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Review

Indigenous leafy vegetables (*imifino*, *morogo*, *muhuro*) in South Africa: A rich and unexplored source of nutrients and antioxidants

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South Africa is endowed with agro-biodiversity that consists of different types of indigenous leafy vegetables (ILVs) with health benefits and rich source of nutrients to cater for over three million people suffering from hunger and malnutrition in the country. Unfortunately, the use of these vegetables is declining at an alarming rate due to negligence and lack of appropriate cultivation practices to improve yield, quality and adaptability of valuable species. The nutritional value and antioxidant potential arising from their rich polyphenolic constituents are described in this review as useful inexpensive resources for reducing hidden hunger, prevention and control of cancer, hypertension, obesity, diabetes and heart disease. A total number of 22 plant species belonging to 12 genera and 10 families have been reviewed. *Amaranthus* species, *Cucurbita pepo*, *Bidens pilosa*, *Chenopodium album* and *Solanum nigrum* appear to be the most popular and most widely occurring leafy vegetables in the rural areas of South Africa. There is a need to create an atmosphere of awareness that would encourage consumption and industrial production of these vegetables in a bid to curb the high level of malnutrition and food insecurity in South Africa.

Key words: Indigenous leafy vegetables, antioxidants, nutritional value, food security, non communicable diseases, South Africa.

INTRODUCTION

Traditional African leafy vegetables are underutilized in South Africa (Voster and van Rensburg, 2005; Mnkeni et al., 2007). They are called *imifino* in isi Zulu or isi Xhosa, *morogo* in Sesotho or isi Pedi and *muhuro* in Tshivenda (van Rensburg et al., 2007; van der Walt et al., 2009). These groups of plants are neglected and despised despite their rich nutrient and mineral content including proteins, carbohydrates, vitamins and dietary fibre which are beneficial in the maintenance of good health and prevention of diseases (Nnamani et al., 2009). They are classified in the Eastern Cape Province and other parts of the country as 'poor peoples' food and knowledge associated with them is referred as 'backward knowledge' leading to an unwillingness of the youth to be associated with these crops (Voster and van Rensburg, 2005). Consequently, knowledge regarding their habitat and importance is hardly being transferred to the younger generation due to their changing social values and

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migration from the rural areas where these crops are consumed to the cities where they are ignored and neglected in favour of exotic western varieties (van Rensburg et al., 2004; van der Walt et al., 2009). There is therefore the need to collect, preserve and document this knowledge which can be useful for crop improvement and maintenance of local cultures and traditions. Chemical elimination of these vegetables, which are often considered as weeds, also makes their survival precarious, resulting in the loss of valuable species (Shackleton, 2003; Lewu and Mavengahama, 2010). In South Africa, just like in many other countries, most human plant food is based on a rather limited number of crops (Misra et al., 2008). This places the national/global food supply and economy at risk of collapse should there be a crisis with the few crops selected for human consumption (Mlakar et al., 2010). The neglect of indigenous leafy vegetables (ILVs) in South Africa is not proper given that the nutritional value of traditional leafy vegetables in most parts of the world has been reported to be higher than several known common vegetables (Sundriyal and Sundriyal, 2001; Ndlovu and Afolayan, 2008).

Indigenous leafy vegetables are usually not available on a commercial scale. However, they have the potential for income generation but fail to compete with exotic varieties due to lack of awareness. Most of the crops are not cultivated, but grow in the wild where they are well adapted to harsh environmental conditions (Lewu and Mavengahama, 2010; Matenge et al., 2012). In fact, some varieties such as *Amaranthus* and *Bidens pilosa* are known to be resistant to pest and diseases and therefore may constitute good sources of genes for genetic improvement of other crop varieties (Adebooye et al., 2004; Mnkeni et al., 2007).

Despite their rich nutrient content and adaptability to harsh climatic conditions, few scientific studies have been done to establish a seed and germplasm for African leafy vegetables and to determine their role and importance in the formulation of healthy diets in South Africa. This is surprising considering that almost 239 million people are suffering from hunger in sub-Saharan Africa, a figure that is likely to increase in the near future (Sasson, 2012). Twenty eight percent of children under the age of five years in Sub-Saharan Africa are moderately or severely underweight, an indicator for protein energy malnutrition (UNICEF, 2006). Close to 190 million young children and more than 15 million pregnant women in the developing world are vitamin A-deficient (WHO, 2009). Many authors have reported scarcity of vegetables in diet as a major cause of this deficiency, which may result in blindness in young children within the semi-arid and arid areas of Africa (Nojilana et el., 2007; Seidu et al., 2012; Nyuar et al., 2012).

In South Africa, most provinces are still challenged by high levels of poverty, especially among rural communities and in some areas the poverty level is as high as 78.2% (Lewu and Mavengahama, 2010). The rate of vitamin A deficiency is also high in the country (Labadarios, 2005). Sixty four percent of 1-9-year old children are vitamin A-deficient, 28% anaemic, 13% have poor iron levels and 45% had low zinc levels (Faber et al., 2011).

More than 40% of the adult population in South Africa is either overweight or obese with malnutrition being the predominant contributor as many people tend to consume processed foods that are high in saturated fats, sugar and salt (Puoane et al., 2002; Faber et al., 2011). On the other hand, consumption of vegetables is generally associated with reduced risk of cardiovascular diseases, cancer, stroke and reduced mortality (He et al., 2006). It is also worth mentioning that the deficiency of one micronutrient can exacerbate the deficiency of another, thus there is likely to be concomitant deficiencies of more than one micronutrient in many of South Africa's undernourished children (Black, 2003; Uusiku et al., 2010). These problems can be prevented by the inclusion of indigenous leafy vegetables like 'umifino umtyuthu', 'cetshana' or 'ityabontyi' (*Amaranthus cruentus*, *Cucurbita pepo*, *Citrillus lanatus*) in the diet as natural and inexpensive sources of vitamin A, iron and zinc. According to Uusiku et al. (2010) and based on the recommended nutrient intake (RNI), 300 g fresh ILVs would fulfil the dietary requirements of vitamin A for children. For adults, 300 g of fresh *Cucurbita pepo* would contribute 116% of female RNI and 97% of males RNI, whereas 300 g of fresh *Vigna unguiculata* would contribute 59% and 50% of female and male daily requirements, respectively.

A recent study on eight African leafy vegetables by van Jaarsveld et al. (2014) also reveals that pigweed and cowpea leaves are good sources of vitamin A, able to meet more than 75% of the recommended daily allowance (RDA) in children followed by spider flower, black night shade, tsamma melon, Jews mallow and pumpkin leaves (50% to 75% RDA). Studies carried out by Faber et al. (2007) also indicated that consumption of dark-green leafy vegetables contributed significantly to the dietary intake of calcium, iron, vitamin A and riboflavin in children in two rural villages of KwaZulu-Natal. There is therefore the dire need to encourage sufficient production, availability and consumption of indigenous leafy vegetables in a bid to curb the problem of malnutrition, obesity, food insecurity and poverty in the country. This review examines the nutritional and medicinal potentials of indigenous leafy vegetables in South Africa in an attempt to create awareness about their roles in the maintenance of good health and prevention of diseases.

COMMON TYPES OF ILVS

The Agricultural Research Council, South Africa has documented numerous types of leafy vegetables in the country including *Amaranthus*, *Brassica*, *Solanum*, *Chorchorus*, *Chenopodium* species and many others (Kleynhans et al., 2013). However, only the most common varieties are described in this review.

Chenopodium album

Known as lamb's quarters, the leaves and young shoots of *C*. *album* are used as vegetables in some rural settings in the Eastern Cape Province and other parts of South Africa (Gqaza et al., 2013). *C*. *album* like with many other indigenous leafy vegetables in the country is usually not cultivated but harvested from the wild or roadside paths where it grows as a weed (Gqaza et al., 2013). It is known as *Imbikicane* in isi Xhosa and is usually prepared in combination with maize as porridge. It is an erect annual herb that may grow to a height of up to 1m (Singh et al., 2011). The stems are angular, ribbed with longitudinal dark green or red streaks. *C*. *album* belongs to the family Chenopodiaceae which consist of about 21 species, including *C*. *botrys*, *C*. *ambrosioides*, *C*. *murale*, *C*. *chilense* and *C*. *amaranticolor*, many of them with medicinal properties (Yadav et al., 2007). *C*. *quinoa* is also used as pseudo cereal in Bolivia and some South American countries (Alvarez-Jubete et al., 2010). They have an under-exploited potential to contribute to food security, nutrition, health and income generation in South Africa.

Portulaca oleracea

P. *oleracea* is commonly referred to as purslane in English, *igwanitsha* in isiXhosa and *amalenyane* in isiZulu (Dweck, 2001). It is a green vegetable with succulent stems and leaves with rich mucilaginous substance. It grows in soils with less water and nutrients, producing yellow flower buds. It grows to a height of 12 to 15 cm as a low-lying creeper, leaves and stems are tender to touch. It belongs to the family Portulacaceae which consist of about 150 species including *P*. *quadrifida*, *P*. *afra*, *P*. *pilosa*, *P*. *insularis* and *P*. *psammotropha* (Chung et al., 2008). It is eaten as a salad and vegetable all around the world and used medicinally for a variety of conditions that include headache, stomach ache, painful urination, enteritis, mastitis, lack of milk flow in nursing mothers and in postpartum bleeding (Dweck, 2001). In some rural settings in South Africa, the succulent weed is a favourite vegetable. Children eat the leaves raw (Dweck, 2001).

Amaranthus species

The genus *Amaranthus* is made of approximately 60 species most of which are cosmopolitan weeds (*Amaranthus retroflexus*, *Amaranthus hybridus*, *Amaranthus powellii* and *Amaranthus spinosus*.) and cultivated amaranth species (*Amaranthus blitum*, *Amaranthus lividus*, *Amaranthus viridis*, *Amaranthus gracilis*, *Amaranthus tricolor*, *Amaranthus gangeticus*, *Amaranthus hypochondriacus* and *Amaranthus thunbergii*) which can be used as food grain, leafy vegetables, forage and ornamentals (Mlakar et al., 2010). They appear as erect plant annuals or short-lived perennials and may grow to a height of 2 m. The mature vegetable amaranths produce tiny shiny seeds that are dark brown to black as opposed to cream-coloured seeds in the grain types (van Rensburg et al., 2007). They belong to the family Amaranthaceae, sub-family Amaranthoideae. The name 'amaranth' signifies 'immortal', 'everlasting' or 'non-wilting' in Greek (Mlakar et al., 2010), which is consistent with its ability to thrive in minimally nutritive soils and harsh environmental conditions. This group of plants has raised a lot of interest among researchers in many European countries because of their high nutrient quality, particularly associated with the grains. Their spinach-like flavour, high yields and ability to grow in hot weather have made them popular vegetable crops in most parts of Africa and Asia (van der Walt et al., 2009). Vegetable amaranths are the most popular and the most widely occurring leafy vegetables in many rural areas in South Africa where they appear as weeds, commonly referred to as pig weed in English and *unomdlomboyi* in isi Xhosa (Modi, 2007).

Bidens pilosa

Also known as black jack, *B*. *pilosa* is a cosmopolitan weed widely distributed in many parts of South Africa and other sub-tropical and tropical countries (Bartolome et al., 2013). It is an annual aggressive plant that may grow to a height of 1m. It flowers, producing white petals on small heads, barbed awns and fruits that easily catch on to animal fur and human clothing, a very effective means of seed dispersal. It belongs to the family Asteraceae which consist of about 240 species (Arthur et al., 2012). Just like most other weeds, *B*. *pilosa* is endowed with a remarkable ability to thrive in minimally nutritive soils. The young tender shoots are used as vegetable in many rural areas in Africa particularly in times of food scarcity. In some rural areas of South Africa, the bitter taste of this vegetable is a delicacy particularly among men who consume it in a mixture of other leafy vegetables (Voster and van Rensburg, 2005). Consumption of the leaves has been reported as a risk factor for oesophageal cancer in South Africa (Arthur et al., 2012). Traditional processing methods which may require boiling and squeezing to remove excess fluids may reduce to safety levels, some of the carcinogenic components. Pharmacological studies of this plant have revealed the presence of many bioactive compounds including terpenes, tannins, essential oils, amino acids and ascorbic acid (Silva et al., 2011). These findings are consistent with its folkloric uses in the treatment of gastrointestinal diseases by the Zulu tribe of South Africa (Voster and van Rensburg, 2005; Arthur et al., 2012).

Solanum nigrum

S. *nigrum* is called black nightshade in English and *Umsobo* in isi Xhosa (van Rensburg et al., 2007). It is an erect annual or biannual herbaceous plant and may sometimes be perennial. It can reach up to 100 cm in height (Akubugwo et al., 2007a). The stem may be smooth or bear small hairs known as trichomes. These plants are widely distributed in South Africa and many other African countries where they grow as weeds in arable lands, gardens and soils rich in nitrogen. *S. nigrum* belongs to the family Solanaceae, a cosmopolitan family containing many essential vegetables and fruits such as tomatoes, aubergines, paprika, chillies, green and red peppers and cape goose berries, as well as ornamentals such as *Petunia, Schizanthus* and *Lycium* species (Edmonds and Cheweya, 1997). There are more than 1500 *Solanum* species, many of which are also economically important throughout their cosmopolitan distribution. The leaves are alternate and bright green in colour but purple pigmentation may be present (van Rensburg et al., 2007). The plant produces small flowers that are about 4 to 10 mm long with white petals and conspicuous yellow anthers that are arranged in a drooping umbel-like inflorescence. Leaves and tender shoots are widely used as vegetables throughout the world and have provided a food source since early times. In South Africa, *S. americanum*, *S. nigrum* and *S. retroflexum* are the most commonly used species (van Rensburg et al., 2007). Most of these vegetables are harvested from the wild and usually not domesticated. These plants are also believed to be medicinal especially against ulcers, toothache and swellings (Edmonds and Cheweya, 1997; Maanda and Bhat, 2010). The leaves in particular contain relatively high levels of oxalate and cyanide, but the processing and cooking done prior to consumption reduces the content of these bitter and potentially toxic compounds (Maina and Mwangi, 2008).

Cleome gynandra L.

C. gynandra is known as spider flower or cats whiskers in English and *amazonde* in isiZulu. It belongs to the family Capparaceae and grows as a weed in common barren land, road sides, open grass lands and crop fields in many parts of the world (van Rensburg et al., 2007; Mishra et al., 2011). It is widespread in Southern Africa extending to Limpopo, North West, Gauteng, Mpumalanga, KwaZulu-Natal, Free State, the Northern Cape and Namibia (Mishra et al., 2011). It is an erect annual herb, 250 to 600 mm tall; much branched and sometimes may become woody with age (Mishra et al., 2011). The leaves are palmately compound with three to five leaflets. The leaf stalk is 20 to 50 mm long with glandular hairs. When the plant flowers, it produces white petals, sometimes fading to rose pink, 20 to 20 × 3 to 5 mm, rounded at the apex and abruptly narrowed to a basal claw (Mishra et al., 2011). Other species which are occasionally used as vegetables include *Cleome hirta* and *Cleome monophylla* (van Rensburg et al., 2007).

Their leaves and the tips are harvested and used as a vegetable in the northern part of South Africa and generally preferred to vegetable amaranth (van Rensburg et al., 2007).

Corchorus species

The main species include *Corchorus olitorius*, *Corchorus tridens*, *Corchorus asplenifolius* and *Corchorus trilocularis* (van Rensburg et al., 2007). The English name is Jew's Mallow. These slimy vegetables are mostly consumed among rural communities in the northern parts of South Africa including Limpopo, Gauteng and Mpumalanga provinces (Ndlovu and Afolayan, 2008). They are known as *delele* in Tshivenda. *Corchorus* belongs to the family Tiliaceae and is an erect annual herb that varies from 20 cm to approximately 1.5 m in height (van Rensburg et al., 2007; Maanda and Bhat, 2010). The plants are usually harvested from the wild but have the potential to be developed into valuable crops. Very little is known about their role in the overall food acquisition system in different parts of South Africa especially in relation to their contribution to the intake of important micronutrients (Ndlovu and Afolayan, 2008).

Pumpkin and melon leaves

The leaves of "ordinary" pumpkin (*Cucurbita pepo*, *Cucurbita moschata* and *Cucurbita maxima*) and bitter melon (*Citrillus lanatus*) are widely consumed in many parts of Africa. In South Africa, *C. lanatus* is occasionally cultivated as a minor crop in maize fields but most other species are harvested from the wild (van Rensburg et al., 2007). They belong to the family Cucurbitaceae which consist mainly of melons, watermelons, various gourds and pumpkins (Maanda and Bhat, 2010). The seeds of *C. lanatus*, a creeping annual herb with hairy stems and leaves spiny to touch are also widely consumed in some West African countries (Ojieh et al., 2007).

Brassica rapa

This is the non-heading type of Chinese cabbage, an annual flowering vegetable with dark green leaves supported by light green to white petioles that form a rosette (van Averbeke et al., 2007). It is known as *Isiqwashumbe* in isiXhosa and *mutshaina* in Tshivenda. It is a common plant in the Vhembe district, north of the Limpopo province of South Africa (van Rensburg et al., 2007). It belongs to the family Brassicaceae or Cruciferae. It has a stout taproot and may grow to a height of 15 to 30 cm (van Averbeke et al., 2007).

NUTRITIONAL COMPOSITION OF ILVS

Indigenous leafy vegetables constitute an inexpensive source of macronutrients (fibre, starch, proteins and fats) and micronutrients (vitamins and minerals) (Odhav et al., 2007; Makobo et al., 2010; Kwenin et al., 2011), with variations in quantities among families, genera and species (Table 1). The leaves of *Amaranthus* for example have been reported to contain 17.5 to 38.3% dry matter as protein of which 5% is lysine (Mnkeni et al., 2007). Both essential and non essential amino acids are represented in different species of *Amaranthus* in varying amounts. In a study on the nutritional composition of *Amaranthus hybridus*, Akubugwo et al. (2007b) reported 41.1% abundance for isoleucine, leucine, lysine, methionine, cysteine, phenylalanine, tyrosine, threonine, valine and 58.9% for the nonessential amino acids. Other authors have also made similar observations (Aremu et al., 2006; Hassan and Umar, 2006). Many studies carried out in South Africa have also documented the high nutrient content of local vegetables including *Corchorus olitorius*, *Cleome gynandra*, *Cleome monophylla* and *Solanum nigrum* (Mnkeni et al., 2007; Ndlovu and Afolayan, 2008; Akula and Odhav, 2008; van der Walt et al., 2009). In one such study, Ndlovu and Afolayan (2008) reported that the magnesium content of *C*. *olitorius*, a locally consumed vegetable was higher than cabbage (*Brassica oleraceae*) and spinach (*Spinacea oleracea*). This is an indication that its consumption might help meet the daily requirements of this mineral and many others especially in African rural settings where the consumption of micronutrient-deficient starchy staples is common place (Uusiku et al., 2010). However, anti-nutritional factors such as cyanogenic glycosides, oxalate, phytate, saponins and tannins have been reported in some African leafy vegetables (Kumari et al., 2004; Uusiku et al., 2010; Umar et al., 2011; Aregheore, 2012). Some of these compounds may affect the palatability of the species or pose a health hazard when consumed in large quantities. There is therefore the need for empirical studies that would shed more light on the safety parameters as well as the mutagenic potentials of African leafy vegetables. However, there is also the general believe that some of the anti-nutritive factors may contribute to the medicinal potentials of these vegetables and therefore are important as well. In addition, the very laborious and time-consuming traditional processing methods used in processing vegetables in most African settings may eliminate or reduce to safety levels many of the anti-nutritive factors (Aregheore, 2012).

VITAMIN-COMPOSITION OF ILVs

Vitamins A and C

Indigenous leafy vegetables are a rich source of vitamin A which occurs as provitamin A carotenoids such as lutein, α- γ- or β-carotene, violaxanthin and neoxanthin (Uusiku et al., 2010; van Jaarsveld et al., 2014)). However, the bioavailability of these components may vary with vegetable species, chemical nature, processing methods, storage time and conditions. Significant amounts of vitamin C, riboflavin and folate have been reported in many species of *Amaranthus* (Table 1). One hundred grams of these vegetables cooked without oil can contribute to 45% of daily vitamin A requirement (Mnkeni et al., 2007). For this reason and prevention of non communicable diseases, nutrition policies have therefore encouraged the consumption of diets containing more than 400 g/day of fresh vegetables and fruits especially in sub-Saharan Africa where many people are likely to suffer from vitamin A deficiency (Venneria et al., 2012).

Processing methods such as microwave-steaming and stir-frying with oil have been reported to offer greater retention of β-carotene in some vegetables than when boiled or stir-fried with water (Masrizal et al., 1997). On the other hand, eating cooked and pureed spinach leads to higher plasma total β-carotene concentrations, compared to raw consumption (Rock et al., 1998). This could be attributed to the heat destruction of enzymes that may be responsible for β-carotene degradation (Kala and Prakash, 2004). De Pee et al. (1995) reported that reduction in bioavailability of vitamin A from green leafy vegetables could be due to physical inaccessibility of carotenoids in plant tissues which may prevent the release of β-carotene from the matrix and competition for absorption with other carotenoids. Studies to determine the effects of traditional processing methods such as cooking and drying on the nutritional content of African indigenous leafy vegetables are therefore imperative as some of the methods could affect the nature and availability of important nutrients such as β-carotene.

Most ILVs also contain a significant amount of ascorbic acid (Table 1). It is however difficult to determine the contribution of ILVs to dietary vitamin C requirements since it is also greatly affected by cooking and processing methods including oxidative, enzymatic or photo degradation activities. Traditional methods of sun drying which do not involve blanching and sulphiting have been reported to cause ascorbic acid loss in okra, sweet pepper and tomatoes by 46.5%, 69.7% and 74%, respectively (Osunde and Makama, 2007). Furthermore, decreases of 19%, 61% and 100% have been reported in cooked amaranth, dried *Vernonia amygdalina* and dried *Adonsonia digitata* respectively (Uusiku et al., 2010). Low temperature storage of dehydrated vegetables may be employed as a better alternative preservative method since it reduces the degradation of vitamin C and browning (Negi and Roy, 2001). Steam blanching, followed by dehydration have been reported as the most effective preservation methods in retaining ascorbic acid (Uusiku et al., 2010).

Other vitamins

Appreciable amounts of vitamins D, E, K, thiamine, niacin, riboflavin, folate, pantothenic acid, pyridoxine and cyanocobalamin have been reported in many African leafy vegetables (Akubugwo et al., 2007a,b; Uusiku et al.,

Table 1. Macronutrient/vitamin-content of indigenous leafy vegetables consumed in the rural areas of South Africa.

Botanical name	Family	Macronutrient					Vitamin				Reference (s)
		H_2O	Carbs	Prot	Fibre	Fat	Vit. A	Vit. C	Ribof.	Folate	
Amaranthus cruentus	Amaranthaceae	83-9 [a]	4-8[a]	4-6[a]	3[a]	0.2-0.6[a]	327[d]	46-126[d]	0.1-0.4[d]	64[d]	(Odhav et al., 2007; Uusiku et al., 2010)
A. hybrdus	Amaranthaceae	83[a]	6.09[a]	6[a]	2.81[a]	0.5[a]	327[d]	46-126[d]	0.1-0.4[d]	64[d]	(Odhav et al., 2007; Uusiku et al., 2010)
A. dubius	Amaranthaceae	85[a]	7.86[a]	4[a]	2.87[a]	0.2[a]	327[d]	46-126[d]	0.1-0.4[d]	64[d]	(Odhav et al., 2007; Uusiku et al., 2010)
A. spinosus	Amaranthaceae	83-9 [a]	4-8[a]	4-6[a]	3[a]	0.2-0.6[a]	327[d]	46-126[d]	0.1-0.4[d]	64[d]	(Odhav et al., 2007; Uusiku et al., 2010)
A. thunbergii	Amaranthaceae	83-91[a]	4-8[a]	4-6[a]	3[a]	0.2-0.6[a]	327[d]	46-126[d]	0.1-0.4[d]	64[d]	(Odhav et al., 2007; Uusiku et al., 2010)
Cucurbita pepo	Cucurbitaceae	967.7[c]	26.23[c]	2.08[c]	3.72[c]	0.55[c]	194[d]	11[d]	0.1[d]	36[d]	(Kim et al., 2012)
C. moschata	Cucurbitaceae	942.31[c]	43.39[c]	3.05[c]	7.41[c]	0.89[c]	194[d]	11[d]	0.1[d]	36[d]	(Kim et al., 2012)
C. maxima	Cucurbitaceae	840.43[c]	133.53[c]	11.31[c]	10.88[c]	4.20[c]	194[d]	11[d]	0.1[d]	36[d]	(Kim et al., 2012)
Cucumis africanus	Cucurbitaceae	-	-	-	-	-	-	-	-	-	-
Cleome gynandra L.	Capparaceae	81.8-89.6[b]	4.4-6.4[b]	3.1-7.7[b]	1.3-1.4[b]	-	1200[d]	13-50[d]	0.1[d]	217[d]	(van der Walt et al., 2008; Uusiku et al., 2010; Mishra et al., 2011)
Cleome monophylla	Capparaceae	88[a]	3.40[a]	5[a]	2.14[a]	0.7[a]	1200[d]	13-50[d]	0.1[d]	346[d]	(Odhav et al., 2007; Uusiku et al., 2010)
Solanum nigrum	Solanaceae	83-90[a]	2[a]	3-5[a]	2-6[a]	0.6[a]	1070[d]	2[d]	0.3[d]	404[d]	(Uusiku et al., 2010)
Solanum retroflexum	Solanaceae	83-90[a]	2[a]	3-5[a]	2-6[a]	0.6[a]	1070[d]	2[d]	0.3[d]	404[d]	(Uusiku et al., 2010)
Chenopodium album	Chenopodiaceae	83[a]	8.34[a]	5[a]	1.92[a]	0.8[a]	917[d]	31[d]	0.3[d]	30[d]	(Odhav et al., 2007; Uusiku et al., 2010)
Portulaca oleracea	Portulacaceae	93[a]	2.65[a]	3[a]	1.21[a]	0.3[a]	-	-	-	-	(Odhav et al., 2007)
P. afra	Portulacaceae	-	-	-	-	-	-	-	-	-	-
Bidens pilosa	Asteraceae	85-88[a]	2[a]	3-5[a]	3-6[a]	0.4-0.6[a]	985-305[d]	23[d]	0.2[d]	351[d]	(Uusiku et al., 2010)
Corchorus olitorius	Tiliaceae	-	695[c]	162.6[c]	20.30[c]	17.2[c]	-	-	-	-	(Ndlovu and Afolayan, 2008)
Senna occidentalis	Fabaceae	77[a]	9.37[a]	7[a]	2.58[a]	2.2[a]	-	-	-	-	(Odhav et al., 2007)
Vigna unguiculata	Leguminosae	86[a]	2[a]	5[a]	4[a]	0.4[a]	99[d]	50[d]	0.2[d]	141[d]	(Uusiku et al., 2010)
Brassica rapa	Brassicaceae	92-94[a]	5-6[a]	1-2[a]	2-4[a]	0.1-0.3[a]	-	30-113[d]	0-0.2[d]	16[d]	(Uusiku et al., 2010)

H_2O, Water; Carbs, carbohydrates; Prot, proteins; Vit. A, vitamin A; Vit. C, vitamin C; Ribof, Riboflavin; [a], g/100 g of fresh weight; [b], % or mg/100g edible parts; [c], g/kg raw weight; [d], µg/100 g fresh weight; -, not determined.

2010; Erukainure et al., 2011). Various species of *Amaranthus*, *Cucurbita*, *Solanum*, *Brassica* and *Cleome* contain significant amounts of these vitamins (Table 1). Folate amounts of between 72 µg/100 g and 217 µg/100 g have been reported in some *Amaranthus* species including *Amaranthus hybridus* and *A*. *thunbergii*. (van der Walt et al., 2009). If consumed on a daily basis therefore, these vegetables could be an important source of dietary folate. Antioxidant and anti-inflammatory functions of folate and other components of ILVs are very important to improve the health of many South Africans at risk of cardiovascular diseases and also meet the high folate requirements of expectant mothers (van der Walt et al., 2008; 2009). In combination with tetrahydrobiopterin and insulin, folate has been reported to suppress superoxide anion generation and increase endothelial nitric oxide and prostacyclin production, both of which are potent platelet anti-aggregators and vasodilators (Lombardo and Chicco, 2006).

MINERAL COMPOSITION OF ILVS

Indigenous leafy vegetables are important sources of dietary minerals such as iron, zinc, calcium, magnesium, sodium, potassium and phosphorus and unlike vitamins; minerals are more stable to cooking and processing methods (Akubugwo et al., 2007a, b; Odhav et al., 2007; van der Walt et al., 2009). Their ratios, particularly sodium/potassium ratios are vital in the control of high blood pressure while calcium and phosphorus are important in the growth and maintenance of bones, teeth and muscles (Akubugwo et al., 2007a, b). Iron is an important element in the formation of haemoglobin and normal functioning of the central nervous system (Odhav et al., 2007). It is therefore very useful in the control of anaemia, especially in children and expectant mothers living in malaria endemic-regions of Africa (Akubugwo et al., 2007a,b; Uusiku et al., 2010). However, it occurs in the form of non haem iron and its absorption is influenced by factors such as the iron status of the individual, and several factors in the diet such as the presence of inhibitors (oxalates, phytate and fibre) (Kumari et al., 2004) and enhancers (ascorbic acid, β-carotene, fermentable carbohydrates and organic acids) (Uusiku et al., 2010). Just like iron, the absorption of zinc is also inhibited by phytates. Its deficiency may impair normal gastrointestinal and immune function (Uusiku et al., 2010).

Vegetable amaranth, *Solanum nigrum*, *Cleome gynandra* and other dark African leafy vegetables have been well documented as excellent sources of iron (Kumari et al., 2004; Faber et al., 2007; Maina and Mwangi, 2008; van der Walt et al., 2009). The mineral content of these vegetables and others as reported by different investigators are presented in Table 2, modified from Odhav et al. (2007) and Uusiku et al. (2010).

ANTIOXIDANT PROPERTIES OF ILVS AND THEIR ROLE IN HEALTH-MAINTENANCE

Generally, vegetables are good sources of roughages, providing an indigestible matrix which stimulates intestinal muscles and keep them in working order and also prevent constipation through their laxative effect (Seidu et al., 2012). Apart from nutritive value, *Amaranthus spinosus*, *A*. *hybridus*, *A*. *dubius*, *Cleome monophylla*, *Chenopodium album* and other ILVs when included in human diet are also known to play a role in reducing the incidence of oxidative stress-related diseases due to beneficial health functionality of their phenolic constituents (Akula and Odhav, 2008; Jimoh et al., 2011). These bioactive non-nutrient phytochemicals have the potential to reduce the risk of many degenerative human diseases and enhance the immune defence (Onyeka and Mwambekwe, 2007; van der Walt et al., 2009). They include flavonoids, hydrolysable and condensed tannins, coumarins, phenolic acids, stilbenes, lignans and lignins (Uusiku et al., 2010). Most of them are important free radical scavengers with higher *in vitro* antioxidant capacity than vitamins (Gardner et al., 2000; van der Walt et al., 2009). They retard or prevent deterioration, damage or destruction by oxidation (Bhuiyan et al., 2009). Some have the potential to reduce low density lipoprotein, which is the cholesterol involved in depositing fat in the arteries and prevents blood clotting which can reduce the risk for a heart attack or a stroke (Onyeka and Mwambekwe, 2007). Sulphur-containing components, some of which are found in ILVs are known to reduce cholesterol-production in the body thereby helping to keep the blood pressure down. As antioxidants, the phenolic constituents of ILVs protect cells from the damaging effects of free radicals arising from cellular redox reactions (Ebrahimzadeh et al., 2010).

Free radicals are unstable oxygen compounds with an unpaired electron in the atomic electron shell (for example O_2, OH, H_2O_2, HOCl, O_3). They are also known as reactive oxygen species (Gramza et al., 2005). Since all molecules tend to have complete electron pairs, the radicals react aggressively with other molecules, trapping electrons away from them (Gramza et al., 2005). They may not be harmful at low concentrations but at high concentrations, they generate oxidative stress, a deleterious process that can damage cell structures, including lipids, proteins and DNA (Ebrahimzadeh et al., 2010). If free radicals are not removed from the system, they may cause problems including many diseases such as cancer, heart disease, neuro-degenerative diseases and stroke and are responsible for aging (Bhuiyan et al., 2009). According to Lamien-Meda et al. (2008), the higher the polyphenolic constituent of the plant; the greater it's free radical-scavenging ability. Plant phenolic constituents may vary with species, geographical region, climate and age (Modi, 2007; Njume et al., 2011). Odhav et al. (2007) reported antioxidant activities of 96% for *Portulaca*

Table 2. Mineral content (mg/100g) of indigenous leafy vegetables consumed in the rural areas of South Africa (Odhav et al., 2007; Uusiku et al., 2010).

Plant name	Mineral					
	Fe	Ca	P	Na	Zn	Mg
Amaranthus cruentus	0.3-3.8[b]	253-425[b]	-	-	0.02-8.4[b]	105-224[b]
A. hybrdus	21[a]	2363[a]	604[a]	427[a]	18[a]	1317[a]
A. dubius	25[a]	1686[a]	487[a]	347[a]	56[a]	806[a]
A. spinosus	32[a]	3931[a]	629[a]	393[a]	1[a]	1156[a]
A. thunbergii	0.3-3.8[b]	253-425[b]	-	-	0.02-8.4[b]	105-224[b]
Cucurbita pepo	1.5[b]	39[b]	-	-	0.06-0.2[b]	38[b]
C. moschata	1.5[b]	39[b]	-	-	0.06-0.2[b]	38[b]
C. maxima	1.5[b]	39[b]	-	-	0.06-0.2[b]	38[b]
Cucumis africanus	-	-	-	-	-	-
Cleome gynandra	2.6-2.9[b]	31-288[b]	-	-	0.6-0.8[b]	44-76[b]
Cleome monophylla	24[a]	3203[a]	784[a]	25[a]	5[a]	371[a]
Solanum nigrum	85[a]	2067[a]	478[a]	431[a]	23[a]	277[a]
Chenopodium album	13[a]	1490[a]	797[a]	683[a]	109[a]	1239[a]
Portulaca oleracea	42[a]	1361[a]	333[a]	148[a]	34[a]	1037[a]
P. afra	-	-	-	-	-	-
Bidens pilosa	17[a]	1354[a]	504[a]	290[a]	22[a]	658[a]
Corchorus olitorius	2.0[b]	-	-	-	0.05[b]	-
Senna occidentalis	11[a]	2230[a]	417[a]	347[a]	9[a]	854[a]
Vigna unguiculata	0.3-3.0[b]	188[b]	-	-	0.23[b]	60[b]
Brassica rapa	0.5-3.5[b]	27-31[b]	-	-	0.9-1.3[b]	13[b]

Fe, Iron; Ca, calcium; P, phosphorus; Na, Sodium; Zn, zinc; Mg, magnesium; [a], mg/100 g dry weight; [b], mg/100 g fresh weight; -, not determined.

oleracea and *Justicia flava* and 92% for *Solanum nigrum* while Stangeland et al. (2009) reported antioxidant activities of 1.56 mmolTE/100 g, 1.0 mmolTE/100 g and 0.87 mmolTE/100 g for *Cleome gynandra*, A*maranthus* species and *Solanum macrocarpon* respectively.

Due to the generally low level of crude fat in many locally consumed indigenous vegetable leaves and their high levels of total unsaturated fatty acid (van der Walt et al., 2008), consumption in large amounts would be beneficial to individuals suffering from overweight or obesity, and this would constitute a good dietary habit (Erukainure et al., 2011). Ascorbic acid found in most ILVs is a free radical scavenger and in addition, is able to regenerate other antioxidants such as tocopheroxyl and the carotene radical cation from their radical species (Uusiku et al., 2010). It is important to note that some of the components classified as antioxidants, for example, tannins reduce the availability of certain nutrients such as proteins and starch by forming complexes with them or the enzymes required for their metabolism. Tannins alongside phenolic acids and flavonoids also reduce iron availability and interfere with protein absorption (Uusiku et al., 2010).

CONCLUSION

Consumption of ILVs could offer significant health-protection benefits given that some of these crops are functional foods with health-promoting and immune-strengthening properties. Considering their potential nutritional value, ILVs could contribute in a major way to the food security and balanced diets of rural households in South Africa and different parts of the world. Identifying ILVs of high nutrient content could be a major step in addressing South Africa's food security problems. There is a need to create market awareness for ILVs considering that they are fairly easy to cultivate, resistant to pest and disease and produce very stable yields even under difficult climatic conditions. In order to avert the loss of micronutrients by traditional processing methods, we advocate the use of shade drying to reduce photo degradation, thin slicing to reduce drying time and use of pre-drying treatment such as blanching or sulphating to reduce enzyme activities and loss of vitamins.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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