

# Phytochemical Composition and Nutritional Quality of Selected Tropical Edible Grains of Northern Nigeria

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## ABSTRACT

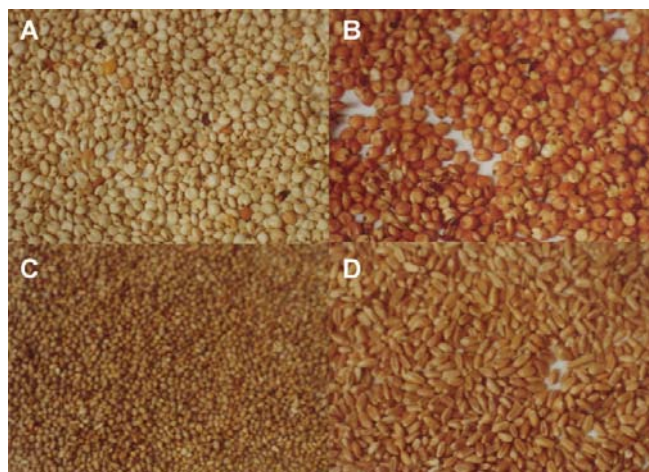
Phytochemical composition, proximate, vitamins and minerals contents of *Sorghum bicolor*, *Pennisetum typhoides* and *Triticum aestivum*, which are well known Nigerian food and medicinal plants were assessed with a view to establishing and understanding their nutritional values. Phytochemical studies revealed the presence of bioactive compounds comprising flavonoids (0.90-6.08 mg.100 g<sup>-1</sup>), alkaloids (1.13-1.63 mg.100 g<sup>-1</sup>), tannins (0.28-1.02 mg.100 g<sup>-1</sup>), phenols (0.05-0.07 mg.100 g<sup>-1</sup>) and saponins (0.09-0.20 mg.100 g<sup>-1</sup>). The protein, carbohydrates, lipids and fiber content were 12.25-18.81%, 71.19-80.41%, 2.68-6.03% and 1.36-4.38%, respectively. The food energy content ranges from 387.54 to 411.86 cal.g<sup>-1</sup>. The grains are rich in B-vitamins such as niacin (1.50-4.60 mg.100 g<sup>-1</sup>), riboflavin (0.10-0.66 mg.100 g<sup>-1</sup>) and thiamine (0.32-1.36 mg.100 g<sup>-1</sup>) while ascorbic acid content ranges from 6.16 to 12.32 mg.100 g<sup>-1</sup>. These grains are good sources of minerals comprising calcium (2.41-2.61 mg.100 g<sup>-1</sup>), phosphorus (0.28-0.32 mg.100 g<sup>-1</sup>), potassium (0.18-0.49 mg.100 g<sup>-1</sup>), and magnesium (1.22-1.95 mg.100 g<sup>-1</sup>). The cereals can be considered as sources of quality raw materials for food and pharmaceutical industries.

**Keywords:** cereals, chemical composition, flavonoids, nutraceutical, phenolic compounds

## INTRODUCTION

Northern Nigeria is richly endowed with edible grains, which serve as food and medicine for man as well as feed for animals. The grains not only serve as industrial raw materials but also as staple food throughout the tropics. They are eaten in different forms; sometimes as pastes, roasts, porridges and pottages. They are processed into flour, starch, bran, oil or cakes (Ihekeonye and Ngoddy 1985). These grains are harvested from selected cereals comprising Guinea corn (*Sorghum bicolor* (L.) Moench), millet (*Pennisetum typhoides* (Brum.) Stapf and Hubb) and wheat (*Triticum aestivum* (L.) Thell) (Fig. 1).

The grains are rich in phytochemicals, which are vital in health promotion, disease prevention and drug production.



**Fig. 1** Seeds of Guinea corn (*Sorghum bicolor* (L.) Moench) var. white dawa (A), var. red dawa (B), (C) millet (*Pennisetum typhoides* (Brum.) Stapf and Hubb) (D) wheat (*Triticum aestivum* (L.) Thell).

Phytochemicals act as antioxidants, stimulate the human system, induce protective enzymes in the liver or block damage to genetic materials (Okwu 2004).

Phytochemicals exhibit a wide range of biological functions due to their antioxidant properties. Several types of polyphenols (phenolic acid, hydrolysable tannins and flavonoids) show anti-carcinogenic and anti-mutagenic effects (Urquiaga and Lieghton 2000; Kamath *et al.* 2004; Okwu 2004). Polyphenols interfere in many steps of malignant tumors, inactivating carcinogens, inhibiting the expression of mutagens and the activity of enzymes involved in the activation of procarcinogens. Polyphenols activate enzymatic systems, which are responsible for the detoxification of xenobiotics (Urquiaga and Leighton 2000; Okwu 2004). Polyphenolic flavonoids inhibit the initiation, promotion and progression of tumors (Urquiaga and Leighton 2000; Kamath *et al.* 2004; Okwu 2004). Recently, plant flavonoids have attracted the attention of researchers as potentially important dietary cancer chemo-protective and preventive agents (Hertog *et al.* 1993). Naturally occurring flavonoids are potentially antiallergic, anticarcinogenic, antiviral and antioxidant (Close and McArthur 2002). Phytochemicals, as antioxidants play vital roles in human health (Elargovan *et al.* 1994; del Rio *et al.* 1997; Close and McArthur 2000; Kamath *et al.* 2004; Okwu 2004).

Isoflavones, which are effectively phytoestrogens, modulate estrogen levels in humans. They are of clinical value in low estrogens states like menopause or imbalanced and toxic estrogen-sensitive conditions such as breast, uterine and prostate tumor growth (Okwu 2005; Okwu and Omodamiro 2005). Phytochemicals regulate, protect and control prostate and testicular cancer and semen quality in men (Verger and Leblanc 2003). Isoflavones prevent breast cancer, cystic ovaries and endometriosis among women (Verger and Leblanc 2003). It is now well known that people who consume grains, seeds and fruits experience less breast, uterine, and prostate cancer and increase in semen quality.

*Sorghum bicolor* (L.) Moench (Guinea corn) is a major

grain of the tropical savannah. It is an indigenous cereal of Africa (Akobundu 1987), cultivated extensively in Ethiopia, but today it is grown not only in Africa but also in India, Pakistan, China and the United States (Enwere 1998). Sorghum belongs to the tribe Andropogonea of the grass family Poaceae. Sugar cane (*Saccharum officinarum*) is a member of this tribe and a close relative of sorghum. The genus sorghum is characterized by spikelets borne in pairs (Lupien 1990). *Sorghums* are now widely distributed throughout the tropics, subtropics and warm temperate areas of the world. It is a summer annual crop, erect with much variability in growth characteristics; culms are solid or sometimes with spaces in pith. It grows from 0.6-5 m tall, depending on the variety and growing conditions (FAO 1980; Carter *et al.* 1989; Maunder 2006; Wikipedia 2006).

The leaves are broad and coarse, similar in shape to those of corn but shorter and wider. The blades are glabrous and waxy; sheaths encircle culm and have overlapping margins, sometimes recurved, usually compact in most grain *Sorghums*. It produces prop roots, which may grow from culm nodes. The seeds are white, red or brown (FAO 1980; Maunder 2006).

In Northern Nigeria, the grains are grown for food, forage, syrup and sugar. It is eaten mostly in the North where the grains are used for the preparation of indigenous foods such as tuwo, ogi, dawa, weaning food (hatis), pap, flour, porridges, pottages and alcoholic drinks (Enwere 1998). *Sorghum* is an important summer fodder where temperatures are high and rainfall insufficient for maize (FAO 1980). In many parts of the world, sorghum has traditionally been used in food products and various food items; porridges, unleavened bread, cookies, cakes, couscous and malted beverages are made from this versatile grain (NGSB, 2006; TGSB, 2006). Most importantly is the use of *Sorghum* for silage or green soiling or for hay when grown under irrigation in very dry areas like Sokoto, Kano and Maiduguri.

The use of *Sorghum* as an adjunct is well known. Adjuncts refer to any material, which can be used in place of malt as a source of carbohydrate for production of beer. Apart from providing cheap carbohydrate material, adjuncts are usually lower in protein and phenolic compounds, resulting in producing beer, which is paler in colour and blander in flavour (Little 1986). Research results confirmed that *Sorghum* could be used as an adjunct (Little 1986). Starch from *Sorghum* can be converted into syrups just as is done for maize (*Zea mays*).

In herbal medicine, *Sorghum* has been reported to be an antiabortive, cyanogenetic, demulcent, diuretic and poison. *Sorghum* is a folk remedy for cancer, epilepsy, flux and stomach ache (Duke and Wain 1981). The seed has been used for breast disease and diarrhoea while the stem is used for tubercular swellings. The root is used for malaria in Southern Zimbabwe (Duke and Wain 1981). The seed husk is braised in brown sugar with little water and applied to the chest of measles patients. The seeds are considered useful in curing fluxes (Perry 1980). It was reported (Morton 1981; Igoli *et al.* 2002, 2005) that people drink the leaf decoction for measles. The seeds are toasted and pulverized for treating diarrhoea. In Brazil, decoction from the seed of *Sorghum* is used for treating bronchitis, cough and other chest ailments. The ash produce from grains is used in treating goiter. However, *Sorghum* contains hydrocyanic acid and the alkaloid hardenine (Morton 1981). Varieties differ considerable in hydrogen cyanide (HCN) poisoning. The cyanide content decreases as the grains mature. Young plants and suckers are more prone to cyanide content, particularly when suffering from drought. HCN is destroyed when fodder is ensiled or cured as hay (FAO 1980). Kaffir-corn grain is edible, but the leaves and stems of the plant are toxic to animals due to the presence of the cyanogenic glucoside dihurin (Enwere 1998; Maunder 2006).

*Triticum aestivum* L. Thell (wheat) provides the world's largest source of plant food. The main center of distribution of cultivated wheat is Egypt, Iran, India, China, Turkey,

Japan, North America, Argentina and Australia (Enwere 1998). The crop is grown in different seasons depending upon the climate and altitude. Wheat is a herbaceous plant with broad leaf which grows up to a height of 0.6-1.2 m. The plant has a small shallow rooting system. Flowers are perfect but incomplete, the petals being absent. The mature seeds are an achene consisting of true seed surrounded by a thick hull (Myers and Mienke 1994). Wheat is used mainly to produce flour for baking, feed and fiber for industrial purposes (Enwere 1998).

In Nigeria, the seed is used to produce farinha flour, semolina and semovita. The flour is used for the production of bread, rolls, pie-cakes, crackers and doughnuts (Enwere 1998). Wheat bran is used mainly for the formulation of animal feed.

In herbal medicine, it is used as an antihemorrhagic, anti-inflammatory and hypotensive drug. The seed is effective against lung ailments including lung tumors and pulmonary sepsis (Bakashi *et al.* 1999).

In India, the roots are used for lung diseases, rheumatism, typhoid and urinary complaints (Bakshi *et al.* 1999).

*Pennisetum typhoides* (Burn) Stapf and Hubb (Bulrush Millet) is the most widely grown member of millet in Northern Nigeria. It is more drought-tolerant than *Sorghum* and is consequently grown in the semi-arid tropics (Akobundu 1987). It is extensively grown in India and Egypt where it is used as human food. It is also cultivated in China for human use but in the United States, it is grown mainly for forage (Enwere 1998). Kalinová (2007) provides a comprehensive review on the nutritionally important constituents of proso millet (*Panicum miliaceum*).

Although millet thrives well in drier parts of the tropics, there are indications that the crop will do better if grown with more adequate water supply. The plants have been used as antioxidants, anti-cancer and anti tumor agents in herbal medicine (Bakshi *et al.* 1999; Kamath *et al.* 2004).

In spite of the various uses of *S. bicolor*, *P. typhoides* and *T. aestivum* as food and drugs, raw materials and feed in Nigeria, there is a paucity of literature regarding the phytochemical profile. The phytoconstituents of these crops have not been fully documented. The present study was undertaken to evaluate the secondary metabolite constituents and consequently assess the nutritional quality of *S. bicolor*, *T. aestivum* and *P. typhoides*. The aim is to generate and provide alternative raw material for food and drug industries and seek means in which peasant farmers of rural communities can economically vary their market produce.

## MATERIALS AND METHODS

Seeds were purchased from Umuahia main Market, Umuahia Abia State, Nigeria. The plant materials were identified and authenticated by Dr. A. Meragini of the Taxonomy Section, Forestry Department, Michael Okpara University of Agriculture, Umudike.

The seeds of *S. bicolor* (white and red varieties), *P. typhoides*, and *T. aestivum* were each weighed to 500 g and separately ground into uniform flour using a Thomas Wiley machine (Model: Ed-5 USA). The flours were then dried and stored for up to three months in airtight bottles for chemical analysis. The yields were as follows: *S. bicolor* (red grain) 380.5 g, *S. bicolor* (white grain) 385.5 g, *P. typhoides* 392.10 g, and *T. aestivum* 393.20 g.

## Chemical analysis

Total nitrogen content was determined by using Kjeldahl digestion apparatus (Micro-Kjeldahl: MD 55 Singapore). 0.2 g of each sample was digested with 5 cm<sup>3</sup> of conc. H<sub>2</sub>SO<sub>4</sub> and 1 g catalyst mixture (99 g of K<sub>2</sub>SO<sub>4</sub> and 0.8 g of CuSO<sub>4</sub> ground together) in a fume cupboard. It was heated until the solution became clear and colourless. A few drops of hydrogen peroxide were added towards the end to assist in clearing. The solution was cooled and transferred into the distillation tube. This was distilled into 5 cm<sup>3</sup> after boric acid indicator solution in a 50 cm<sup>3</sup> flask. 10 cm<sup>3</sup> of 40% NaOH was added and distilled until the volume of distillate reached 10 cm<sup>3</sup>. The outside of the delivery tube was washed with

a little water. The solution in the flask was titrated with 0.01 M HCl until the first permanent tinge appears. The blank was also titrated in the same way and the titre values for sample were obtained.

$$\%N = \frac{\text{Vol. of HCl used} \times \text{Molarity} \times 14 \times 100}{\text{Mass of sample}} \quad (1)$$

Most protein contain about 16% nitrogen, so that:

16 mg N = 100 mg protein

1 mg N = 6.25

$$\% \text{ Protein} = N \times 6.25 \quad (2)$$

where N = % nitrogen.

Crude fat (ether extract), crude fiber and ash content were determined according to the methods of AOAC (1984).

Total carbohydrates were estimated as the remainder after accounting for ash, crude fiber, protein and fat (Muller and Tobin 1980). The gross food energy was estimated according to the methods of Osborne and Voogt (1978), by using the equation:

$$FE = (\%CP \times 4) + (\%CHO \times 4) + (\%Fat \times 9) \quad (3)$$

where:

FE = food energy (in g calories)

Cp = crude protein (in %), CHO = carbohydrates

The major elements were comprised of calcium, phosphorus, sodium, potassium and magnesium, all of which were determined according to the method of Shahidi *et al.* (1999). The ground plant samples were stirred with a 2 mm rubber sieve and 2 g of each of the plant samples were weighed and subjected to dry ashing in a well-cleaned porcelain crucible at 555°C in a muffle furnace. The resultant ash was dissolved in 5 ml of HNO<sub>3</sub>/HCl/H<sub>2</sub>O (1: 2: 3) and heated gently on a hot plate until brown fumes disappeared. To the remaining material in each crucible, 5 ml deionised water was added and heated until a colourless solution was obtained. The mineral solution in each crucible was transferred into a 100 cm<sup>3</sup> volumetric flask by filtration through a Whatman No. 42 filter paper and the volume was made to the mark with deionized water. The solution was used for elemental analysis by atomic absorption spectrophotometer (AAS) UNICAM 919 Solar Model.

A 10 cm long cell was used and concentration of each element in the sample was calculated according to the percentage of dry matter. Phosphorus content of the digest was determined calorimetrically according to the method described by Nahapetain and Bassiri (1995). To 0.5 ml of the diluted digest, 4 ml of demineralised water, 3 mls of 0.75 M H<sub>2</sub>SO<sub>4</sub>, 0.4 mls of 10% (NH<sub>4</sub>)<sub>6</sub>Mo<sub>7</sub>O<sub>24</sub>.4H<sub>2</sub>O and 0.4 mls of 2% w/v ascorbic acid were added and mixed. The solution was allowed to stand for 20 mins and absorbance readings were recorded at 660 nm. The content of phosphorus in the extract was determined.

### Phytochemical determination

Two g of the sample were defatted with 100 ml of diethyl ether using a Soxhlet apparatus for 2 hrs to get a fat-free sample.

### Alkaloid determination

Five g of the sample were weighed into a 250 ml beaker and 200 ml of 20% acetic acid in ethanol was added and covered to stand for 4 hrs. This was filtered and the extract was concentrated using a water-bath to one-quarter of the original volume. Concentrated ammonium hydroxide was added drop wise to the extract until the precipitation was complete. The whole solution was allowed to settle and the precipitate was collected by filtration and weighed. (Harborne 1973; Obadoni and Ochuko 2001).

### Tannin determination

500 mg of the sample was weighed into 100 ml plastic bottle. 50 ml of distilled water was added and shaken for 1 hr in a mechanical shaker. This was filtered into a 50 ml volumetric flask and

made up to the mark. Then 5 ml of the filtrate was pipette out into a tube and mixed with 3 ml of 0.1 M FeCl<sub>3</sub> in a 0.1 N HCl and 0.008 M potassium ferrocyanide. The absorbance was measured in a spectrophotometer at 760 nm wavelength within 10 min. A blank sample was prepared and the colour also developed and read at the same wavelength. A standard was prepared using tannic acid to get 100 ppm and measured (Van-Burden and Robinson 1981).

### Determination of phenols

For the extraction of the phenolic component, the fat free sample was boiled with 50 ml of ether for 15 min. Five ml of the extract was pipette into a 50 ml flask then 10 ml of distilled water was added. Two ml of ammonium hydroxide solution and 5 ml of concentrated amyl alcohol were also added. The samples were made up to mark and left to react for 30 min for colour development. The absorbance of the solution was read using a spectrophotometer at 505 nm wavelength (Harborne 1973; Obadoni and Ochuko 2001).

### Saponin determination

The samples were ground. Twenty g of each plant samples were dispersed in 200 ml of 20% ethanol. The suspension was heated over a hot water bath for 4 hrs with continuous stirring at about 55°C. The mixture was filtered and the residue re-extracted with another 200 ml of 20% ethanol. The combined extract was reduced to 40 ml over water bath at about 90°C. The concentrate was transferred into a 250 ml separator funnel and 20 ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the other layer was discarded. The purification process was repeated. 60 ml of *n*-butanol was added. The combined *n*-butanol extract were washed twice with 10 ml of 5 % aqueous sodium chloride. The remaining solution was heated in a water bath. After evaporation, the samples were dried in the oven to a constant weight. The saponin content was calculated in percentage (Obadoni and Ochuko 2001).

### Flavonoid determination

Ten g of the plant samples were extracted repeatedly with 100 ml of 80% aqueous methanol at room temperature. The whole solution was filtered through Whatman filter paper No 42 (125 mm). The filtrate was later transferred into a crucible and evaporated to dryness over a water bath and weighed (Boham and Kocipai 1994).

### Determination of riboflavin

Five g of the sample was extracted with 100 ml of 50% ethanol solution and shaken for 1 hr. This was filtered into a 100 ml flask; 10 ml of the extract was pipette into 50 ml volumetric flask. 10 ml of 5 % potassium permanganate and 10 ml of 30% H<sub>2</sub>O<sub>2</sub> were added and allowed to stand over a hot water bath for about 30 min. 2 ml of 40% sodium sulphate was added. This was made up to 50 ml mark and the absorbance measured at 510 nm in a spectrophotometer (SKALAR Analyzers 2000).

### Determination of thiamin

Five g of the sample were homogenized with ethanolic sodium hydroxide (50 ml). It was filtered into a 100 ml flask. Ten ml of the filtrate was pipette and the colour developed by addition of 10 ml of potassium dichromate and read at 360 nm. A blank sample was prepared and the colour also developed and read at the same wavelength (SKALAR Analyzers 2000).

### Determination of niacin

Five g of the sample was treated with 50 ml of 1 N sulphuric acid and shaken for 30 min. 3 drops of ammonia solution were added to the sample and filtered. Ten ml of the filtrate were pipette into a 50 ml volumetric flask and 5 ml potassium cyanide was added. This was acidified with 5 ml of 0.02 N H<sub>2</sub>SO<sub>4</sub> and absorbance measured in the spectrophotometer at 470 nm wavelength (SKALAR Analyzers 2000).

## Determination of ascorbic acid (Vitamin C)

Five g of the sample was weighed into an extraction tube and 100 ml of EDTA/TCA (2:1) extracting solution were mixed and the mixture shaken for 30 min. This was transferred into a centrifuge tube and centrifuge at 3000 rpm for about 20 min. It was transferred into a 100 ml volumetric flask and made up to 100 ml mark with the extracting solution. 20 ml of the extract was pipette into a volumetric flask and 1% starch indicator was added. These were added and titrated with 20% CuSO<sub>4</sub> solution to get a dark end point (Baraket *et al.* 1993).

## Statistical analysis

All measurements were replicated three times and standard deviation determined. The students *t*-test at  $P < 0.05$  was applied to assess the difference between the means (Steel and Torrie 1980).

## RESULTS AND DISCUSSION

The phytochemical content of *S. bicolor*, *P. typhoides* and *T. aestivum* is shown in **Table 1**. The flavonoid content was very high in *S. bicolor* (red dawa), at 6.08 mg.100 g<sup>-1</sup>. White dawa contained 1.88 mg.100 g<sup>-1</sup> while *P. typhoides* contained 1.70 mg.100 g<sup>-1</sup> of flavonoids and *T. aestivum* contained 0.90 mg.100 g<sup>-1</sup> of flavonoid. The flavonoid pigments are responsible for the red colours of *S. bicolor*. Flavonoids are widely distributed groups of polyphenolics compounds characterized by a common benzopyrone ring structure that has been reported to act as antioxidants in many biological systems. The family encompasses flavonoids, flavanones, anthocyanidins, flavones and flavonols (Waladkhami and Clemens 2001). In addition to their free-radical scavenging activity, flavonoids have multiple biological activities, including vasodilatory, anti-carcinogenic, anti-allergic, anti-viral and estrogenic effects as well as being inhibitors of phospholipase A2, cyclooxygenase, lipoxygenase, glutathione reductase and xanthine oxidase (Ho *et al.* 1992; Middleton and Kandaswami 1992; Kandaswami and Middleton 1998; Waladkhami and Clemens 2001; Okwu and Omodamiro 2005). Hyperin, rutin and quercetin are the major flavonoids isolated from *S. bicolor* and *T. aestivum* and these compounds have been known to be powerful anti-oxidants (Fabjan *et al.* 2003). Rutin and quercetin prevents platelet stickiness and hence platelet aggregation (Okwu and Emenike 2006).

In relation to the flavonoid content, cereals reinforce the stability of the capillary vessels and improve venous blood flow. As antioxidants, flavonoids from cereals help in the digestion and assimilation of food to the body system (Kamath *et al.* 2004; Okwu and Emenike 2006). These supported the use of *S. bicolor*, *T. typhoides* and *T. aestivum* in herbal medicine as a remedy for cancer, epilepsy and flux.

Apart from flavonoids, other secondary metabolite constituents of *S. bicolor*, *T. aestivum* and *P. typhoides* detected include the alkaloids. High quantity of alkaloids was found in *S. bicolor* (red dawa), at 1.63 mg.100 g<sup>-1</sup>, followed by *T. aestivum*, which contained (1.26 mg.100 g<sup>-1</sup>) of alkaloids. The least alkaloids were detected in *P. typhoides* (1.13 mg.100 g<sup>-1</sup>). The high alkaloid content of these crops may be responsible for the toxic effects of cereals, particularly *S. bicolor* in which dhurrin has been isolated in many varieties (Enwere 1998). Evidently dhurrin is highly toxic due to its ability to produce hydrogen cyanide HCN when hydrolysed. As little as 0.5 g of HCN is sufficient to

kill cattle (Enwere 1998). It should be noted that dhurrin occurs in the leaves but not in the grains. However, pure isolated plant alkaloids and their synthetic derivatives are used as a basic medicinal agent for their analgesic, anti-spasmodic and bacterial effects (Okwu 2004, 2005). They exhibit marked physiological activity when administered to animals like cattle, goats and sheep. Again, the high alkaloid content explains their therapeutic and medicinal properties. Most plant parts that are used in the curing of diseases contain alkaloids, for example *Azadirachta indica* (the neem tree) used in the cure of malaria also contains alkaloids (Stray 1998; Adesegun and Coker 2001). Quinine, isolated from *Cinchona* bark is the oldest known effective anti-malaria agent (Volhard and Schone 1994).

Tannin content is high in *S. bicolor* (red dawa), at 1.02 mg.100 g<sup>-1</sup>, followed by *P. typhoides* with 0.98 mg.100 g<sup>-1</sup> and *T. aestivum* with 0.59 mg.100 g<sup>-1</sup>. Some *Sorghum* varieties contain tannins, which are polyphenolics and can be used as basis for classifying *Sorghum* into two groups comprising those containing negligible levels of tannins, as contained in the white dawa variety (0.28 mg.100 g<sup>-1</sup>) of tannin and those containing appreciable levels of tannins like the red dawa variety containing 1.02 mg.100 g<sup>-1</sup>). The presence of tannins and alkaloids on the grains behave as a nutritional inhibitor because they combine with proteins and this makes them indigestible and unavailable to the body (Enwere 1998). Therefore these grains with high tannins and alkaloid content should be properly processed before being used as food, especially for humans. Indigenous people have learnt how to use these grains as a source of digestible food. Some of the methods include germination, soaking in water for a long time and adequate cooking (Ihekoye and Ngoddy 1985; Enwere 1998). The phenolic content ranges from 0.05 mg.100 g<sup>-1</sup>, obtained in both *S. bicolor* and *T. aestivum* to 0.07 mg.100 g<sup>-1</sup> found in *P. typhoides*. The two main phenolic classes are flavonoids and condensed tannins. They were found in considerable quantities in the grains and they exist as polyphenolics. Polyphenols levels are high in *Sorghum* types with a brown pericarp and colored testa. There are significant levels of polyphenols in *Sorghum* with a red pericarp and no testa and very low polyphenols content exist in unpigmented grains (Enwere 1998). Although sorghum is rich in phenolics and tannins which are proven anticancer and cardioprotective constituents, human consumption of sorghum is limited (Kamath *et al.* 2004). However, antioxidant rich sorghum varieties currently being studied offer high levels of phenols and tannins, which are two phytochemicals that have been linked to cancer prevention and improved cardiovascular health (Wikipedia 2006).

Recently, there is a growing interest in polyphenolic compounds as therapeutic agents against many diseases such as cardiac and cerebral ischemia, arteriosclerosis and rheumatic or pulmonary diseases (Quettier-Delen *et al.* 2000; Oladiji *et al.* 2007). The activated phagocytic cells are known to produce potentially destructive oxygen species like superoxide anion (O<sub>2</sub><sup>-</sup>), hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) and hypochlorous acid (HOCl) during chronic inflammatory disorders (Ho *et al.* 1991; Quettier-Delen *et al.* 2000; Bhargava *et al.* 2005). Many polyphenolics are known to exhibit antioxidative properties (Kamath *et al.* 2004). They are oxygen free radical scavengers (Quettier-Delen *et al.* 2000; Kamath *et al.* 2004). Phenolic flavonoids are also excellent hydroxyl radical scavengers (del Rio *et al.* 1997; Kamath *et al.* 2004). Some sorghum varieties are rich

**Table 1** Phytochemical composition of *Sorghum bicolor*, *Pennisetum typhoides* and *Triticum aestivum* grains on a dry weight basis (mg.100 g<sup>-1</sup>).

Scientific name	Common name	Local name	Alkaloids	Flavonoids	Tannins	Phenols	Saponins
<i>Sorghum bicolor</i>	Guinea corn	Red dawa	1.63 ± 0.22 <sup>a</sup>	6.08 ± 0.11 <sup>b</sup>	1.02 ± 0.11 <sup>b</sup>	0.05 ± 0.01 <sup>a</sup>	0.18 ± 0.20 <sup>a</sup>
<i>S. bicolor</i>	Guinea corn	White dawa	1.18 ± 0.10 <sup>a</sup>	1.88 ± 0.22 <sup>a</sup>	0.28 ± 0.20 <sup>a</sup>	0.06 ± 0.11 <sup>a</sup>	0.20 ± 0.10 <sup>a</sup>
<i>Pennisetum typhoides</i>	Millet	Jero	1.13 ± 0.11 <sup>a</sup>	1.70 ± 0.10 <sup>a</sup>	0.98 ± 0.10 <sup>a</sup>	0.07 ± 0.10 <sup>a</sup>	0.17 ± 0.10 <sup>a</sup>
<i>Triticum aestivum</i>	Wheat	Wheat	1.26 ± 0.20 <sup>a</sup>	0.90 ± 0.10 <sup>a</sup>	0.59 ± 0.10 <sup>a</sup>	0.05 ± 0.10 <sup>a</sup>	0.09 ± 0.11 <sup>a</sup>

Data are the means ± standard deviation of triplicate determinations on a dry weight basis. Values with the same superscript in each column are not significantly different at  $P < 0.05$ .

in antioxidants and all sorghum varieties are gluten-free, an attractive alternative for wheat allergy sufferers (TGSB 2006). The antioxidant content and other health benefits such as absence of wheat-type glutens, which aggravate celiac sprue and other wheat gluten allergies, prevention of cancer and cardiovascular disease prompted the utilization of sorghum as nutraceutical and functional foods. Functional foods are those that resemble traditional foods but render benefits beyond their nutrition and energy value in promoting health and preventing certain chronic diseases especially cardiovascular disease, cancer, diabetes, arthritis and arrhythmia (Shahidi 2002; Zhao 2007).

The grains of *S. bicolor*, *P. typhoides* and *T. aestivum* have a high content of protein, carbohydrates, lipids and fiber (Table 2). The highest protein content was obtained from *T. aestivum* (18.81%) followed by *S. bicolor* (white dawa) which contained 14.88% of protein while the red dawa variety of *S. bicolor* had the least protein content (12.25%). The protein content of these grains is comparable to the protein content of buckwheat (*Fagopyrum esculentum*), oats (*Avena sativa*), barley (*Hordeum vulgare*) and two-rowed barley (*Hordeum distichum*) grains (Bhargava *et al.* 2005). Our results are similar to the findings of Robinson (1980) and Bhargava *et al.* 2005 who reported the nutritional composition of buckwheat seed to be 12% protein, 2.3% fat, 73.3% carbohydrate, 10.9% fiber and 2.1% ash content. The amino acid profile of *S. bicolor*, *T. aestivum* and *P. typhoides* protein is quite good as compared to other traditional used cereals such as buckwheat, maize, barley and rye (Thacker *et al.* 1984; Bhargava *et al.* 2005). However, nutritionally, they are limited in lysine, threonine, tryptophan and methionine (Ihekeronye and Ngoddy 1985). The intake of *S. bicolor*, *T. aestivum* and *P. typhoides* grains reduces hypertension and hypercholesterolemia in humans (He *et al.* 1995; Jiang *et al.* 1995; Kayashita *et al.* 1997). The protein and starch in sorghum grain are more slowly digested than other cereals and slower rates of digestibility are particularly beneficial for diabetes (Wikipedia 2005). *S. bicolor* have the highest carbohydrate with red dawa containing 80.41% and white dawa 76.96%; *P. typhoides* had 74.12% and *T. aestivum* 71.19%. The carbohydrate content of cereals mainly comprises starch, dietary fiber, sucrose, glucose, fructose and raffinose (Lupien 1990; Maunder 2006). With the exception of dietary fiber and starch, all other carbohydrates (glucose, fructose, sucrose and raffinose) are water soluble and sweet tasting sugars.

Insoluble starch is made up of amylose and amylopectin (Lupien 1990).

Similarly, the value of crude fiber was found to be highest in *S. bicolor* (white dawa) containing (4.38%), followed by *T. aestivum* (2.34%) and *P. typhoides* (1.96%). The least crude fiber content was found in *S. bicolor* (red dawa) varieties, which contained 1.36%. Cereals provide dietary fiber, soften stool and enhance waste elimination, including bile acids, sterols and fat (Lupein 1990). Fiber acts as an authentic broom in the intestine absorbing toxins and carrying out harmful substances such as biliary acids, the precursor of cholesterol (Roger 1999). Cereal fiber, when taken, swells with water. This however, increases in volume many fold. This consequently gives consistency to the feces and facilitates its transit throughout the colon until it is expelled through the rectum. When the diet contains too little fiber, the feces are hard, dry and concentrated. This eventually causes the intestine to make effort to eliminate them. It therefore results in, or worsens several problems such as intestinal diverticulum, hemorrhoids and even cancer of the colon (Roger 1999, 2002; Okwu and Emenike 2007). Fiber is an indispensable component of a healthy food. This is because it is devoid of intestinal constipation. Fiber has a physiological effect on the gastrointestinal function by promoting the reduction of tracolonic pressure, which is beneficial in diverticular disease such as cancer of the colon and hemorrhoids (Akobundu 1999; Roger 1999; Okwu and Emenike 2007).

*P. typhoides* have the highest lipid content (6.03%), followed by *S. bicolor* (red dawa), which contains 4.58%; *T. aestivum* contains 3.06% and *S. bicolor* (white dawa) 2.68%. The fatty acid profile comprises myristic, palmitic, stearic, hexadecanoic, oleic and linoleic acids as well as phospholipids (Enwere 1998). The energy values ranged from 387.54 cal g<sup>-1</sup> in *T. aestivum* to 411.86 cal g<sup>-1</sup> in red dawa while white dawa and *P. typhoides* contained 391.48 cal g<sup>-1</sup> and 405.51 cal g<sup>-1</sup> respectively. This high energy value might be due to high lipids content from the grains particularly *P. typhoides* and red dawa which contained 6.02% and 4.58% of lipids respectively. *P. typhoides* and *T. aestivum* had 4.20% and 4.00% ash content respectively while *S. bicolor* had low ash content with red dawa 1.40% and white dawa had 1.10% ash content. This gives an indication of the levels of macro and micro elements in the grains. With regards to the vitamin content, *S. bicolor* had the highest content of ascorbic acid: white dawa contained 18.48 mg.100

**Table 2** Proximate composition (%) and energy content (g.Cal<sup>-1</sup>) of *Sorghum bicolor*, *Pennisetum typhoides* and *Triticum aestivum* on a dry weight basis and food energy.

Scientific name	Common name	Local name	CP	CF	Lipid	CHO	Ash	FE
<i>Sorghum bicolor</i>	Guinea corn	Red dawa	12.25 ± 0.11 <sup>a</sup>	1.36 ± 0.10 <sup>a</sup>	4.58 ± 0.10 <sup>b</sup>	80.41 ± 0.20 <sup>b</sup>	1.40 ± 0.22 <sup>a</sup>	411.86 ± 0.20 <sup>a</sup>
<i>S. bicolor</i>	Guinea corn	White dawa	14.88 ± 0.10 <sup>b</sup>	4.38 ± 0.20 <sup>b</sup>	2.68 ± 0.20 <sup>a</sup>	76.96 ± 0.10 <sup>b</sup>	1.10 ± 0.10 <sup>a</sup>	391.48 ± 0.11 <sup>b</sup>
<i>Pennisetum typhoides</i>	Millet	Jero	13.69 ± 0.20 <sup>b</sup>	1.96 ± 0.22 <sup>a</sup>	6.02 ± 0.11 <sup>b</sup>	74.12 ± 0.20 <sup>a</sup>	4.20 ± 0.11 <sup>b</sup>	405.51 ± 0.10 <sup>a</sup>
<i>Triticum aestivum</i>	Wheat	Wheat	18.81 ± 0.10 <sup>b</sup>	2.34 ± 0.10 <sup>b</sup>	3.06 ± 0.10 <sup>a</sup>	71.19 ± 0.20 <sup>a</sup>	4.00 ± 0.11 <sup>b</sup>	387.54 ± 0.22 <sup>b</sup>

Data are the means ± standard deviation of triplicate determinations on a dry weight basis. Values with the same superscript in each column are not significantly different at P<0.05. CP = crude protein, CF = crude fibre, CHO = carbohydrates, FE = food energy.

**Table 3** Vitamin content of *Sorghum bicolor*, *Pennisetum typhoides* and *Triticum aestivum* grains on a dry weight basis (mg.100 g<sup>-1</sup>).

Scientific name	Common name	Local name	Ascorbic acid	Riboflavin	Thiamin	Niacin
<i>Sorghum bicolor</i>	Guinea corn	Red dawa	12.32 ± 0.10 <sup>b</sup>	0.36 ± 0.20 <sup>a</sup>	0.32 ± 0.02 <sup>a</sup>	4.60 ± 0.11 <sup>b</sup>
<i>S. bicolor</i>	Guinea corn	White dawa	18.48 ± 0.20 <sup>b</sup>	0.10 ± 0.20 <sup>a</sup>	0.62 ± 0.11 <sup>b</sup>	2.05 ± 0.10 <sup>a</sup>
<i>Pennisetum typhoides</i>	Millet	Jero	6.16 ± 0.22 <sup>a</sup>	0.66 ± 0.11 <sup>b</sup>	1.36 ± 0.10 <sup>a</sup>	4.11 ± 0.20 <sup>b</sup>
<i>Triticum aestivum</i>	Wheat	Wheat	7.92 ± 0.22 <sup>a</sup>	0.26 ± 0.22 <sup>a</sup>	0.36 ± 0.20 <sup>a</sup>	1.50 ± 0.10 <sup>a</sup>

Data are the means ± standard deviation of triplicate determinations on a dry weight basis. Values with the same superscript in each column are not significantly different at P<0.05.

**Table 4** Mineral compositions of *Sorghum bicolor*, *Pennisetum typhoides* and *Triticum aestivum* grains on a dry weight basis (mg.100 g<sup>-1</sup>).

Scientific name	Common name	Local name	P	K	Ca	Mg	Na
<i>Sorghum bicolor</i>	Guinea corn	Red dawa	0.32 ± 0.10 <sup>a</sup>	0.18 ± 0.22 <sup>a</sup>	2.41 ± 0.10 <sup>b</sup>	1.70 ± 0.22 <sup>a</sup>	0.06 ± 0.10 <sup>a</sup>
<i>S. bicolor</i>	Guinea corn	White dawa	0.32 ± 0.20 <sup>a</sup>	0.61 ± 0.10 <sup>b</sup>	3.81 ± 0.22 <sup>a</sup>	1.95 ± 0.10 <sup>a</sup>	0.05 ± 0.20 <sup>a</sup>
<i>Pennisetum typhoides</i>	Millet	Jero	0.31 ± 0.11 <sup>a</sup>	0.19 ± 0.22 <sup>a</sup>	3.21 ± 0.10 <sup>a</sup>	1.46 ± 0.20 <sup>a</sup>	0.09 ± 0.11 <sup>a</sup>
<i>Triticum aestivum</i>	Wheat	Wheat	0.28 ± 0.10 <sup>a</sup>	0.49 ± 0.10 <sup>b</sup>	2.61 ± 0.10 <sup>b</sup>	1.22 ± 0.10 <sup>a</sup>	0.05 ± 0.10 <sup>a</sup>

Data are the means ± standard deviation of triplicate determinations on a dry weight basis. Values with the same superscript in each column are not significantly different at P<0.05.



$\text{g}^{-1}$  and red dawa had  $12.32 \text{ mg} \cdot 100 \text{ g}^{-1}$ ; *T. aestivum* contained  $7.92 \text{ mg} \cdot 100 \text{ g}^{-1}$  ascorbic acid while *P. typhoides* had  $6.16 \text{ mg} \cdot 100 \text{ g}^{-1}$  of ascorbic acid. The cereals also contained mostly B-vitamins such as niacin, riboflavin and thiamine (Table 3). They are particularly rich in niacin. Among the vitamins inherently present only niacin is stable during the processing of cereals (Ihekoronye and Ngoddy 1985). The content of these vitamins are fairly similar to those of maize, oats, barley and two-rowed barley. These findings agreed with the results of Ihekoronye and Ngoddy (1985) and Enwere (1998) who reported that the value of thiamine to be  $0.26 \text{ mg} \cdot 100 \text{ g}^{-1}$  in barley,  $0.20 \text{ mg} \cdot 100 \text{ g}^{-1}$  in maize and  $0.32 \text{ mg} \cdot 100 \text{ g}^{-1}$  in oats while riboflavin was reported to be  $0.10 \text{ mg} \cdot 100 \text{ g}^{-1}$  in barley,  $0.6 \text{ mg} \cdot 100 \text{ g}^{-1}$  in maize and  $0.8 \text{ mg} \cdot 100 \text{ g}^{-1}$  in oats.

The mineral contents comprise calcium, potassium, phosphorus, magnesium and sodium (Table 4). Calcium was the most abundant macroelement present with *S. bicolor* (white dawa) containing  $3.81 \text{ mg} \cdot 100 \text{ g}^{-1}$  of calcium, followed by *P. typhoides* ( $3.21 \text{ mg} \cdot 100 \text{ g}^{-1}$ ) and *T. aestivum* contained  $2.61 \text{ mg} \cdot 100 \text{ g}^{-1}$  of calcium. A lack of calcium or phosphorus in the diet causes rickets (Okwu and Emenike 2007) and osteoporosis (Hunt *et al.* 1980). In osteoporosis, the bone is so decreased that adequate mechanical support can no longer be provided and sustained; spontaneous fractures often result (Hunt *et al.* 1980). It occurs more in adult humans, particularly women. Improvement of the nutritional status as mode of combating osteoporosis has revolved around increased intake of calcium and fluorine (Hunt *et al.* 1980). These can be derived through the consumption of *S. bicolor*, *T. aestivum* and *P. typhoides*. However, the sodium content in these cereals is low. This is an added advantage due to the direct relationship of sodium intake with hypertension in humans (Okwu and Emenike 2007).

*S. bicolor*, *T. aestivum* and *P. typhoides* provide great benefits as nutritious food crops requiring low levels of inputs for production. Their high protein content, vitamin and mineral composition can be useful for the poor who cannot afford protein-rich foods. The crops provide numerous medicinal benefits and the presence of phytochemicals (natural flavonoids) enable them to function not only as antioxidants but also as anti-inflammatory and anticarcinogenic agents. The main problem with *S. bicolor*, *T. aestivum* and *P. typhoides* is their availability particularly in Southern Nigeria. Production of these crops in Nigeria does not meet its demands as a staple food. Moreover, farmers in Northern Nigeria cultivate locally adopted varieties, whose grain quality depend on variety and breed. Superior high quality grains should be supplied to growers. A grain breeding programme to develop varieties and hybrids that will make *S. bicolor*, *T. aestivum* and *P. typhoides* more dependable, sustainable and profitable food crops for peasant farmers and better products for industrial utilization must be undertaken by Governments and Research Institutes in the country. The nutritional and health benefits place these crops in an excellent position for utilization as nutraceuticals.

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## REFERENCES

- Adesegun SA, Coker HAB (2001) Plants used in traditional medicine against malaria. *The Nigerian Journal of Pharmacy* **32**, 50-62
- Akobundu ENT (1999) Healthy foods in human nutrition. *Journal of Sustainable Agriculture and Environment* **1**, 1-7
- Akobundu IO (1987) *Weed Science in the Tropics*, John Wiley and Sons, Chichester, pp 335-355
- AOAC (1984) *Official Methods of Analysis* (14<sup>th</sup> Edn) Association of official Analytical Chemists, Washington DC, pp 602-612
- Bakshi DNG, Sensarma P, Pal DC (1999) *A Lexicon of Medicinal Plants of India*, Naya Prakash, Calcutta, pp 405-415
- Barakat MZ, Shehab SK, Darwish N, Zahermy EI (1993) Determination of ascorbic acid from plants. *Analytical Biochemistry* **53**, 225-245
- Bhargava A, Bhargava M, Shukla S, Ohri E (2005) *Fagopyrum* – a potential source for nutraceuticals. *Journal of Medicinal and Aromatic Plant Sciences* **27**, 505-514
- Boham AB, Kocipai A (1994) Flavonoids and condensed tannins from leaves of *Hawaiian vaccinium vaticulum* and *V. calycinium*. *Pacific Science* **48**, 458-463
- Carter PR, Hicks DR, Oplinger ES, Doll JD, Bundy LG, Schuler RT, Holmes BJ (1989) Grain sorghum (Milo). Alternative field crops manual. Available online: [www.hort.purdue.edu/newcrop/afem/sorghum.html](http://www.hort.purdue.edu/newcrop/afem/sorghum.html)
- Close DC, McArthur C (2002) Rethinking the role of many plants phenolics Protection from photodamage. *Oikos* **99**, 166-172
- del Rio A, Obdulio BG, Castillo J, Marin FR, Ortuno A (1977) Uses and properties of citrus flavonoids. *Journal of Agriculture and Food Chemistry* **45**, 4505-4515
- Duke JA, Wain KK (1981) Medicinal plants of the world computer index. 3 Vols., Plenum Press, New York, pp 220-227
- Duke JA (1983) *Handbook of Energy Crops*, unpublished
- Enwere NJ (1998) Foods of plant origin. Afro-Orbis Publications Ltd. University of Nigeria pp 77-118
- Elangovan V, Sekar N, Gorindasamy S (1994) Chemo preventive potential of Dietary biflavonoids against 20-methylcholanthrene induced tumorigenesis. *Cancer Letters* **87**, 107-113
- Fabjan N, Rode J, Kosir IJ, Wang Z, Kreft I (2003) Tartary buckwheat (*Fagopyrum tataricum* Geartn). A source of dietary rutin and quercitrin. *Journal of Agricultural and Food Chemistry* **51**, 6452-6455
- FAO (1980) *Production Year Book* (Vol 33), FAO, Rome, pp 60-65
- Harborne JB (1973) *Phytochemical Methods*, Chapman and Hall, London, 113 pp
- He J, Klag MJ, Whelton PK, Mo JP, Chen JY (1995) OATS and buckwheat intakes And cardiovascular disease risk factors in an ethnic minority of China. *American Journal of Clinical Nutrition* **61**, 366-372
- Hertog MGI, Feskeen EJM, Hokman CH, Katan A (1993) Dietary antioxidant flavonoids and risk of coronary heart disease. *Lancet* **342**, 2007-1011
- Ho CT, Chen Q, Shi H, Zhang KQ, Rosen RT (1992) Antioxidative effects of polyphenols extract prepared from various Chinese teas. *Preventive Medicine* **21**, 520-528
- Hunt SM, Groll JF, Holbrook JM (1980) *Nutrition, Principles and Clinical Practice*, John Wiley and Sons, New York, pp 451-452
- Igoli Jo, Tor-Anyiin TA, Usman SS, Oluma HOA, Igoli NP (2002) Folk medicine of the lower Benue valley of Nigeria. In: Singh VK, Govil JN, Hashmi S, Singh G (Eds) *Recent Progress in Medicinal Plants* (Vol 7) *Ethnomedicine and Pharmacognosy II*, SciTech Publishers, USA, pp 327-338
- Igoli JO, Ogaji OG, Tor-Anyiin TA, Igoli NP (2005) Traditional medicine practice amongst the Igede people of Nigeria Part II. *African Journal of Traditional, Complimentary and Alternative Medicine* **2**, 134-152
- Ihekeonye, Ngoody PO (1985) *Integrated Food Science and Technology for the Tropics*, Macmillan, London, pp 236-264
- Jiang H, Kleg MJ, Whelton PK, Mo JP, Chen TY, Olan MC, Mo PS, He GQ (1995) oats and buckwheat intakes and cardiovascular disease risk factors in an ethnic minority in China. *American Journal of Clinical Nutrition* **61**, 366-372
- Kalinová J (2007) Nutritionally important components of proso millet (*Panicum miliaceum*). *Food* **1**, 91-100
- Kamath VG, Chandrasshekar A, Rajini PS (2004) Antiradical properties of sorghum (*Sorghum bicolor* L. Moench) flour extracts. *Journal of Cereal Science* **40**, 283-288
- Kandaswani C, Middle E (1994) Free radical scavenging and antioxidant activity of plants flavonoids. *Advanced Experimental Medical Biology* **129**, 351-366
- Kayashita J, Shimaoka I, Nakajo M, Yamazaki M, Kato N (1997) Consumption of buckwheat protein lowers plasma cholesterol and raises fecal neutral sterols in Cholesterol fed rats because of its low digestibility. *Journal of Nutrition* **127**, 1395-1400
- Li SQ, Zhang QH (2001) Advances in the development of functional foods from buckwheat. *Journal of Food Science and Nutrition* **41**, 451-464
- Little BT (1986) Input of bottling and brewing industries and their prospect of local substitutes. In: Onoh JK (Edn) *Industrial Potentials of Nigeria's Raw Material*, Imo State University Press, Owerri, Nigeria, pp 158-164
- Lupien JR (1990) Sorghum and millets in human Nutrition. Codex standards for cereals, pulses, legumes and derived products. Codex Alimentarius Vol XVIII Romc, FAO/WHO, 33 pp
- Mauder B (2006) *Sorghum: The Global Grain of the Future*, National Sorghum Producers, Mexico, pp 33-45
- Middleton E, Kandaswani (1992) effects of flavonoids on immune and inflammatory functions. *Biochemistry and Pharmacology* **43**, 1167-1172
- Morton JF (1981) *Atlas of Medicinal Plants of Middle America: Bahamas to Yucatan*, CC Thomas, Springfield, IL, pp 125-130
- Muller HG, Tobin G (1980) *Nutrition and Food Processing*, Groom Helm Ltd., London, pp 152-156
- Myers RL, Mienke LJ (1994) Wheat: A multipurpose short season alternative.

- Agricultural Publications G 4306, University of Missouri, Columbia, pp 20-28
- Nahapatian A, Bassiri A** (1995) Changes in concentration and interrelationships of phytate, P, Mg, Cu Zn in wheat during maturation. *Journal of Agricultural and Food Chemistry* **23**, 1179-1182
- NGSB** (2006) *Sorghum Handbook*, Nebraska Grains Sorghum Board, Lincoln, pp 33-39
- Obadoni BO, Ochuko PO** (2001) Phytochemical studies and comparative efficacy of the crude extracts of some homeostatic plants in Edo and Delta States of Nigeria. *Global Journal of Pure and Applied Sciences* **8**, 203-208
- Okwu DE** (2004) Phytochemical and vitamin content of indigenous spices of South Eastern Nigeria. *Journal of Sustainable Agriculture and Environment* **6**, 30-37
- Okwu DE** (2005) Phytochemicals, vitamins and mineral contents of two Nigerian medicinal plants. *International Journal of Molecular Medicine and Advances in Science* **1**, 375-381
- Okwu DE, Omodamiro OD** (2005) Effect of hexane extract and phytochemical content of *Xylopiya aethiopica* and *Ocimum gratissimum* on uterus of Guinea pig. *Bio-Research* **3**, 40-44
- Okwu DE, Emenike IN** (2006) Evaluation of the phytonutrients and vitamins contents of citrus fruits. *International Journal of Molecular Medicine and Advances in Science* **2**, 1-6
- Okwu DE, Emenike IN** (2007) Nutritive value and mineral content of different varieties of citrus fruits. *Journal of Food Technology* **5**, 105-108
- Oladiji AT, Jacob TO, Yakubu MT** (2007) Anti-anaemic potentials of aqueous extract of *Sorghum bicolor* L. Moench stem bark in rats. *Journal of Ethnopharmacology* **3**, 651-656
- Osborn DR, Voogt P** (1978) *Calculations of Calorific Value in the Analysis of Nutrients in Roots*, Academic Press, New York, pp 239-244
- Perry LM** (1980) *Medicinal Plants of East and South East Asia*, MIT Press, Cambridge, pp 115-130
- Quettier-Delen C, Gressier B, Vasscur J, Dine T, Brunnet C** (2000) Phenolic compounds and antioxidant activities of buckwheat (*fagopyrum esculentum* Moench) Hulls and Flour. *Journal of Ethnopharmacology* **72**, 35-42
- Robinson RG** (1980) The buckwheat crop in Minnesota. Agricultural Experimental Bulletin 539, University of Minnesota, St. Paul, 405 pp
- Roger GDP** (1999) *New Life Style, Enjoy It*, Editorial Safeliz S.L., Spain, pp 75-76
- Roger GDP** (2002) *Encyclopedia of Medicinal Plants* (Vol 1), Education and Health Library, Editorial Safeliz S.L., Spain, pp 153-154, 265-267
- Shahidi F, Chavan FUD, Bal AK, Mckenzie OB** (1999) Chemical composition of beach pea (*Lathyrus maritimus* L.). *Plant Parts Food Chemistry* **64**, 39-44
- Shahidi F** (2002) Research address bioactive compounds. *Food Technology* **56**, 23-28
- SKALAR Analyzers** (2000) *Segmented Flow Analyser for Analytical Process Laboratories*, Offset Drakokerij Faculfaider, The Netherlands, pp 45, 50, 60
- Stray F** (1998) *The Natural Guide to Medicinal Herbs and Plants*, Tiger Books Intl., London, pp 12-16
- Steel RGD, Torrie JH** (1980) *Principles and Procedures of Statistics: With Special Reference to Biological Science*, McGraw-Hill, New York, 481 pp
- TGSB** (2006) Sorghum, grain sorghum; various plants of the genus *Sorghum*, family Poaceae, a cereal grain. Texas Grains Sorghum Board, Lubbock, pp 20-28
- Thacker PA, Anderson DM, Bowland JP** (1984) Buckwheat as a potential feed ingredient for use in pig diets. *Pig News Information* **5**, 77-81
- Uruquiga I, Leighton FI** (2000) Plant polyphenols antioxidants and oxidative stress. *Biological Research* **33**, 159-165
- van Burden TP, Robinson WC** (1981) Formation of complexes between protein and tannin acid. *Journal of Agriculture and Food Chemistry* **1**, 77-82
- Verger PH, Leblanc JC** (2003) Concentration of phytohormone in food and feed and their impact on the human exposure. *Journal of Pure and Applied Chemistry* **75**, 1873-1880
- Volhard KPC, Schone WE** (1984) *Organic Chemistry*, WCH Freeman and Co., New York, pp 205-208
- Waladkhani AR, Clemens MR** (2001) Effects of dietary phytochemicals on cancer development. In: Watson RR (Ed) *Vegetables, Fruits and Herbs in Health Promotion*, CRC Press, Boca Raton, pp 3-12
- Wikipedia** (2006) Sorghum Wikipedia, The free Encyclopaedia, USA. Available online: <http://en.wikipedia.org/wiki/sorghum>
- Zhao J** (2007) Nutraceuticals, Nutritional Therapy, Phytonutrients and human health; A perspective on plant biotechnology Application. *Recent Patents in Biotechnology* **1**, 75-97
- Zrelinst H, Kozłowska H** (2000) Antioxidant activity and total phenolics in selected cereals grains and their different morphological fractions. *Journal of Agricultural and Food Chemistry* **48**, 2008-2016