, the book *Kenya trees, shrubs and lianas* gives about 5400 local names, of which 12% are used for more than one species (Beentje, 1994). For example, 'Ochol' in Luo can be used for five different species, each in a different genus: *Diospyros abyssinica* (Hiern) F. White, *Lepisanthes senegalensis* (Poir.) Leenh., *Mystroxylon aethiopicum* (Thunb.) Loes., *Pseudospondias microcarpa* Engl. and *Schrebera alata* (Hochst.) Welw. 'Mgunga' in Swahili can mean any of seven species of Acacia: *Acaca etbaica* Schweinf., *A. nilotica* (L.) Del., *A. robusta* Burch., *A. senegal* (L.) Willd., *A. seyal* Del., *A. stuhlmannii* Taub. and *A. tortilis* (Forssk.) Hayne.

There are many instances of botanical research of limited usefulness because species were not identified correctly, and voucher specimens not accessioned (Barkworth and Jacobs, 2001). For example, in the field of plant chromosome counts, it has been suggested that half of the many thousands of chromosome counts published prior to 1965 are based on questionable identifications. Owing to the lack of voucher specimens, these cannot now be verified (Goldblatt et al., 1992).

At first sight, this may appear a daunting list of difficulties. However, the same problems are experienced by ethnobotanists and ethnopharmacologists who study the medicinal properties and uses of species. These two disciplines have well-established field procedures and publication standards that resolve these problems. In the next section, we review current practice in these disciplines to create a model of best practice against which published food composition literature can be tested. We distinguish among: *identification*—working out to which taxon (typically a species or infra-specific entity) a plant belongs; *nomenclature*—use of a botanical name currently accepted by botanists; and *publication*—publishing the plant name prominently in the abstract, title or keywords so that other researchers can find data associated with it.

3. Rationale for botanical methodology

3.1. Plant identification

3.1.1. The role of the botanist

Plant identification depends on the work of taxonomists, often based in herbaria, who publish Floras and checklists. A herbarium is in essence a library of dried, pressed plants, against which newly collected, unknown plants can be compared. A Flora is a written account of plants from a particular region or country, including identification keys, and is compiled using specialist botanical expertise and herbarium specimens. Shorter versions of Floras may be published as field guides or without guidance on identification as checklists. *Both* herbarium specimens and Floras have an essential role in identification of difficult plants by botanists. Use of herbaria and identification manuals requires a specialist understanding of plant morphology and relationships acquired by botanists during many years of training and experience (Smith, 2006).

Standard practice in ethnobotany is to form working relationships with botanists familiar with the region under study, usually before fieldwork begins (Cotton, 1996: 114; Martin, 1995: 6). This is reflected in the instructions for authors for the *Journal of Ethnopharmacology*, in which the person responsible for identifying any plant species researched must be named. Some researchers argue that botanists are only required for 'difficult to identify' species; we discuss this later (Section 4.6).

Because of the need for specialist skills in plant identification, we would expect the participation of a *botanist* or *botanical institution* in the publication of food composition data of all plants sampled, except perhaps the best-known wild and cultivated species.

3.1.2. The role of voucher/herbarium specimens

A voucher specimen is usually a herbarium specimen gathered during fieldwork. Their collection is standard practice in botany and ethnobotany, followed by deposition in one or more herbaria, usually including a national herbarium.

Collection of a voucher specimen of a researched plant is important for two reasons. First, it increases the security of the initial identification, because the specimen can be identified at leisure, by comparison to other herbarium specimens. Difficult material can be sent on to specialists. Secondly, if at a later date the identification is questioned, or the definition of a species changes, the original plant can be re-examined, and its identity confirmed or updated. This is likely to arise in the case of lesser-known plant species, as their taxonomy has not been fully explored. In the homogeneous food systems of the developed world, where industrialisation has reduced the diversity of foods at the intra-species level, voucher specimens may be less important for major crop plants. Voucher specimens also have a less obvious importance: they can be a source of plant material for new analyses in future years, such as secondary metabolites (Jiang et al., 2005) or environmental pollutants (Penuelas and Filella, 2002).

Herbarium specimens have been an essential component of taxonomic botany for several hundred years, but it is only in the last two decades that their importance to plant sciences other than taxonomy has been appreciated. Calls have been made for voucher specimens in plant genetics (Goldblatt et al., 1992), plant conservation (Snow and Keating, 1999), ethnopharmacology (Hedberg, 1993) and ethnobotany (Bye, 1986; Cotton, 1996: 113–118; Martin, 1995: 28–39). Voucher specimens are also vital to mycology (Agerer et al., 2000) and zoology. The importance of voucher specimens is reflected in the fact that three leading journals in ethnobotany and two in the related field of phytochemistry (*Economic Botany*, *Journal of Ethnobiology*, *Journal of Ethnopharmacology*, *Phytochemistry*, *Journal of Natural Products*) all require the collection of voucher specimens, their deposition in a herbarium, and citation in publication, at least for lesser-known species. As a considerable number of their articles deal with chemical analysis of plants, we can draw parallels with the generation of food composition data and the papers we are investigating.

We would expect that a *voucher specimen* is collected, prepared and deposited in a *named herbarium*.

3.2. Plant names

3.2.1. Genus and species

The botanical (scientific) names of plants are based on the Latin binomial system established in the 18th century by the Swedish botanist, Linnaeus. Binomials are composed of genus (capitalised) and species (never capitalised). These terms are formally known as the generic name and specific epithet (Jeffrey, 1982), and together they form a unique identifier for a plant species when combined with an author name. For example, the botanical name of ginger is *Zingiber officinale* Roscoe. *Zingiber* is the genus; *officinale* is the species epithet, and Roscoe the author of this botanical name. A species may be divided into subspecies or varieties (the lowest formal rank). A botanical name may therefore comprise up to four elements: genus, species, subspecies and variety; two elements (genus and species) are essential, and subspecies and/or variety are sometimes added. Botanical names are cited in italics.

Distinct forms of cultivated plants may bear an additional formal name: a cultivar name appended to the main botanical name, for example *Taxus baccata* L. 'Variegata' or *Taxus baccata* L. cv. Variegata. Cultivar names were not assessed in our study.

We would expect publication of a plant name to include at least its *genus* and *species*.

3.2.2. Author name

The name of the original author of a plant name is placed after the genus and species. For example, the species '*Moringa oleifera*' was first named by Jean-Baptiste Lamarck, whose name is abbreviated to 'Lam.'. Therefore the full plant name is: '*Moringa oleifera* Lam.'. The use of author names in routine publication of plant names has been criticised (Boa, 2000; Garnock-Jones and Webb, 1996), but they are vitally important in differentiating between homonyms, where one plant name has been ascribed to two distinctly different plant species. Unless the source of plant names used in a paper are fully referenced and made clear to the reader, for example by citation of the published source from which they are drawn, author names will be needed for clarification.

We would therefore expect that either the *author name* or *source of name* (i.e. Flora, field guide or checklist) is given in the publication, and where given, the author name is correct.

3.2.3. Accepted names and synonyms

Although botanical names are far less ambiguous than common names, they do not form an entirely stable system of nomenclature. The botanical name used for a plant species 50 years ago may not be currently accepted, even if identity of the species has not changed. There are three reasons for this:

- *Botanical history*. Since 1906 the botanical names of plants have been governed by the *International Code of Botanical Nomenclature* (ICBN). Names that are found to be in contravention of the code must be changed, except in certain special cases. Most commonly this occurs when an earlier application of a different name is found; that name must be used. Recent provisions (since 1981) have allowed for continued use of some names found to be incorrect, but some names continue to be changed for these procedural reasons.
- *Plant systematics (the study of how plants are related to each other)*. A species previously placed in one genus may be moved to another, because of new evidence (or a different scientific opinion) that shows it to be more closely related to the other species in the second genus. When this occurs, the generic name and, sometimes, the specific epithet will change. For example, although the botanical name *Cassia senna* L. is still widely used, many species from the genus *Cassia* have now been placed in the genus *Senna* for reasons of evolutionary relationships. This species, the senna pod of pharmacy, was transferred to *Senna* in 1982; because the combination *Senna senna* is not allowed under the rules of the ICBN, the 'new' name for this species is *Senna alexandrina* Mill. In another example, the citrus fruit lime was known as *Limonia aurantiifolia* Christm. up to 1913, when Swingle placed it in the genus *Citrus*: since then it is known as *Citrus aurantiifolia* (Christm.) Swingle.
- *Changing circumscription (boundaries) of a taxon*. For example, two species regarded as distinct may be found to be one species; in this case, one botanical name will be discarded by following the rules of the ICBN. Alternatively a species (or genus, subspecies, etc.) may be found to contain distinct entities and need to be split, creating new taxa.

The result of 250 years of taxonomic endeavour is that a given species is very likely to have been assigned more than one botanical name since it was first identified. Within any given taxonomic scheme such as a Flora, only one name will be *accepted*. Other names previously applied to that species are termed *synonyms*. Some synonyms will be rejected because they are inadmissible under the terms of the ICBN; others will be rejected because they embody a different view of the evolutionary relationships of the species. Because an accepted name is only 'accepted' within the context of a particular taxonomic treatment, it is possible for a plant to have more than one accepted name in general use. For example, the almond nut is known in different taxonomic treatments as *Prunus dulcis* (Mill.) D. A. Webb, *Prunus amygdalus* Batsch and *Amygdalus communis* L. The sources for accepted names include published regional Floras and checklists and, increasingly, global checklists.

We would expect that *botanical names* used were *accepted*, in other words used in a Flora or global checklist current at the time of publication, whether published or online.

3.2.4. Spelling

As botanical names are in Latin, they may be unfamiliar to non-taxonomists. This very often leads to spelling errors which are preserved by most electronic retrieval systems. Using a misspelt (or out-of-date) botanical name in a bibliographic or food composition database will result in a failure to retrieve relevant data. Although expert users may be able to compensate by correcting spelling and cross-referencing out-of-date names (McBurney et al., 2004), this is a time-consuming process that requires skill (cf. Table 8).

We would therefore expect the *correct spelling* of botanical names.

3.3. Keywording of plant names

An important attribute of up-to-date, correctly spelt plant names is their role in searches of bibliographic databases such as *CAB Abstracts*, *Web of Science* and *Food Science and Technology Abstracts*. To be found, the plant name, acting as the 'passport' for scientific information, must be present in the title, abstract, or keywords of the publication. With the increasing sophistication of bibliographic databases and full-text searching, this will become less important for future publications. However, there is already a vast amount of information published, with only the title, abstract, and keywords available electronically. The rest of the article may still be available only as a hard copy.

We would expect correctly spelt *botanical* names of all plant species studied to be published in the title, abstract, or keywords of papers.

4. Methodology: assessment of published research

4.1. Development of evaluation flowchart

We developed a flow chart (Fig. 1) and associated list of definitions (Table 1), for evaluating plant identification, nomenclature, and availability in citation databases. This was based on the rationale discussed above. Evaluation begins in double-edged boxes, and ends in one of three categories for stage 1 (plant identification), five categories for stage 2 (plant nomenclature), and four categories for stage 3 (publication).

4.2. Selection of scientific papers for evaluation

Fifty peer-reviewed scientific journal papers, containing quantitative food composition data with value and scale (a quantitative measure and a clear unit of measurement), were taken from 94 papers found in a previous review of 20 wild or locally cultivated food plants eaten in Ethiopia (McBurney et al.,

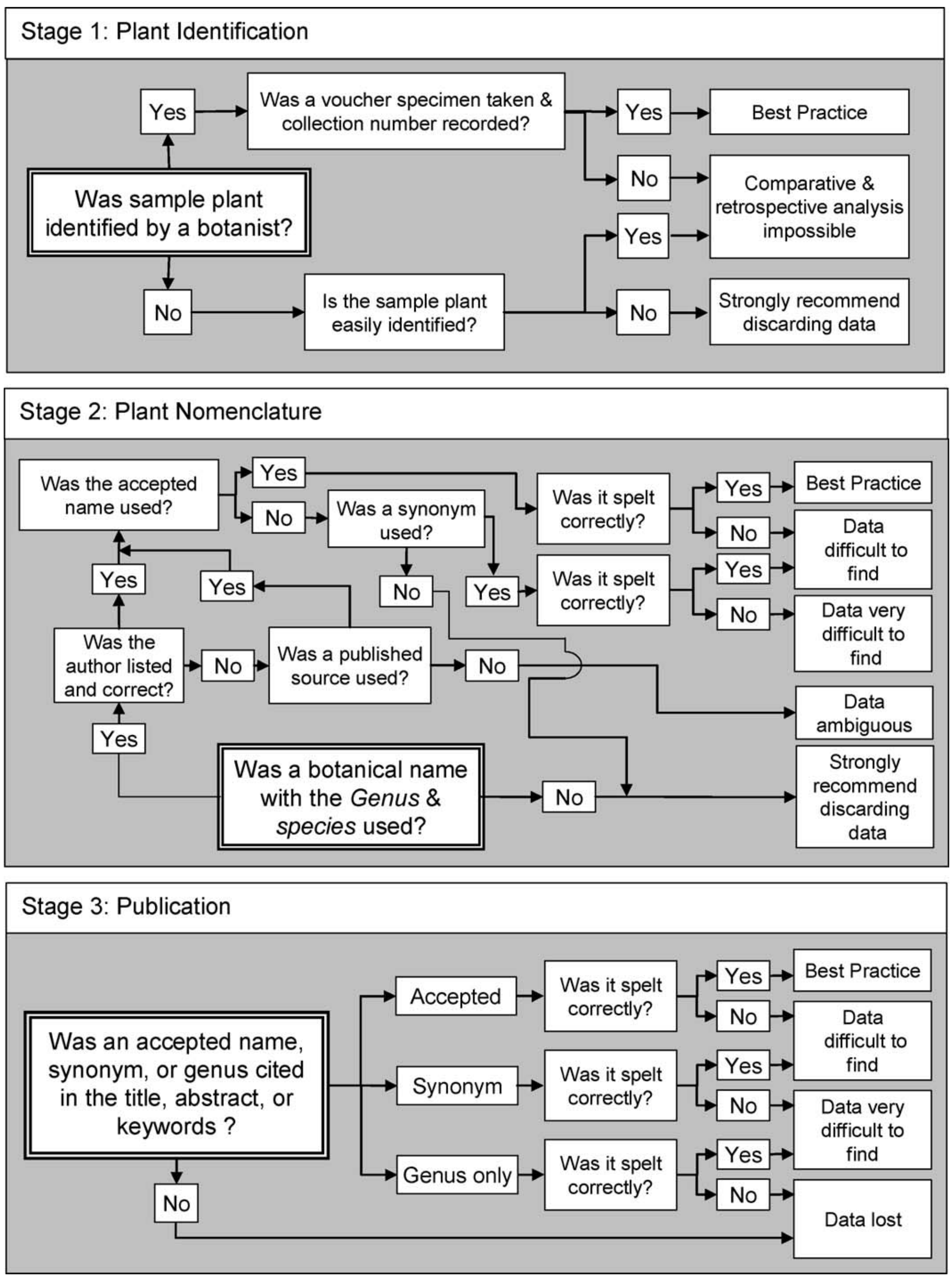

Fig. 1. Flow chart for identification, nomenclature, and publication evaluation.

Table 1
Definitions for plant identification, nomenclature and publication evaluations.

Stage 1: Plant identification

Was the sample plant identified by a botanist?
- YES: *Botanists* (defined broadly to include agronomists, foresters and horticulturalists); *Suppliers* (where the plant came from an institution such as a genebank or commercial nursery).
- NO: *Non-botanists* (persons appearing not to be fully trained botanists); *None* (no mention of the identifier).

Is the sample plant easily identified?[a]
- YES: If an experienced botanist felt able to identify both the genus and species of the sample plant, in the field, without the help of a Flora.
- NO: If an experienced botanist could not identify the genus and species of the sample plant, without a voucher specimen and Flora.

Was a voucher specimen taken and collection number recorded?[b]
- YES: *Voucher specimen*: Collection of a botanical voucher specimen and deposition in a permanent, named depository; *Collection number*: was a collection number given, or in the case of material obtained from an institute, accession number or (in the case of newly-bred cultivars) plant breeding number?
- NO: *Neither of the above.*

Stage 2: Plant nomenclature definitions

Was a botanical name used?
- YES: if a complete botanical name (genus and species) was used.
- NO: if the plant name was incomplete (lacking species) or was not a botanical name (not named, or only a common (vernacular) name).

Was the author listed and correct?
- YES: if a correct author for that plant name was listed.
- NO: if a correct author was not listed.

Was a published source used?
- YES: if the botanical name was cited from a named published source.
- NO: if the botanical name was not cited from a named published source.

Was an accepted botanical name used?
- YES: If the name was accepted by the published source mentioned above, or one of the Floras or online databases listed in Table 2.
- NO: if the named published source was not considered reliable, or if the name was not accepted in any of the sources in Table 2.

Was a synonym used?
- YES: If a non-accepted name could be traced in either the International Plant Names Index, or another reliable source of plant names.
- NO: if the plant name could not be found in any reliable botanical publication.

Was it (the name) spelt correctly?[c]
- YES: If the genus and species was spelt exactly as in one or more of the the published sources in which it appeared, either as an accepted name or synonym.
- NO: if there was any deviation from the spellings that could be traced in one of the published sources (Table 2).

Stage 3: Publication

Was an accepted name, synonym, or genus for the sample plant cited in the title, abstract, or keywords?
- ACCEPTED: If the name was accepted by the published source mentioned above, or one of the Floras or online databases listed in Table 2.
- SYNONYM: If a non-accepted name could be traced in the International Plant Names Index or another reliable source of plant names.
- GENUS ONLY: If the genus name of an accepted name or synonym was cited.

Was the name spelled correctly?
- YES: If it was spelt as in one or more of the published sources, whether as an accepted name or synonym.
- NO: if there was any deviation from the published spellings.

[a] The experienced field ethnobotanist Patrick Maundu was asked: could you identify the genus and species of this sample plant, in the field without the aid of a field guide, or Flora. He answered yes or no.
[b] Both a collection number and herbarium name are needed to subsequently locate a voucher specimen. Collection of temporary specimens during fieldwork was not considered collection of a voucher specimen.
[c] Spellings were assessed regardless of whether the name was accepted or a synonym.

2004). All of the 50 articles are listed in either: *CAB Abstracts*; *Scientific Citation Index*/ISI; BIOSIS/*Biological Abstracts*; or *Medline*, and are in Appendix A, numbered 1–50. The 44 papers not used from the previous work had nutritional data without value or scale, or were missing a plant name completely.

4.3. The sample plant and extraction of plant names from papers

The ‘sample plant’ is the species (or other taxon) from which the sample which was chemically analysed was taken, and to which the nutritional value in the paper refers. Thus the term ‘sample plant’ refers to each species chemically analysed in a paper. Sample plant names for evaluation were drawn from the first table in the paper which contained quantitative (value *and* scale) food composition data or, if the data were not tabulated, from the plant’s first mention in the text in association with quantitative food composition data. If the name associated with the nutritional values was not a botanical binomial, then this was looked for elsewhere in the text. If found, then it was used, otherwise the original non-botanical name associated with the sample plant was used. These rules were devised because a particular plant name may be listed more than once within a paper. Where the main text of a paper was in a language other than English, the main (non-English) version was used by a native speaker.

For this study we focus on seed plants, thus excluding plant groups such as mosses (bryophytes) and ferns.

4.4. Evaluation of scientific papers

Each sample plant name cited in the manuscript was evaluated according to the flow chart (Fig. 1) and criteria (Table 1) using an MS Access database. Data were checked in MS Excel, and converted to SPSS 14.0 for the analyses reported here.

4.5. Accepted names and synonyms

Acceptance of an extracted name associated with a sample plant was checked in a number of regional Floras and online resources (Table 2). If an extracted name was accepted in any of these resources, we treated it as accepted for the purposes of this study (except in two cases discussed below). This is an inclusive approach that allows for the facts that authors of the survey papers may not have had access to the most up-to-date sources. The synonyms used in the survey papers are listed in Table 3.

Table 2
Selected sources for accepted plant names.

Source	Description
African Flowering Plant database URL: www.ville-ge.ch/cjb/bd/africa	Comprehensive list of accepted names for all higher African plants; available in English and French versions, compiled by South African National Biodiversity Institute, Conservatoire et Jardin Botanique de Geneve & Tela Botanica. Online since 2007.
FTEA (Flora of Tropical East Africa) Not available online	Covers the flowering plants and ferns native and naturalised in Kenya, Tanzania and Uganda; 1952–, about 80% complete in 2007.
FWTA (Flora of West Tropical Africa) Not available online	Covers the flowering plants of West Africa, including Burkina Faso, Ivory Coast and Nigeria, and substantial parts of Mali, Niger and Cameroon; 1954–1972.
FZ (Flora Zambesiaca) URL: www.kew.org/efloras/	Covers native and naturalised plants of the Zambezi River basin, covering the territories of Botswana, Malawi, Mozambique, Zambia, Zimbabwe and the Caprivi Strip; 1960–, about 60% complete in 2007. Online since 2003.
GRIN (Germplasm Resources Information Network) URL: www.ars-grin.gov/cgi-bin/npgs/html/index.pl	Covers 36,000 economically relevant species, compiled by the United States Department of Agriculture. Also published as Wiersema, J.H., León, B., 1999. World Economic Plants: A Standard Reference. CRC Press, Boca Raton, Florida (online since 1994).
ILDIS (International Legume Database & Information Service) URL: www.ildis.org	Covers almost all members of the Fabaceae (Leguminosae) family. Online since 1997.
Mansfeld (Mansfeld's World Database of Agricultural & Horticultural Crops) URL: mansfeld.ipk-gatersleben.de/	6000 economically important species, compiled by the Institut für Pflanzengenetik und Kulturpflanzenforchung, Gatersleben. Also published as Hanelt, P. (Ed.), 2001. Mansfeld's Encyclopedia of Agricultural and Horticultural Crops (Except Ornamentals). Springer, Berlin (online since 2001).
World Checklist of Selected Plant Families URL: www.kew.org/wcsp/	Global checklist of accepted plant names from the Royal Botanic Gardens, Kew. At an early stage in 2007.
World Checklist of Monocotyledons URL: www.kew.org/wcsp/monocots	Near-comprehensive global checklist of plant names for palms, orchids and other monocot families from the Royal Botanic Gardens, Kew.

Two names that are accepted in the *Flora of West Tropical Africa* (FWTA) were nonetheless treated as synonyms, *Fagara zanthoxyloides* and *Pennisetum americanum* (Table 3). *Fagara zanthoxyloides* Lam. is accepted in a 1958 volume of FWTA, but has been widely known as *Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler since the publication of a paper by Zepernick and Timler (1981). *Pennisetum americanum* (L.) K. Schum. is accepted in a 1972 volume of FWTA, but this important crop plant, pearl millet, has been widely known as *P. glaucum* (L.) R. Br. since the early 1980s, following the clarification of the early naming of this species (Clayton and Renvoize, 1982: 672). Given that the survey papers were published between 1991 and 2002, it is reasonable to expect that the 'new' accepted names would be used.

4.6. 'Difficult to identify' plant species, and testing the need for a botanist

Some researchers would argue that a botanist is needed only for plants that are 'difficult to identify'. We would therefore expect that 'difficult to identify' plants from our 50 research papers would have been identified by a botanist. For it to hold true, non-botanists *must* be able to differentiate between the 'difficult to identify' and 'easy to identify'. This is *without* the assistance of a botanist.

For us to test what is 'difficult' or 'easy' from the perspective of botanists and researchers would require a panel of expert botanists, and tests of the identification ability of researchers. Cost and logistical constraints prohibit this, so a proxy indicator was used—the ability of an experienced East African botanist.

4.6.1. Exclusions

Sample plants with exclusively common, or incomplete, botanical names were excluded in stage 2 question 1.

4.6.2. Determining 'difficult to identify'

Patrick Maundu, an East African botanist with an interest in wild and locally cultivated food plant species, was asked the following question of each of the sample plants: 'Could you identify the genus and species of this sample plant, in the field, without the aid of a field guide or Flora?' ($n = 467$). The inverse of this was used as 'difficult to identify'.

4.6.3. Determining 'identified by a botanist'

In defining a 'botanist' we took a broad approach and included those with plant identification skills in the disciplines of agronomy, horticulture and forestry. We also considered gene-banks and commercial nurseries as 'botanists'.

Table 3
Use of synonyms as botanical names in the survey papers; abbreviations refer to Table 2.

Synonym	Accepted name	Flora/checklist accepting synonym	Ref.
Butyrospermum parkii	*Vitellaria paradoxa* C.F. Gaertn. subsp. *paradoxa*	FWTA (1963)	16, 20, 47
Fagara zanthoxyloides	*Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler	FWTA (1958)	47
Heliotropium somalense	*Heliotropium longiflorum* (A. DC.) Jaub & Spach var. *stenophyllum* O. Schwartz	FTEA (1991)	36
Hibiscus esculentus	*Abelmoschus esculentus* (L.) Moench	FWTA (1958)	9, 11, 12, 20 (×2), 47
Hyphaene ventricosa	*Hyphaene petersiana* Klotzsch ex Mart.	FTEA (1986)	44
Momordica tuberosa	*Momordica cymbalaria* Hook. f.	FTEA (1967)	41
Moringa pterygosperma	*Moringa oleifera* Lam.	Only very old ones (pre-1900)	22
Pennisetum americanum	*Pennisetum glaucum* (L.) R. Br.	FWTA (1972) FTEA (1982)	20, 47
Salacia owabiensis	*Salacia pyriformis* (Sabine) Steud.	Only very old ones (pre- 1900)	21
Sorghum vulgare	*Sorghum bicolor* (L.) Moench	Only very old ones (pre- 1900)	20, 47

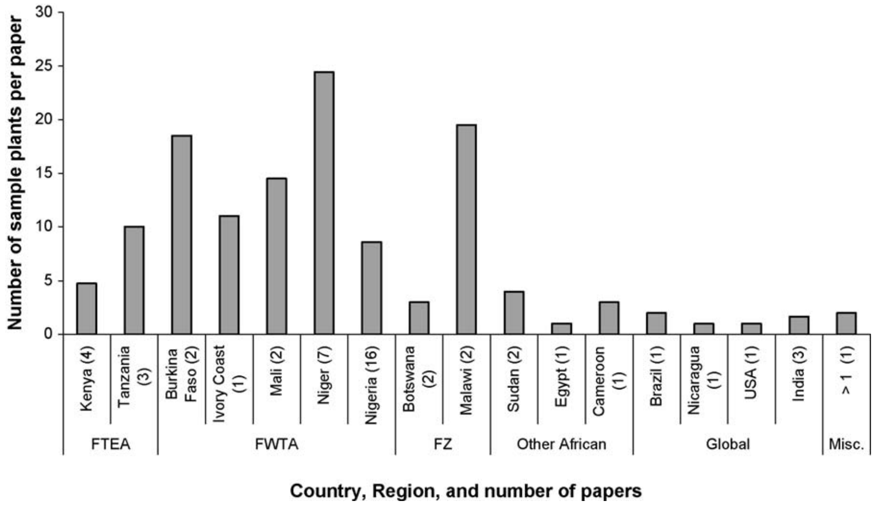

Fig. 2. Origin of sample plants by country and botanical region. Regions are as covered by published floras; abbreviations refer to Table 2.

4.6.4. Statistical testing

Using the *G*-test for independence (Sokal and Rohlf, 1995) we tested the null hypothesis that: 'identified by a botanist' was *independent* of 'difficulty of identification'.

5. Results and discussion

5.1. Descriptive statistics

Fifty peer-reviewed, published scientific papers contained 502 sample plants which were analysed for food composition data. These 502 sample plants represent 222 different plant species, with *Adansonia digitata* L., the baobab tree, being the most frequent. Most food composition data were based on sample plants from our geographical area of interest, tropical Africa, with 23 out of 502 sample plants from North Africa and the rest of the world (Fig. 2). One paper had sample plants from more than one country and region. Two-thirds of papers had 10 or fewer sample plants (Fig. 3), but 2 papers reporting work in Niger contained more than 30 sample plants each.

5.2. Stage 1: Plant identification

Data for only 36 out of the 502 sample plants were published following best practice, with identification by a named botanist or supplier, and a voucher specimen accessioned for material not obtained from a genebank or similar supplier (Table 4). Although a further 96 sample plants were described as identified by a botanist, comparative or retrospective analysis would not be possible, as no voucher specimens were accessioned. Where a voucher specimen or named botanist has not been cited in the text, this places the onus on the end users of the data to decide if a plant has been reliably identified. They must assess the botanical skill of the research team and the distinctiveness of the sample plant.

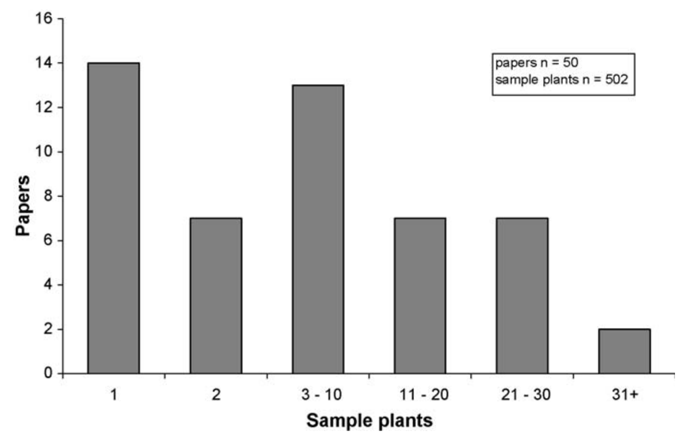

Fig. 3. Sample plants per paper.

Table 4
Results for analysis of plant identification.

Stage 1						
	Question?		Papers	No. of papers	Sample plants	Evaluation (in bold)
1	Was the sample plant identified by a botanist?	YES	5, 7, 11, 14, 18, 25, 26, 30, 31, 32, 35, 37, 38, 42, 43, 44, 49, 50	18	**132**	Go to 2
		NO	1, 2, 3, 4, 6, 8, 9, 10, 12, 13, 15, 16, 17, 19, 20, 21, 22, 23, 24, 27, 28, 29, 33, 34, 36, 39, 40, 41, 45, 46, 47, 48	32	**370**	Go to 3
2	Was a voucher specimen taken and the collection number recorded?	YES[a]	5, 7, 25, 26, 30, 31, 49, 50	8	**36**	**BEST PRACTICE**
		NO	11, 14, 18, 32, 35, 37, 38, 42, 43, 44	10	**96**	**Comparative & retrospective analysis impossible**
3	Is the sample plant easily identified?	YES	All yes: 2, 4, 6, 10, 12, 13, 19, 23, 29, 33, 34, 40, 45, 46. Some yes: 1, 3, 8, 9, 15, 16, 17, 20, 21, 22, 27, 28, 36, 39, 41, 47, 48	14 pure 17 mix Total	**(55)** **(232)** **287**	
		NO	All no: 24. Some no: 1, 3, 8, 9, 15, 16, 17, 20, 21, 22, 27, 28, 36, 39, 41, 47, 48	1 pure 17 mix Total	**(1)** **(82)** **83**	**Strongly recommend discarding data**

[a] Reference 25 (21 plants identified by botanist) was the only one in which voucher specimens were collected and herbarium location and collection numbers given. In references 5, 7, 26, 30, 31, 49, 50 accession numbers from genebanks and similar institutions were supplied.
[b]The evaluation is in bold below.

Table 5
G-Test for independence of 'difficult to identify' plants to 'identification by a botanist'.

G test for independence (Sokal & Rohlf 1995)				
		Did a botanist identify the sample plant? (botanist or supplier)		
		Yes	No	Total
Is the sample plant difficult to identify?	Yes	27	61	88
	No	101	278	379
	Total	128	339	467
G value	0.573468	[0,3-5]As *G* is considerably less than the critical value we accept the null hypothesis that **Difficulty of identification is independent of a botanist identifying the plant**		
Williams correction	0.568940			
G – critical at the 5% level ($\chi^2_{0.5[1]}$)	3.841			

Note: To define 'difficult to identify' we used the inverse of 'easy to identify' by Patrick Maundu. Note that exclusions removed 34 sample plants from the analysis.

Table 6
Results for analysis of plant nomenclature including criteria for author name or checklist.

Stage 2						
	Question?		Papers	No. of papers	Sample plants	Evaluation (in bold)
1	Was a botanical name with *Genus & species* used?	YES	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50	50	467	Goto 2
		NO	1, 9, 11, 20, 22, 35, 36, 47, 48	9	**35**	**Strongly recommend discarding data**
2	Was the author listed and correct?	YES	2, 5, 21, 23, 24, 25, 31, 34, 39, 41	10	31	*Goto 4*
		NO[a]	(W) 2, 21, 25, 33, 37, 39, 50 (A) 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 26, 27, 28, 29, 30, 32, 35, 36, 38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49 (A)	45	436	Goto 3
3	Was a published source cited for the botanical name?	YES	11, 50	2	9	*Goto 4*
		NO	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49	48	**427**	**Data ambiguous**
4	Was the accepted name used?	YES	2, 5, 25, 31, 39, 50	6	37	Goto 5
		NO	11, 21, 41	3	3	Goto 6
5	Was the accepted name spelt correctly?	YES	2, 5, 25, 31, 39, 50	6	**37**	**BEST PRACTICE**
		NO	N/A	0	**0**	**Data difficult to find**
6	Was a synonym used?	YES	11, 21, 41	3	3	Goto 7
		NO	N/A	0	**0**	**Strongly recommend discarding data**
7	Was the synonym spelt correctly?	YES	11, 21, 41	3	**3**	**Data difficult to find**
		NO	N/A		**0**	**Data very difficult to find**

[a] Of these 436, 14 from 7 papers were wrong, and 422 from 38 papers were absent.

The *G*-test (Table 5) shows that in the 50 papers reviewed, 'difficult to identify' plants were generally not 'identified by a botanist'. Although based on a limited study, the *G*-test results support common sense logic stated in Section 4.6 and the need for lesser-known wild or locally cultivated food plants to be identified by a botanist.

5.3. Stage 2: Plant nomenclature

Only 37 sample plants followed best practice in plant nomenclature (Table 6), with an accepted botanical name, author or published source of name cited, and correct spelling. Based on the model presented in Table 1, the data associated with 35 sample plants (7% of the total) would have to be discarded, as 11 had no botanical name, and a further 24 were only identified to genus level.

It is striking that 89% of the sample plants were published using names that are accepted, either in current taxonomic treatments, or in older texts that are still the main published floras for the region (Table 7). Only 4% of sample plants were published using names that are synonyms; the rest of the non-accepted names are accounted for by those species published without a full botanical name. All the botanical names seen in this survey were found to be 'real' names; in other words, names that have been published. We have seen, in other publications, 'fantasy' names which cannot be found in any botanical literature, and therefore do not exist.

However, the names we considered as accepted do include some that are no longer in widespread use. For example, three synonyms from the *Cassia* genus are here treated as accepted, because they are in the *Flora of Tropical East Africa* (Brennan, 1967: 47–103) and the *Flora of West Tropical Africa* (Hutchinson et al., 1958: 450–455). Neither of these Floras has been updated since publication. The three plant names (found in five papers) are *C.*

Table 7
Summary results for plant nomenclature.

	Sample plants	Number of papers
Names accepted, correct spelling	367 (73%)	25
Names accepted, incorrect spelling	81 (16%)	21
Synonyms (names not accepted), correct spelling	15 (3%)	11
Synonyms (names not accepted), incorrect spelling	4 (1%)	2
Genus name only	24 (5%)	7
Vernacular name only	11 (2%)	5
Total	502	

Table 8
Thirty-five representative spelling errors, subjectively assigned to categories.

Published name	Correct spelling	Ref.
Handwriting errors		
Annona grenaria	*Annona arenaria* Schumach. & Thonn.	22
Bixa orellano	*Bixa orellana* L.	48
Borassus arthiopum	*Borassus aethiopum* Mart.	27
Citrillus lanatus	*Citrullus lanatus* (Thunb.) Mansf.	22
Dacryodes edulls	*Dacryodes edulis* (G. Don) H. J. Lam	1
Ipomoea aserifolia	*Ipomoea asarifolia* (Desr.) Roem. & Schult.	14
Lannea schiniperi	*Lannea schimperi* (A. Rich.) Engl.	27
Manihot esculanta	*Manihot esculenta* Crantz	20
Piper quineense	*Piper guineense* Thonn.	1
Haematostaphis berteri	*Haematostaphis barteri* Hook. f.	16
Insertions/deletions of letters		
Balanites aegytiaca	*Balanites aegyptiaca* (L.) Delile	16
Butrospermum parkii	*Butyrospermum parkii* Kotschy	47
Cerathotheca sesamoides	*Ceratotheca sesamoides* Endl.	47
Crataeva religiosa	*Crateva religiosa* G. Forst.	22
Croton dichogamus	*Croton dichogamous* Pax	25
Enterolobium cyclocarpium	*Enterolobium cyclocarpum* (Jacq.) Griseb.	17, 18, 42
Ficus dekdekenna	*Ficus dekdekena* (Miq.) A. Rich	22
Hibiscus sabdarifa	*Hibiscus sabdariffa* L.	12, 19
Parkiia biglobosa	*Parkia biglobosa* (Jacq.) R. Br. ex G. Don	20, 48
Veronia colorate	*Vernonia colorata* (Willd.) Drake	27
Phonetic spellings		
Cola pachycupa	*Cola pachycarpa* K. Schum.	1
Denattia tripetola	*Dennettia tripetala* Baker f.	1
Emilia santifolia	*Emilia sonchifolia* (L.) Wight	14
Gongronema ratifolia	*Gongronema latifolium* Benth.	1
Stylochiton hypogaues	*Stylochaeton hypogaeus* Lepr.	47
Random errors		
Allium vavitum	*Allium sativum* L.	1
Dereium microcarpum	*Detarium microcarpum* Guill. & Perr.	27
Mangafera indica	*Mangifera indica* L.	47
Napoleaonaea vogelii	*Napoleonaea vogelii* Hook. & Planch.	21
Prosopos africana	*Prosopis africana* (Guill. et al.) Taub.	27
Sorghum vulgaris	*Sorghum vulgare* Pers.	20, 47
Syzigium guineense	*Syzygium guineense* (Willd.) DC	43
Voadzeiia subterranea	*Voandzeia subterranea* (L.) Verdc.	47
Xylopia aethiopicum	*Xylopia aethiopica* (Dunal) A. Rich.	1
Zizyphus spina-christi	*Ziziphus spina-christi* (L.) Desf.	37

obtusifolia L., *C. occidentalis* L. and *C. tora* L. From the 18th century there have been proposals to move some species of *Cassia* into a separate genus *Senna*. It was not until the publication of two seminal papers in the early 1980s that this happened (Irwin and Barneby, 1981, 1982). By the late 1980s most Floras and checklists accepted the change, with *Senna* a genus of c. 300 species, and *Cassia* retaining a small group of c. 30 species (Lewis et al., 2005). The five survey papers that named *Cassia* species were published between 1992 and 2002 and should ideally have used the newer names. Inevitably updating of plant names in printed Floras will take time, making it all the more important that names be checked by a specialist botanist who will be aware of these changes. Online databases such as ILDIS, which covers the Fabaceae (Leguminosae) family, are also increasingly important in spreading word of name changes in advance of their incorporation into printed Floras.

Some of the synonyms in use are old; in particular *Sorghum vulgare* Pers. (invariably misspelt as *S. vulgaris*) instead of the accepted *Sorghum bicolor* (L.) Moench. Bullock (1962) proposed *S. bicolor* as the correct name in 1962 and it was rapidly adopted by botanists for this important grain crop.

Eighty-five sample plant names were misspelt (17%). This is a serious problem; it is relatively easy for a search strategy to encompass synonyms likely to be still in use, but the variety of spelling errors would challenge a search of digital data (Table 8). Spelling mistakes can be divided into four groups: (1) handwriting errors (e.g. a ↔ g, e ↔ r); (2) insertions or deletions of letters; (3) phonetic spellings; (4) apparently random errors. Interpretation of some spelling errors was a challenge even to experienced taxonomists. The variety of spelling errors throws some doubt on the quality of the plant identifications; it is difficult to imagine that many of these derive from copying of typed or printed determination lists of the kind usually prepared by botanists upon formal examination of plant specimens.

A total of 427 sample plants (85%) had neither a correct author name nor reference to a named Flora or checklist. Using ILDIS (Table 2) we found that, of the sample plants in the Fabaceae (Leguminosae) family, 17% had names that occurred as homonyms. If the pattern holds good for all the sample plants, 73 sample plants have homonyms and may pose serious naming problems in future.

5.4. Stage 3: Plant name publication in title, abstract and keywords

A total of 306 sample plant names were not cited in the title, abstract or keywords (Table 9). Of the other 196 sample plants, 153 would be found by standard electronic searching of bibliographic

Table 9
Results for analysis of plant name publication.

Stage 3						
	Question		Papers	No. of papers	Sample plants	Evaluation (in bold)
1	Was an accepted name, synonym or genus cited in the title, abstract, or keywords?	Accepted	2, 3, 4, 5, 6, 7, 8, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50	44	184	Goto 2
		Synonym	11, 20, 21, 41	4	6	Goto 3
		Genus only	11, 20, 47, 48	4	6	Goto 4
		No	1, 3, 7, 8, 9, 11, 12, 14, 15, 16, 17, 18, 20, 22, 25, 27, 35, 36, 41, 43, 44, 47, 48	23	**306**	**Data lost**
2	Was the accepted name spelt correctly?	YES	3, 4, 5, 6, 8, 10, 11, 13, 15, 16, 17, 18, 19, 20, 21, 22, 23, 26, 27, 28, 29, 30, 31, 32, 33, 34, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49	39	**153**	**BEST PRACTICE**
		NO	3, 7, 14, 18, 19, 20, 21, 22, 25, 27, 30, 37, 42, 43, 46, 47, 48, 50	18	**31**	**Data Difficult**
3	Was the synonym spelt correctly?	YES	11, 20, 21, 41	4	**6**	**to find**
		NO	0	0	**0**	**Data very difficult**
4	Was the genus spelt correctly?	YES	11, 20, 47, 48	4	**6**	**to find**
		NO	0	0	**0**	**Data lost**

database using the accepted name, and a further 43 could be found using Boolean logic to search synonyms and misspellings (McBurney et al., 2004). The maximum number of botanical names given in an abstract was 11, and 34 of the 50 papers covered 10 or fewer sample plants. Misspelling of a botanical name was generally consistent throughout a paper (citation and body text); in two cases the misspelling was introduced in the abstract.

Although there is obviously a limitation as to the number of plant names that can be included in the citation component of a paper, 10 can reasonably be included in the abstracts or keyword. Thirty-four of the 50 survey papers covered 10 or fewer sample plants. If food composition data for a species is included in the body text of a paper, but not as part of searchable text, then it will be inaccessible to the wider scientific community.

6. Conclusions

6.1. The problem

Of the plant names given in the survey papers, 27% were incomplete, out-of-date, or misspelt, representing an impediment to database or full-text searching, and use of food composition data for comparative studies or construction of regional food tables. A full 60% of plant names would not have been found by searching a bibliographic database. At a more fundamental level, uncertainty surrounds many of the plant identifications, as more than half the botanical names are published without citation of assistance from an experienced botanist. This might be acceptable if these were the names of 'easy to identify' species; however, we found no correlation between 'difficulty of identification' and involvement of a botanist in identification. In cases of doubt, identifications can only be verified for the few sample plants for which voucher specimens have been deposited or which have been obtained from sources such as genebanks. Uncertainty also surrounds plant names assumed in this study to be accepted names. In the almost universal absence of author names, it is unclear whether some of these names are homonyms, referring to a different species to that usually meant.

However, it is encouraging that botanical names are relatively up-to-date, although there are some survivals of names abandoned by the botanical community in the 1960s and 1980s. This may reflect continuing circulation of local manuals dating from this time. It is a matter of concern that the most recent published Flora for most of the study area is the *Flora of West Tropical Africa*, published 1954–1972, but the greater availability of online checklists will help researchers check names for accepted status and spelling. Current online checklists of accepted names, such as ILDIS, Grin and the Kew World Checklist of Selected Plant Families, only cover about 141,000 of the c. 350,000 known species of seed plants (Paton et al., 2008: 606). A comprehensive list of online checklists for plant families, is given by Paton et al. (2008: E1–E15), who report on progress towards a complete checklist of all plant species.

In summary, botanical practice in the food composition and analysis of wild or locally cultivated food plants diverges from the standards of related academic disciplines such as field botany and ethnobotany. Given that the cost of a single proximate analysis of a food plant can range from $US200 in Asia (Kuhnlein et al., 2006: 40) to ~$US1500 for proximate, mineral, and vitamin analysis in developed countries, the generation of new food composition data is expensive. Researchers carrying out nutritional analyses of wild or locally cultivated plant species have a responsibility to identify and name plants to minimum botanical standards and to publish them in an accurate and accessible manner.

6.2. The solution

The solution is to adopt some of the well-established methodology of field botany and, wherever possible, work in collaboration with botanists with specialist knowledge of the study area. Often these will be based at herbaria or other research establishments in, or close to, the study area. In our experience such collaborations (especially if initiated early on) benefit all partners, and lead to an overall higher standard of scientific work. Specific recommendations for good practice are given in Appendix B to this paper, and the literature cited therein.

We believe journal editors and reviewers can also play a major part in encouraging adherence to good botanical standards. It is significant that the only paper in the study group to name the botanist responsible for plant identifications and give full details of voucher specimens was published in *Journal of Ethnopharmacology*, which lists these requirements in its instructions for authors.

Acknowledgements

The authors would like to gratefully acknowledge Patrick Maundu from the East African Herbarium, at the National Museums of Kenya in Nairobi, Kenya, for his help in classifying the ease of identification of plants. We would also like to thank Dr. Matt Daws of the Millennium Seed Bank, Royal Botanic Gardens, Kew and Dr. Andris Abukuks of Birkbeck College, University of London, for their assistance in statistical analysis. Two anonymous reviewers offered helpful comments.

Appendix A. Survey papers

1. Achinewhu, S.C., Ogbonna, C.C., Hart, A.D., 1995. Chemical composition of indigenous wild herbs, spices, fruits, nuts and leafy vegetables used as food. Plant Foods for Human Nutrition 48, 341–348.

2. Addy, E.O.H., Salami, L.I., Igboeli, L.C., Remawa, H.S., 1995. Effect of processing on nutrient composition and anti-nutritive substances of African locust bean (*Parkia filicoidea*) and baobab seed (*Adansonia digitata*). Plant Foods for Human Nutrition 48, 113–117.

3. Aganga, A.A., Mosase, K.W., 2001. Tannin content, nutritive value and dry matter digestibility of *Lonchocarpus capassa*, *Zizyphus mucronata*, *Sclerocarya birrea*, *Kirkia acuminata* and *Rhus lancea* seeds. Animal Feed Science and Technology 91, 107–113.

4. Akpata, M.I., Miachi, O.E., 2001. Proximate composition and selected functional properties of *Detarium microcarpum*. Plant Foods for Human Nutrition 56, 297–302.

5. Amarteifio, J.O., Munthali, D.C., Karikari, S.K., Morake, T.K., 2002. The composition of pigeon peas (*Cajanus cajan* (L.) Millsp.) grown in Botswana. Plant Foods for Human Nutrition 57, 173–177.

6. Arogba, S.S., 1997. Physical, chemical and functional properties of Nigerian mango (*Mangifera indica*) kernel and its processed flour. Journal of the Science of Food and Agriculture 73, 321–328.

7. Barbeau, W.E., Hilu, K.W., 1993. Protein, calcium, iron and amino acid content of selected wild and domesticated cultivars of finger millet. Plant Foods for Human Nutrition 43, 97–104.

8. Barminas, J.T., Charles, M., Emmanuel, D., 1998. Mineral composition of non-conventional leafy vegetables. Plant Foods for Human Nutrition 53, 29–36.

9. Boukari, I., Shier, N.W., Fernandez R.X.E., Frisch, J., Watkins, B.A., Pawloski, L., Fly, A.D., 2001. Calcium analysis of selected western African foods. Journal of Food Composition and Analysis 14, 37–42.

10. Cook, J.A., VanderJagt, D.J., Pastuszyn, A., Mounkaila, G., Glew, R.S., Glew, R.H., 1998. Nutrient content of two indigenous

plant foods of the western Sahel: *Balanites aegyptiaca* and *Maerua crassifolia*. Journal of Food Composition and Analysis 11, 221–230.

11. Cook, J.A., VanderJagt, D.J., Pastuszyn, A., Mounkaila, G., Glew, R.S., Millson, M., Glew, R.H., 2000. Nutrient and chemical composition of 13 wild plant foods of Niger. Journal of Food Composition and Analysis 13, 83–92.

12. Delisle, H., Bakari, S., Gevry, G., Picard, C., Ferland, G., 1997. Teneur en provitamine A de feuilles vertes traditionnelles du Niger. Cahiers Agricultures 6, 553–560.

13. Ejoh, A.R., Mbiapo, F.T., Fokou, E., 1996. Nutrient composition of the leaves and flowers of *Colocasia esculenta* and the fruits of *Solanum melongena*. Plant Foods for Human Nutrition 49, 107–112.

14. Ekpa, O.D., 1996. Nutrient content of three Nigerian medicinal plants. Food Chemistry 57, 229–232.

15. Elseed, A.M.A.F., Amin, A.E., Khadiga, Ati, A.A., Sekine, J., Hishinuma, M., Hamana, K., 2002. Nutritive evaluation of some fodder tree species during the dry season in central Sudan. Asian-Australian Journal of Animal Sciences 15, 844–850.

16. Eromosele, I.C., Eromosele, C.O., Kuzhkuzha, D.M., 1991. Evaluation of mineral elements and ascorbic acid contents in fruits of some wild plants. Plant Foods for Human Nutrition 41, 151–154.

17. Ezeagu, I.E., Petzke, J.K., Metges, C.C., Akinsoyinu, A.O., Ologhobo, A.D., 2002. Seed protein contents and nitrogen-to-protein conversion factors for some uncultivated tropical plant seeds. Food Chemistry 78, 105–109.

18. Ezeagu, I.E., Petzke, K.J., Lange, E., Metges, C.C., 1998. Fat content and fatty acid composition of oils extracted from selected wild-gathered tropical plant seeds from Nigeria. Journal of the American Oil Chemists' Society 75, 1031–1034.

19. Freiberger, C.E., Vanderjagt, D.J., Pastuszyn, A., Glew, R.S., Mounkaila, G., Millson, M., Glew, R.H., 1998. Nutrient content of the edible leaves of seven wild plants from Niger. Plant Foods for Human Nutrition 53, 57–69.

20. Glew, R.H., VanderJagt, D.J., Lockett, C., Grivetti, L.E., Smith, G.C., Pastuszyn, A., Millson, M., 1997. Amino acid, fatty acid, and mineral composition of 24 indigenous food plants of Burkina Faso. Journal of Food Composition and Analysis 10, 205–217.

21. Herzog, F., Farah, Z., Amadò, R., 1994. Composition and consumption of gathered wild fruits in the V-Baoulé, Côte d'Ivoire. Ecology of Food and Nutrition 32, 181–196.

22. Humphry, C.M., Clegg, M.S., Keen, C.L., Grivetti, L.E., 1993. Food diversity and drought survival. The Hausa example. International Journal of Food Sciences and Nutrition 44, 1–16.

23. Isong, E.U., Adewusi, S.A.R., Nkanga, E.U., Umoh, E.E., Offrong, E.E., 1999. Nutritional and phytogeriatological studies of three varieties of *Gnetum africanum* ('afang'). Food Chemistry 64, 489–493.

24. Isong, E.U., Idiong, U.I., 1997. Comparative studies on the nutritional and toxic composition of three varieties of *Lesianthera africana*. Plant Foods for Human Nutrition 51, 79–84.

25. Johns, T., Mahunnah, R.L.A., Sanaya, P., Chapman, L., Ticktin, T., 1999. Saponins and phenolic content in plant dietary additives of a traditional subsistence community, the Batemi of Ngorongoro District, Tanzania. Journal of Ethnopharmacology 66, 1–10.

26. Lalas, S., Tsaknis, J., 2002. Characterization of *Moringa oleifera* seed oil variety 'Periyakulam 1'. Journal of Food Composition and Analysis 15, 65–77.

27. Lockett, C.T., Calvert, C.C., Grivetti, L.E., 2000. Energy and micronutrient composition of dietary and medicinal wild plants consumed during drought. Study of rural Fulani, northeastern Nigeria. International Journal of Food Sciences and Nutrition 51, 195–208.

28. Madubuike, F.N., Ojimelukwe, P.C., Ajah, P.O., 1994. Proximate composition, energy content and physiochemical properties of *Afzelia africana* and *Brachystegia eurycoma* seeds. Plant Foods for Human Nutrition 46, 339–344.

29. Makkar, H.P.S., Becker, K., 1996. Nutrional value and antinutritional components of whole and ethanol extracted *Moringa oleifera* leaves. Animal Feed Science and Technology 63, 211–228.

30. Marconi, E., Ruggeri, S., Carnovale, E., 1997. Chemical evaluation of wild under-exploited Vigna spp. seeds. Food Chemistry 59, 203–212.

31. Mnembuka, B.V., Eggum, B.O., 1993. The nutritive value of some selected Tanzanian plant food sources. Plant Foods for Human Nutrition 44, 1–10.

32. Mohamed, A.I., Hussein, A.S., 1994. Chemical composition of purslane (*Portulaca oleracea*). Plant Foods for Human Nutrition 45, 1–9.

33. Mohamed, A.M., Wolf, W., Spiess, W.E.L., 2002. Physical, morphological and chemical characteristics, oil recovery and fatty acid composition of *Balanites aegyptiaca* Del. kernels. Plant Foods for Human Nutrition 57, 179–189.

34. Murage, E.N., Chweya, J.A., Imungi, J.K., 1996. Changes in leaf yield and nutritive quality of the black nightshade (*Solanum nigrum*) as influenced by nitrogen application. Ecology of Food and Nutrition 35, 149–157.

35. Murray, S.S., Shoeninger, M.J., Bunn, H.T., Pickering, T.R., Marlett, J.A., 2001. Nutritional composition of some wild plant foods and honey used by Hadza foragers of Tanzania. Journal of Food Composition and Analysis 13, 17–36.

36. Mwajumwa, L.B.S., Kahangi, E.M., Imungi, J.K., 1991. The prevalence and nutritional value of some Kenyan indigenous leafy vegetables from three locations of Machakos district. Ecology of Food and Nutrition 26, 275–280.

37. Nazif, N.M., 2002. Phytoconstituents of *Zizyphus spina-christi* L. fruits and their antimicrobial activity. Food Chemistry 76, 77–81.

38. Nordeide, M.B., Hatløy, A., Følling, M., Lied, E., Oshaug, A., 1996. Nutrient composition and nutritional importance of green leaves and wild food resources in an agricultural district, Koutiala, in southern Mali. International Journal of Food Sciences and Nutrition 47, 455–468.

39. Oliveira, J.T.A., Vasconcelos, I.M., Bezerra, L.C.N.M., Silveira, S.B., Monteiro, A.C.O., Moreira, R.A., 2000. Composition and nutritional properties of seeds from *Pachira aquatica* Aubl., *Sterculia striata* St. Hil. & Naud. and *Terminalia catappa* Linn. Food Chemistry 70, 185–191.

40. Onimawo, I.A., 2002. Proximate composition and selected physicochemical properties of the seed, pulp and oil of sour sop (*Annona muricata*). Plant Foods for Human Nutrition 57, 165–171.

41. Parvathi, S., Kumar, V.J.F., 2002. Studies on chemical composition and utilization of the wild edible vegetable athalakkai (*Momordica tuberosa*). Plant Foods for Human Nutrition 57, 215–222.

42. Proll, J., Petzke, K.J., Ezeagu, I.E., Metges, C.C., 1998. Low nutritional quality of unconventional tropical crop seeds in rats. Journal of Nutrition 128, 2014–2022.

43. Saka, J.D.K., Msonthi, J.D., 1994. Nutritional value of edible fruits of indigenous wild trees in Malawi. Forest Ecology and Management 64, 245–248.

44. Saka, J.D.K., Msonthi, J.D., Sambo, E.Y., 1992. Dry matter, acidity and ascorbic acid contents of edible wild fruits growing in Malawi. Tropical Science 32, 217–221.

45. Sawe, J.J., Tuitoek, J.K., Ottaro, J.M., 1998. Evaluation of common tree leaves or pods as supplements for goats on range area of Kenya. Small Ruminant Research 28, 31–37.

46. Sena, L.P., Vanderjadgt, D.J., Rivera, C., Tsin, A.T.C., Muhamadu, I., Mahamadou, O., Millson, M., Pastuszyn, A., Glew, R.H., 1998. Analysis of nutritional components of eight famine foods of the Republic of Niger. Plant Foods for Human Nutrition 52, 17–30.

47. Smith, G.C., Clegg, M.S., Keen, C.L., Grivetti, L.E., 1996. Mineral values of selected plant foods common to southern

Burkina Faso and to Niamey, Niger, West Africa. International Journal of Food Sciences and Nutrition 47, 41–53.

48. Smith, G.C., Dueker, S.R., Clifford, A.J., Grivetti, L.E., 1996. Carotenoid values of selected plant foods common to southern Burkina Faso, West Africa. Ecology of Food and Nutrition 35, 43–58.

49. Tsaknis, J., Lalas, S., Gergis, V., Dourtoglou, V., Spiliotis, V., 1999. Characterization of *Moringa oleifera* variety Mbololo seed oil of Kenya. Journal of Agricultural and Food Chemistry 47, 4495–4499.

50. Vadivel, V., Janardhanan, K., 2002. Agrobotanical traits and chemical composition of *Cassia obtusifolia* L.: a lesser-known legume of the Western Ghats region of South India. Plant Foods for Human Nutrition 57, 151–164.

Appendix B. Recommendations for researchers

Before starting fieldwork

1. Contact a botanist with expert knowledge of study area (often based in or near the area) and arrange collaboration. Offer funding and/or co-authorship, as appropriate to level of assistance required. Botanists can be located using the web-based Index Herbariorum (Holmgren and Holmgren, 1998). For projects involving crop plants, trees or medicinal plants, consult local experts at appropriate local institutes such as agricultural or forestry research centres.
2. Choose herbaria to hold voucher specimens from the study and initiate contact. Ideally (for future ease of access) one repository will be local to the study area; one will be a national herbarium. In rare cases there may be no herbarium or botanist in the fieldwork country. Instead, consider collaboration with scientists in another country, or establishing a project herbarium locally, particularly if the project is large-scale.
3. Check export/import regulations if it is desired to export a set of voucher specimens. Special arrangements often apply to ease transfer of specimens from one herbarium to another; your collaborating botanist can advise on these.
4. Become familiar with key botanical publications relating to the study area, such as a Flora or other identification handbook. In addition to local advice, guidance can be found in the library catalogues of major botanical libraries, and in the *Guide to standard floras of the world* (Frodin, 2001).
5. Consult one or more guides to collecting plants, such as those by Martin (1995), Alexiades (1996) and Bridson and Forman (2004), and gather the modest equipment necessary for this. For larger-scale projects, it can be economical to hire a graduate student from a local institution to assist with collection and identification of plants.

   We wish to stress that the collection of voucher specimens is an easy process, requiring no expensive equipment or specialist training. It can be self-taught using the manuals referred to above.

During fieldwork

1. Collect the common name(s) of the plant from the community with whom you are working. When working with crops, be sure to collect the name for the particular landrace or cultivar under study.
2. Collect one or more voucher specimens to act as herbarium specimens for each plant. The voucher specimen should be from the same population collected for food use. Where it is unrealistic to press material, for example in the case of market-bought fleshy fruits, then try to show fresh material to the project botanist. Photographs of fresh material are useful, but are not a substitute for voucher specimens. Bear in mind that botanists find it extremely difficult to identify plants to species level from photographs alone.
3. Note the location, habitat and date of collection of the herbarium specimen. As well as being essential for preparation of a specimen label, these data may be useful in interpreting differences in nutritional composition.
4. Allocate a collection number to the voucher specimen. This might be the same as the reference number you use for the matching specimen sent for analysis. Conventionally, a collection number consists of two parts, the name of the collector (personal name or expedition name) and a number, e.g. H.J. Beentje 2862.
5. Attempt a provisional identification. Trying to identify a plant may flag up any problems with voucher specimens, such as missing plant parts, at a point when it is possible to re-collect material.

After fieldwork and before laboratory analysis

1. Finalise identifications with your botanical consultant. This should be done as soon as possible after fieldwork. This helps avoid delays creeping in. Any problematic material can be identified at this point and, if necessary, voucher specimens can be sent to other specialists for identification.
2. Ask the botanist to provide a typed or printed list of botanical names, including the authors. The list should refer to the Flora or checklist from which the names are derived. Botanical names should of course be linked to the relevant voucher specimens by collection numbers.
3. Take a little time to check the botanical data. Have all the plants been named and voucher specimens labelled and deposited in herbaria? It is easier to resolve problems such as unlabelled specimens within a few weeks of collection, rather than 5 years later.
4. Consider excluding poorly documented plants from food composition analyses. Analysis of foodstuffs is expensive. When it has not been possible to identify a plant to species, the value of carrying out an analysis is questionable.

Publication

1. Provide core botanical information, including:
   a. Name of person/institution carrying out identifications.
   b. Published source (if any) used for botanical names.
   c. Collection (reference) number of voucher specimens or accession numbers of material obtained from genebanks and similar sources.
   d. Place(s) of deposit voucher specimens.
2. Include a list of botanical names and common names of plants in the study, including family name, genus, species and author name.
3. Send a copy of your manuscript to your collaborating botanist for comments. Ask for special attention to be given to spelling of plant names.
4. Place all botanical names in the abstract or keywords; if impracticable, other options are to:
   a. Divide long tables of food composition into several papers.
   b. Place genera (rather than species) in the abstract or keywords, where 10 or fewer genera are covered. If these guidelines cannot be followed, editors, authors, and the food composition community must negotiate with each other on an acceptable level of data exclusion, and its implications for availability to the wider scientific community through citation databases.
5. Re-check all spellings in proof prior to publication.

References

Agerer, R., Ammirati, J., Blanz, P., Courtecuisse, R., Desjardin, D.E., Gams, W., Hallenberg, N., Halling, R., Hawksworth, D.L., Horak, E., Korf, R.P., Mueller, G.M., Oberwinkler, F., Rambold, G., Summerbell, R.C., Triebel, D., Watling, R., 2000. Open letter to the scientific community of mycologists. Canadian Journal of Botany 78, 981–983.

Alexiades, M.N. (Ed.), 1996. Selected Guidelines for Ethnobotanical Research: A Field Manual. New York Botanical Garden, Bronx, NY.

Barkworth, M.E., Jacobs, S.W.L., 2001. Valuable research or short stories: what makes the difference? Hereditas 135, 263–270.

Beentje, H.J., 1994. Kenya Trees, Shrubs and Lianas. National Museums of Kenya, Nairobi.

Boa, E., 2000. Letters and comments: writer questions use of nomenclatural authorities. Economic Botany 54, 2.

Brennan, J.P.M., 1967. Flora of Tropical East Africa. Leguminosae Subfamily Caesalpinioideae. Crown Agents for Oversea Governments and Administrations, London.

Bridson, D., Forman, L. (Eds.), 2004. The Herbarium Handbook. Royal Botanic Gardens, Kew.

Bullock, A.A., 1962. Nomenclatural notes: XV. Kew Bulletin 15, 389–396.

Bye, R.A., 1986. Voucher specimens in ethnobiological studies and publications. Journal of Ethnobiology 6, 1–8.

Clayton, W.D., Renvoize, S.A., 1982. Flora of Tropical East Africa. Gramineae. Part 3. A.A. Balkema, Rotterdam.

Convention on Biological Diversity, 2006. Biodiversity for Food and Nutrition. Retrieved 2006-12-16: www.cbd.int/programmes/areas/agro/food-nutrition/default.shtml.

Cotton, C.M., 1996. Ethnobotany: Principles and Applications. John Wiley & Sons, Chichester.

Frison, E.A., Smith, I.F., Johns, T., Cherfas, J., Eyzaguirre, P., 2006. Agricultural biodiversity, nutrition, and health: making a difference to hunger and nutrition in the developing world. Food and Nutrition Bulletin 27, 167–179.

Frodin, D.G., 2001. Guide to Standard Floras of the World: An Annotated, Geographically Arranged Systematic Bibliography of the Principal Floras, Enumerations, Checklists and Chorological Atlases of Different Areas, 2nd ed. Cambridge University Press, Cambridge.

Garnock-Jones, P.J., Webb, C.J., 1996. The requirement to cite authors of plant names in botanical journals. Taxon 45, 285–286.

Goldblatt, P., Hoch, P.C., McCook, L.M., 1992. Documenting scientific data: the need for voucher specimens. Annals of the Missouri Botanic Garden 79, 969–970.

Hedberg, I., 1993. Botanical methods in ethnopharmacology and the need for conservation of medicinal plants. Journal of Ethnopharmacology 38, 121–128.

Holmgren, P.K., Holmgren, N.H., 1998 (continuously updated). Index Herbariorum: A Global Directory of Public Herbaria and Associated Staff. New York Botanical Garden's Virtual Herbarium. sweetgum.nybg.org/ih.

Hutchinson, J., Dalziel, J.M., Keay, R.W.J., 1958. Flora of West Tropical Africa. Volume I. Part 2. Crown Agents for Oversea Governments and Administrations, London.

Irwin, H.S., Barneby, R.C., 1981. Cassieae Bronn. In: Polhill, R.M., Raven, P.H. (Eds.), Advances in Legume Systematics. 1. Royal Botanic Gardens, Kew, pp. 97–106.

Irwin, H.S., Barneby, R.C., 1982. The American Cassiinae. A synoptical revision of Leguminosae tribe Cassieae subtribe Cassiinae in the New World. Memoirs of the New York Botanical Garden 35 (1–2), 1–918.

Jeffrey, C., 1982. An Introduction to Plant Taxonomy. Cambridge University Press, Cambridge.

Jiang, B., Yang, H., Nuntanakorn, P., Balick, M.J., Kronenberg, F., Kennelly, E.J., 2005. The value of plant collections in ethnopharmacology: a case study of an 85-year-old black cohosh (*Actaea racemosa* L.) sample. Journal of Ethnopharmacology 96, 521–528.

Johns, T.E., Eyzaguirre, P.B., 2006. Linking biodiversity, diet and health in policy and practice. Proceedings of the Nutrition Society 65, 182–189.

Kuhnlein, H.V., Yesudas, S., Dan, L., Ahmed, S., 2006. Documenting Traditional Food Systems of Indigenous Peoples: International Case Studies. Centre for Indigenous Peoples' Nutrition and Environment, McGill University, Sainte-Anne-de-Bellevue, Quebec. Downloadable from: www.mcgill.ca/files/cine/manual.pdf.

Lewis, G., Schrire, B., Mackinder, B., Lock, M., 2005. Legumes of the World. Royal Botanic Gardens, Kew.

Martin, G.J., 1995. Ethnobotany: A Methods Manual. Chapman & Hall, London.

Maundu, P.M., Ngugi, G.W., Kabuye, C.H.S., 1999. Traditional Food Plants of Kenya. National Museums of Kenya, Nairobi.

McBurney, R.P.H., Griffin, C., Paul, A.A., Greenberg, D., 2004. The nutritional composition of African wild food plants: from compilation to utilization. Journal of Food Composition and Analysis 17, 277–289.

Paton, A.J., Brummitt, N., Govaerts, R., Harman, K., Hinchcliffe, S., Allkin, B., Lughadha, E.N., 2008. Towards Target 1 of the Global Strategy for Plant Conservation: a working list of all known plant species—progress and prospects. Taxon 57, 602–611.

Penuelas, J., Filella, I., 2002. Metal pollution in Spanish terrestrial ecosystems during the twentieth century. Chemosphere 46, 501–505.

Scoones, I., Melnyk, M., Pretty, J.N., 1992. The Hidden Harvest: Wild Foods and Agricultural Systems, a Literature Review and Annotated Bibliography. International Institute for Environment and Development, London.

Smith, P.P., 2006. Wild-seed banks and taxonomy. In: Leadlay, E., Jury, S. (Eds.), Taxonomy and Plant Conservation. Cambridge University Press, Cambridge, pp. 294–304.

Snow, N., Keating, P.L., 1999. Relevance of specimen citations to conservation. Conservation Biology 13, 943–944.

Sokal, R.R., Rohlf, F.J., 1995. Biometry, The Principles and Practice of Statistics in Biological Research, 3rd ed. Freeman & Co., New York.

Zepernick, B., Timler, F.K., 1981. *Zanthoxylum zanthoxyloides* (Lam.) Zepernick & Timler comb. nova (Rutaceae). Willdenowia 11, 361–362.