Food ©2012 Global Science Books

A Comparative Evaluation of the Chemical Properties of Wild Tamarind (*Tamarindus indica* L.) Fruits in Nigeria

Abiodun Aderoju Adeola[1*] • Ogugua Charles Aworh[2]

[1] Institute of Food Security, Environmental Resources and Agricultural Research, Federal University of Agriculture, Abeokuta, Nigeria
[2] Department of Food Technology, University of Ibadan, Ibadan, Nigeria

Corresponding author: * **adeolaroni@yahoo.com**

ABSTRACT

A comparative study was carried out to evaluate the chemical properties of mature wild tamarind fruits in Nigeria. Samples of the fruits were collected from 19 major towns in the savannah vegetation of Nigeria. Fruit pulp was hand-scraped from the seeds and separated from other non-pulp materials. Proximate composition, physicochemical properties, ascorbic acid and mineral composition, total carotenoids and antinutritional factors of mature tamarind fruit pulp were analysed. Proximate and mineral compositions were expressed as g/100 g fresh weight (FW) of the fruit pulp, the ascorbic acid and total carotenoids as mg/100 g FW and µg/100 g FW, respectively; the colour as optical density at a wavelength of 325 nm and total acidity as tartaric acid. Moisture content of the mature fruits ranged between 16.8 and 36.2%. The crude protein, crude fat, ash and total crude carbohydrate of the mature tamarind fruit pulp ranged from 3.5 to 7.4, 3.5 to 7.4, 3.0 to 6.9 and 52.0 to 62.7, respectively. The ascorbic acid, colour and soluble solids varied between 3.7 and 11.3, 0.30 and 1.42, and 5.2 and 6.4 °Brix, respectively. The mature tamarind fruits were high in acid (pH 2.3-3.3) but low in total carotenoids, antinutrients and micronutrients. Calcium and sodium were the most abundant macro- and micro-nutrients. Tamarind fruits are good sources of nutrients and could be effectively employed in combating food insecurity in developing sub-Saharan countries where tamarind fruits grow.

Keywords: antinutrients, food security, micronutrients, proximate composition, underutilised

INTRODUCTION

The aim of this study was to evaluate the chemical properties of tamarind fruits in Nigeria. The study also investigated into some antinutritional factors of tamarind fruits.

The search for novel high quality but cheap sources of food is a major concern of governments and organisations concerned with the responsibility for food and nutrition in many parts of the world (Balogun and Fetuga 1986; Sánchez 2005). Projections based on current trends indicate a gap between human population and food supply (Vijayakumari *et al.* 1997; Spore 2010). Hence, research efforts are being directed towards identifying and evaluating underexploited crops, which have been grossly neglected to the detriment of human development, as alternate food crops for the future (Egbe and Akinyele 1990; Adekunle and Ojerinde 2004; Anhwange *et al.* 2004; Abdullahi and Abdullahi 2005). According to Afolabi *et al.* (1985) and Kamel and Dawson (1985), two areas that have often been neglected in augmenting available raw materials, for domestic and industrial consumption, are the use of underexploited food crops and the lack of production of these substitutes on an industrial scale. The enhancement of underutilised crops is a key to food security, to the conservation of biological diversity and to the preservation and restoration of fragile and degraded environment throughout the world (El-Siddig *et al.* 2006). Indeed, strategies to combat malnutrition in developing countries should aim at developing, utilising and promoting the traditional food plant materials, including the underutilised and neglected ones (Okigbo 1986; Bello *et al.* 2008). The plant species would not only satisfy the physiological needs of man, but also alleviate the economic problems of the developing countries.

Tamarind (*Tamarindus indica* L.) is a leguminous tree that grows wild in the tropics (Ishola *et al.* 1990). Tamarind has a wide range of domestic and industrial uses (Vadivel and Pugalenthi 2010). Tamarind tree is easy to cultivate, free of any serious pests and diseases, and has a long life span of 150-200 years (Gunasena and Hughes 2000). Tamarind tree is especially valuable for its fruit which has a sweet acidic taste due to a combination of high contents of tartaric acid and reducing sugars (Gunasena and Hughes 2000; De Caluwe *et al*. 2009). Tamarind fruit pulp is extensively exploited in cooking and flavouring of Asian dishes (De Caluwe *et al.* 2009). Gunasena and Hughes (2000) and De Caluwe *et al.* (2009) reported that tamarind pulp could be used for seasoning, in prepared foods, to flavor confections, curries and sauces, and as a major ingredient in juices and other beverages. Commercial tamarind-based drinks are available from many countries (De Caluwe *et al.* 2009; Adeola and Aworh 2010). Consumption of tamarind had a beneficial effect on the mobilisation of deposited fluoride from bone by enhancing urinary excretion of fluoride (Khandare *et al.* 2004). Adeola *et al.* (2010) and Jadhav *et al.* (2010) also reported that tamarind pulp contained important phytochemical and antimicrobial properties.

Researchers in India, Thailand and the Philippines, recognising the unexploited potentials of tamarind, have exhibited some interest in tamarind in the last two decades (Gunasena and Hughes 2000; Vadivel and Pugalenthi 2010). The potential of tamarind is underscored by its impact in these countries where it is firmly entrenched as a key component of sustainable livelihoods, with special cultural, dietary and economic significance. However, the impact of research findings has been of little significance due to the sporadic nature of research undertaken by various research institutions. The research covers different topics but appears less coherent (Gunasena and Hughes 2000). Many African countries, including Nigeria, which are presently classified as food-deficit countries (FAO 2007) and where tamarind is

Received: 3 April, 2012. Accepted: 6 May, 2012.

Original Research Paper

found growing wild have not given any significant focus to this plant. Hence, the economic and nutritional benefits of tamarind are yet to be adequately exploited.

MATERIALS AND METHODS

Sources of raw materials

Mature tamarind fruits were collected from 19 towns (Abuja, Azare, Bauchi, Bichi, Birni kebbi, Funtua, Gombe, Gwarzo, Jega, Jos, Kaduna, Kano, Katsina, Langtang, Maiduguri, Mallamsidi, Minna, Oyo, Sokoto), which were randomly selected from major towns in the savannah vegetation of Nigeria between March and May 2005. To minimise problems caused by insect infestation, fruit pulp was hand-scraped from the seeds and stored in an industrial freezer at –20°C until the time of analyses and processing. Prior to analyses and processing, samples were inspected for non-plant materials, and all visible dirt and insect-infested parts of the fruits were removed.

Except otherwise stated all chemical used for this study were products of BDH (VWR) (Lutterworth, UK).

Determination of proximate composition of tamarind pulp

The moisture, protein, crude fat, crude fibre, ash, pH, total acidity and soluble solids contents of the fruit pulp samples were determined according to A.O.A.C (1995).

Determination of ascorbic acid content and physico-chemical properties of tamarind fruit pulp

The 2, 6-dichlorophenolindophenol method as outlined by A.A.C.C. (1983) was used to determine the ascorbic acid at 520 nm. The colour of the fruit samples were measured by using the method of Salem and Hegazi (1973), with modifications. About 0.5 g of tamarind fruit pulp was extracted with 100 ml distilled water and filtered with No.4 Whatman filter paper. Thereafter 2 ml of the filtrate was scanned with a UV-VIS spectrophotometer equipped with Aurora scanning software, to obtain the wavelength of maximum absorbance, which was found to be 325 nm. The colour of the samples was then determined by measuring the absorbance at 325 nm, after extracting 0.5 g sample with 100 ml distilled water. Carotenoids were extracted according to Chan and Cavaletto (1982). About 30 g pulp was mixed with about 5 g of hyflosupercel (celite, a filtration aid) and 75 ml of 70% methanol (v/v), and filtered through a Buchner funnel with filter paper. The residue was extracted two more times with 75 ml acetone-petroleum ether 1:1 (v/v). The extracts were then transferred to 500 ml separatory funnel. About 25 ml of 10% KOH in methanol (v/v) was added and the mixture allowed to stand for 1.5 h. Partition was achieved by adding 75 ml of petroleum ether and 100 ml of 20% NaCl (w/v), and mixing gently. The hypophasic (lower) layer was discarded. The epiphasic (upper) layer was washed three times with 200 ml of distilled water to remove excess acetone, filtered through a small funnel containing about 15 g anhydrous sodium sulphate to remove residual water. The funnel was plugged with glass to hold the sodium sulphate. The filtrate was made up to 250 ml with petroleum ether and the absorbance measured at 450nm, the wavelength of maximum absorption for β-carotene in petroleum ether (Rodríguez-Amaya and Kimura 2004). The total carotenoids were expressed as β-carotene equivalents (µg/100 g) of fresh weight.

Total carotenoids content (µg/g) = (A × volume (ml) × 10^4)/ ($A^{1\%}_{1cm}$ × sample weight (g))

where A = absorbance, Volume = total volume of extract; $A^{1\%}_{1cm}$ = absorption coefficient of β-carotene in petroleum ether (2,592).

Determination of minerals

The method of IITA (1991) was used. About 2.0 g of ash was digested with 5 ml of 2 M HCl in a crucible and heated over a low flame to dryness. About 5 ml of HCl was again added, heated to boiling and filtered through a Whatman No. 1 filter paper into a 100 ml volumetric flask. The filtrate was made up to mark with distilled water. This was used to read the concentration of calcium (Ca), potassium (K) and sodium (Na) on a Jenway digital flame photometer (PFP7 Model), using the filter corresponding to each mineral element. The concentration of each element was calculated using the formula:

% Ca or % K or % Na =
(metre reading × slope × dilution factor)/10,000

Phosphorus (P) was determined by colorimetry by treating ash of each sample with 2 M HCl as earlier described for Ca, K and Na determination. About 10 ml of the filtrate was pipetted into 50 ml standard flask and 10 ml of molybdovanadate (HACH Loveland, Colorado, USA) yellow solution was added. The flask was made up to mark with distilled water, stoppered and left for 10 min for full yellow colour development. The absorbance of the solution was then read on a Bausch and Lomb Spectronic 20 spectrophotometer at a wavelength of 470 nm. % P was calculated using the formula:

% P = (metre reading × slope × dilution factor)/10,000

Other minerals were determined by using a Buck Atomic Absorption Spectrophotometer. magnesium (Mg), lead (Pb), iron (Fe), zinc (Zn) and copper (Cu) were respectively read at wavelengths of 285.2, 283.3, 248.3, 213.8 and 324.7 nm using air-acetylene as fuel- oxidant combination.

Determination of antinutritional factors

1. Tannin

About 0.2 g of the dried fruit pulp was weighed into a beaker and soaked in a solvent mixture (80 ml of acetone and 20 ml of glacial acetic acid) for 5 h to extract tannins. The filtrate was removed by filtering through a double layer filter paper. Standard solutions of tannic acid were prepared ranging from 10 to 50 ppm and their absorbance read at 500 nm (Griffiths and Jones 1977) on a spectrophotometer (Spectronic 20). The absorbance of the filtrate was also read at this wavelength and the percentage tannin calculated as:

% Tannin = (absorbance (sample) × average gradient of slope × dilution factor)/10,000

2. Trypsin inhibitor activity

The samples were defatted with petroleum ether. Extraction was performed according to the method of Kakade *et al.* (1974). Approximately 0.2 g of the defatted sample was extracted with 50 ml 0.01 N NaOH for 3 h with regular shaking to keep the sample in suspension. The pH of the suspension was adjusted to 9.3 and 1 ml of the suspension was diluted with 20 ml of distilled water, giving an inhibition range of 40-60% with 2 ml of the sample extract.

Trypsin inhibitor (TI) activity was assayed according to the method of Hamerstrand *et al.* (1981). Two ml aliquots each of the diluted sample extracts were transferred to three test tubes with a micropipette. A fourth test tube was prepared for standard trypsin by adding 2 ml of distilled water. About 2 ml of trypsin solution obtained from a solution of 4 mg standard trypsin (bovine pancreas, salt-free, Sigma-Aldrich chemical Co., St. Louis, USA) in 200 ml 0.001 N HCl were each added to the first two test tubes and the fourth one containing distilled water. The test tubes were placed in a water bath at 37°C for 10 min. About 5 ml of BAPNA, $C_{19}H_{23}ClN_6O_4$, (benzoyl-DL-arginine-p-nitro-anilide hydrochloride (Energy Chemical, China) pre-warmed at 37°C was rapidly added to each test tube. The contents were placed in a water bath maintained at 37°C and stirred. The reaction was terminated exactly 10 min by adding 1 ml of 30% acetic acid, with immediate stirring. A sample blank (the third test tube containing only the sample extract) was prepared by the same procedure, except that the trypsin solution was added after the reaction was terminated by the

Table 1 Proximate composition of tamarind (*Tamarindus indica* L.) fruits.

Location	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Crude fibre (%)	Carbohydrate (%)
Abuja	25.0 ± 1.7 efg	4.6 ± 0.6 cde	5.1 ± 0.4 ef	5.0 ± 0.3 cd	2.7 ± 0.5 ef	60.3 ± 2.6 cde
Azare	25.5 ± 0.7 ef	4.8 ± 0.2 cd	4.5 ± 0.4 fghi	4.7 ± 0.6 cd	3.0 ± 0.5 def	60.4 ± 0.8 cde
Bauchi	19.3 ±1.2 ij	5.9 ± 0.7 b	6.8 ± 0.7 ab	5.4 ± 0.4 c	4.7 ± 0.7 a	62.3 ± 0.4 ef
Bichi	28.5 ± 0.9 c	3.9 ± 0.2 efg	4.2 ± 0.4 ghij	4.8 ± 0.4 cd	2.6 ± 0.3 f	58.5 ± 0.3 bc
Birni Kebbi	36.2 ± 1.0 a	3.5 ± 0.5 g	3.5 ± 0.4 j	4.9 ± 0.4 cd	2.6 ± 0.4 f	52.0 ± 0.81 a
Funtua	24.4 ± 0.7 fg	4.6 ± 0.5 cdef	5.0 ± 0.5 efg	4.7 ± 0.6 cd	2.7 ± 0.4 ef	61.3 ± 0.8 def
Gombe	18.8 ± 0.7 ij	7.4 ± 0.5 a	7.1 ± 0.3 a	6.1 ± 0.4 b	4.1 ± 0.4 abc	60.5 ± 0.6 cde
Gwarzo	25.0 ± 0.5 efg	4.2± 0.5 defg	4.5 ± 0.4 fghi	5.4 ± 0.4 c	2.8 ± 0.3 ef	60.8 ± 1.6 def
Jega	27.2 ± 0.5 cd	3.7 ± 0.6 g	4.6 ± 0.5 fgh	5.2 ± 0.4 c	3.0 ± 0.4 def	59.3 ± 1.49 bcd
Jos	19.4 ± 1.0 ij	7.4 ± 0.3 a	6.1 ± 0.3 cd	5.2 ± 0.6 c	2.7 ± 0.3 ef	61.9 ± 0.4 ef
Kaduna	30.6 ± 0.6 b	4.7 ± 0.5 cde	3.8 ± 0.3 ij	3.0 ± 0.2 e	2.4 ± 0.5 f	57.9 ± 0.52 b
Kano	18.1 ± 0.3 j	6.7 ± 0.5 a	7.4 ± 0.4 a	5.4 ± 0.3 cd	3.5 ± 0.5 cde	62.1 ± 0.3 ef
Kastina	31.3 ± 0.4 b	3.6 ± 0.5 g	4.1 ± 0.3 hij	3.7 ± 0.6 e	2.7 ± 0.4 ef	57.4 ± 0.4 b
Langtang	25.4 ± 0.7 ef	4.2 ± 0.5 defg	4.6 ± 0.6 fgh	5.2 ± 0.4 c	2.7 ± 0.5 ef	60.5 ± 0.2 cde
Maiduguri	23.8 ± 0.4 g	5.4 ± 0.3 bc	6.2 ± 0.7 bc	5.2 ± 0.4 c	2.6 ± 0.5 ef	59.4 ± 1.04 bcd
Mallamsidi	26.2 ± 0.7 de	3.9 ± 0.4 fg	5.0 ± 0.3 efg	4.6 ± 0.5 cd	2.8 ± 0.3 ef	60.4 ± 0.9 cde
Minna	19.8 ± 0.7 i	5.4 ± 0.5 bc	7.1 ± 0.3 a	4.9 ± 0.4 cd	3.9 ± 0.6 abc	62.7 ± 1.08 f
Oyo	21.5 ± 0.7 h	6.9 ± 0.3 a	5.4 ± 0.4 de	4.4 ± 0.5 d	3.7 ± 0.6 bcd	61.8 ± 0.4 ef
Sokoto	16.8 ± 0.6 k	7.4 ± 0.4 a	7.2 ± 0.3 a	6.9 ± 0.3 a	4.3 ± 0.5 ab	61.8 ± 1.2 ef

Means in the same column with the same letter are not significantly different ($P \leq 0.05$)

addition of acetic acid.

The absorbance of each solution was read with Spectronic 401 spectrophotometer at 410 nm against the sample blank. Values obtained from each of the two sample extracts were subtracted from that of the trypsin standard. The TI activity was determined from the following equation.

TI, mg/g of sample = $[(A_{std} - A_s)/0.019 \times$ sample weight (g)]/ [dilution factor/(1000 × sample volume (ml)]

where A_{std} = absorbance of standard trypsin; A_s = absorbance of sample; 0.019 = absorbance of 1 µg of pure trypsin.

3. Phytates

Sample preparation was similar to that reported for TI extraction, except that the tamarind samples were not defatted. Phytates in 1 g sample were extracted with 50 ml 3% trichloroacetic acid (TCA) for 45 min with occasional swirling by hand. The suspension was then centrifuged at 5,800 rpm for 30 min. The phytic acid in 10 ml aliquot of the supernatant was precipitated with 4 ml $FeCl_3$ solution containing 0.2% $FeCl_3$ in 3% TCA. The precipitate of ferric phytate was converted to $Fe(OH)_3$ with 3 ml 1.5 N NaOH after a series of washing, heating, centrifuging and decanting of the precipitate according to the method of Wheeler and Ferrel (1971). The Fe $(OH)_3$ was dissolved in 40 ml of hot 3.2 N HNO_3 in a 100-ml volumetric flask. The flask and its content were cooled to room temperature and diluted to volume with distilled water. A 5-ml aliquot was transferred to another 100-ml volumetric flask and diluted to approximately 70 ml with distilled water. About 20 ml of 1.5 M KSCN (Sigma-Aldrich) was added and the content of the flask was thereafter diluted to volume. The absorbance of the solution was read immediately in a Milton Roy Spectronic 401 spectrophotometer at 480 nm against a reagent blank for each set of samples. The iron content was calculated from $Fe(NO_3)_3$ standard curve according to AOAC (1995). Phytate phosphorus was calculated from iron determinations assuming a 4:6 iron phosphorus molecular ratio while phytic acid content was calculated on the assumption that it contains 28.20% phosphorus (Reddy and Salunkhe 1980).

4. Oxalate

Oxalates in the samples were determined using the modified method of Ketiku and Adepoju (2005). About 100 ml distilled water was added to 1 g tamarind pulp in a 250-ml conical flask. The mixture was allowed to stand for 3 hrs before filtering through a double layer No. 4 Whatman filter paper. About 10, 20, 30, 40 and 50 mg/l standard solutions of oxalic acid were then prepared and the absorbances of filtrates of the samples and standards were read. The percentage oxalate was calculated using the formula:

% Oxalate = (sample absorbance × average gradient from the curve for standard × dilution factor)/10,000

Statistical analyses

Three determinations were done for each analysis with each determination replicated three times. The results of these determinations were pooled together, and the means and the standard deviations calculated. One-way analysis of variance was used to test for significant difference ($P \leq 0.05$) and the means separated by Duncan's multiple range test (SAS 1995).

RESULTS AND DISCUSSION

Proximate composition of tamarind pulp

Table 1 shows the proximate composition of tamarind fruits from different locations in Nigeria. The moisture contents indicated wide variations in the fruit samples ranging from 16.8% for Sokoto sample to 36.2% for Birni-Kebbi sample. Samples from Bauchi, Gombe, Jos, Kano, Minna, and Sokoto had relatively low moisture contents (<20%) when compared with other samples. Variations in the moisture contents of the tamarind samples may be due to differences in the relative humidity of the surrounding atmosphere at harvest and cultural practices. Benero *et al.* (1974) had earlier reported differences in cultural practices in the handling of tamarind fruits. According to Benero *et al.* (1974), Krithika and Radhai Sri (2007) and Sadik (2011), mature tamarind fruits are sometimes left to dry on trees till the next harvesting season. The range in values for the moisture contents of the tamarind fruits is similar to the reports of other workers (**Table 2**) but higher than Parvez *et al.* (2003). However, Hassan and Ijaz (1972) and Krithika and Radhai Sri (2007) reported higher moisture content for tamarind pulp. Ishola *et al.* (1990) and Siddhuraju *et al.* (1995) further reported moisture contents of 8.0-10.1% for tamarind seeds. The crude protein of the tamarind fruits ranged from 3.5% (Birni-Kebbisample) to 7.4% (Gombe, Jos and Sokoto samples). The protein contents of the tamarind samples are similar to those of previous workers (**Table 2**) but higher than that reported by Krithika and Radhai Sri (2007). In comparison with the reports of Ishola *et al.* (1990), Siddhuraju *et al.* (1995), Glew *et al.* (1997), Yusuf *et al.* (2007), and Vadivel and Pugalenthi (2010), the result of this study may indicate that the protein content of tamarind fruits is concentrated in the seeds. According to Sawaya *et al.* (1983), Edem *et al.* (1984), Kuhnlein (1989), Ishola *et al.* (1990), Nahar *et al.* (1990), Essien *et al.* (1992), fruits are generally not considered as excellent sources of proteins. The lipid contents of the tamarind fruit samples were found

Table 2 Values in the literature for the proximate composition of tamarind fruit pulp.

Constituent	A (%)	B (%)	C (%)	D (%)	E (%)	F (%)	G g/100 g dry weight	H g/100 g dry weight	I g/100 g dry weight
Dry matter	-	-	-	-	-	73.10	-	95.00	-
Moisture	22.60	33.89	65.85	20.60	31.00	-	18.93	-	20.00
Protein	3.10	3.28	4.70	3.10	9.20	4.10	8.79	8.20	8.50-9.1
Fat	0.40	0.5	0.76	0.40	0.5	1.60	2.53	2.40	2.7-3.1
Carbohydrate	71.80	59.76	26.13	70.80	62.50	85.00	66.87	80.80	82.1-82.6
Crude fibre	3.00	1.79	-	3.00	5.10	5.90	2.20	-	2.8-3.4
Ash	2.10	2.57	2.88	2.10	2.85	3.40	2.28	3.60	2.9-3.3

A: Leung and Flores (1961); B: Wenkam and Miller (1965); C: Hassan and Ijaz (1972); D: Purseglove (1987); E: FAO (1988); F: Saka and Msonthi (1994); G: Ishola *et al.* (1990); H: Nordeide *et al.* (1996); Source: A-H: De Caluwe *et al.* (2010); I: Parvez *et al.* (2003)

Table 3 Ascorbic acid content and physico-chemical properties of tamarind (*Tamarindus indica* L.) fruits.

Location	Ascorbic acid (mg/100g)	Colour (absorbance at 325 nm)	Soluble solids (°Brix)	pH	Total acidity (%)
Abuja	7.8 ± 0.04 bc	0.90 ± 0.03 a	5.9 ± 0.2 abcd	2.5 ± 0.4 cd	1.4 ± 0.06 bc
Azare	6.4 ± 0.36 e	1.42 ± 0.04 a	6.3 ± 0.4 a	2.8 ± 0.2 abcd	1.4 ± 0.2 bc
Bauchi	5.3 ± 0.57 f	0.84 ± 0.05 bc	5.7 ± 0.5 abcd	3.0 ± 0.2 ab	1.5 ± 0.3 bc
Bichi	8.2 ± 0.40 b	0.35 ± 0.05 h	6.4 ± 0.4 a	3.2 ± 0.2 ab	1.5 ± 0.0.2 bc
Birni-kebbi	6.4 ± 0.35 e	0.32 ± 0.04 h	6.0 ± 0.3 abc	2.8 ± 0.3 abc	1.3 ± 0.1 bc
Funtua	5.3 ± 0.51 f	0.59 ± 0.07 f	5.5 ± 0.5 bcd	2.7 ± 0.2 bcd	1.7 ± 0.3 b
Gombe	3.7 ± 0.50 g	0.72 ± 0.05 de	6.3 ± 0.4 a	3.2 ± 0.2 ab	1.5 ± 0.3 bc
Gwarzo	7.3 ± 0.40 cd	0.64 ± 0.04 ef	5.9 ± 0.2 abcd	3.3 ± 0.3 a	1.5 ± 0.2 bc
Jega	6.3 ± 0.29 e	0.31 ± 0.04 h	6.2 ± 0.7 ab	3.3 ± 0.3 a	1.3 ± 0.3 bc
Jos	7.3 ± 0.46 cd	0.79 ± 0.07 cd	5.2 ± 0.4 d	2.6 ± 0.2 bcd	1.3 ± 0.1 bc
Kaduna	7.3 ± 0.50 cd	0.74 ± 0.04 d	6.1 ± 0.4 abc	2.6 ± 0.3 bcd	1.7 ± 0.2 b
Kano	6.9 ± 0.40 de	0.73 ± 0.05 de	5.4 ± 0.4 cd	2.9 ± 0.4 abc	1.5 ± 0.1 bc
Kastina	7.9 ± 0.35 bc	0.63 ± 0.03 f	5.3 ± 0.6 d	2.4 ± 0.5 cd	1.2 ± 0.1 c
Langtang	4.5 ± 0.29 f	0.81 ± 0.06 cd	5.3 ± 0.4 cd	2.8 ± 0.2 abcd	1.6 ± 0.2 bc
Maiduguri	5.1 ± 0.66 f	0.30 ± 0.03 h	5.7 ± 0.3 abcd	3.1 ± 0.3 ab	1.6 ± 0.2 bc
Mallamsidi	4.5 ± 0.40 f	0.75 ±0.03 d	5.3 ± 0.5 d	3.3 ± 0.3 a	1.3 ± 0.1 bc
Minna	5.1 ± 0.30 f	0.43 ± 0.05 g	6.2 ± 0.2 a	3.3 ± 0.3 a	3.0 ± 0.3 a
Oyo	11.3 ± 0.56 a	0.62 ± 0.05 f	6.4 ± 0.3 a	2.3 ± 0.3 d	1.6 ± 0.3 bc
Sokoto	6.2 ± 0.47 e	0.72 ± 0.07 de	6.1 ± 0.2 abc	2.8 ± 0.3 abcd	3.0 ± 0.1 a

Means in the same column with the same letter are not significantly different ($P \leq 0.05$)

to be in the range of 3.5% for Birni-kebbi and 7.4% for Kano sample. Tamarind pulps from Kaduna and Sokoto had the lowest (3.0%) and highest (6.9%) ash contents, respectively. The range of values for fat and ash contents of the tamarind pulp samples are higher than those reported by other workers (Wenkam and Miller 1965; Hassan and Ijaz 1972; Morton 1987; Ishola *et al.* 1990; Coronel 1991; Salunkhe and Kadam 1995; Feungchan *et al.* 1996; Parvez *et al.* 2003; Krithika and Radhai Sri 2007) may be as a result of differences in soil condition and cultivar type. Grela (1996) and Gunasena and Hughes (2000) have also reported similar observations. The carbohydrate contents which ranged between 52.0% for Birni-Kebbi sample and 62.7% for Minna sample is comparable to the range of values reported by Ishola *et al.* (1990), Salunkhe and Kadam (1995) and Gunasena and Hughes (2000) but lower than the range of 82.1-82.6 reported by Parvez *et al.* (2003). The protein and carbohydrate contents of the tamarind samples confirm the report of BAIF (2002) that tamarind fruits contain one of the highest levels of protein and carbohydrate of any fruit. A comparison of the quality attributes of the tamarind fruits (*Tamarindus indica*) with those of velvet tamarind (*Dialium guineense*) as reported by Achoba *et al.* (1993) and Arogba *et al.* (2006) showed similarities only in the acidity and fat content. *Tamarindus indica* fruits contained higher protein, sugar and ash but lower carbohydrate contents than *Dialium guineense*.

Ascorbic acid content and physico-chemical properties of tamarind fruits

Table 3 shows the ascorbic acid content and physico-chemical properties of the tamarind fruit samples. The ascorbic acid content of the fruit samples was between 3.7 mg/100 g for Gombe and 11.3 mg/100 g for Oyo sample. The wide differences obtained in the ascorbic contents of the tamarind samples may be due to soil condition, age of the tamarind trees, and genetic factors. Akinyele and Keshinro (1980), in a tabulated summary of the ascorbic acid contents of common tropical fruits in Nigeria, reported a minimum content of 9.4 mg/100 g and a maximum content of 56.0 mg/100 g. Aworh *et al.* (1983), on the other hand, reported 21.8 mg ascorbic acid/100 g fresh weight for Nigerian tomatoes. Thus, tamarind fruits are a poor source of ascorbic acid when compared with the common fruits in Nigeria. It had been earlier reported by Morton (1987) and Gunasena and Hughes (2000) that the ascorbic acid of tamarind pulp is very low.

The colour, measured as optical density at 325 nm, ranged between 0.3 for Maiduguri sample and 1.42 for Azare sample. The relatively high value of colour for Azare sample may be due to environmental and soil conditions. The soluble solids of tamarind pulp ranged between 5.2 °Brix for Jos sample and 6.4 °Brix for Bichi and Oyo samples, respectively. The pH and total acidity of the tamarind pulp samples revealed that the fruits are high in acid and also that tamarind fruits are more acidic than such underutilised fruits as prick pear pulp and soursop (Sawaya *et al.* 1983; Yusof and Ibrahim 1994). According to Coronel (1991), tamarind fruits are known to be simultaneously the most acidic and sweetest fruits. The high acidity of tamarind pulp is desirable from food processing standpoint, since acidity is important in determining the quality of fruit juices (Yusof and Ibrahim 1994). Acidity contributes to the development of flavour by maintaining a proper sugar: acid ratio thereby modifying the sweetness of sugar and palatability of food products, lends tartness to taste and also provides a thirst-quenching effect by encouraging saliva formation in the mouth (Yusof and Ibrahim 1994; Omobuwajo 1998). Acidity also increases the efficiency of heat processing and inhibits the growth of surviving heat resistant microorganisms (Schoenemann *et al.* 1974).

Table 4 Mineral composition of tamarind (*Tamarindus indica* L.) fruit.

Location	Ca (%)	Mg (%)	K (%)	Na (%)	Pb (%)
Abuja	1.11 ± 0.04 b	0.56 ± 0.07 ab	0.63 ± 0.05 c	0.37 ± 0.04 a	ND
Azare	0.92 ± 0.44 cde	0.55 ± 0.04 ab	0.38 ± 0.05 d	0.23 ± 0.05 de	0.03 ± 0.02 a
Bauchi	0.99 ± 0.11 bc	0.51 ± 0.03 bc	0.42 ± 0.04 d	0.21 ± 0.04 def	ND
Bichi	0.90 ± 0.03 cde	0.37 ± 0.06 de	0.38 ± 0.04 d	0.27 ± 0.04 bcd	ND
Birni Kebbi	0.90 ± 0.10 cd	0.44 ± 0.03 cd	0.63 ± 0.03 c	0.31 ± 0.03 ab	ND
Funtua	1.28 ± 0.13 a	0.61 ± 0.03 a	0.43 ± 0.02 d	0.15 ± 0.04 fgh	ND
Gombe	0.70 ± 0.05 g	0.43 ± 0.04 cd	1.45 ± 0.08 a	0.16 ± 0.04 efg	ND
Gwarzo	0.99 ± 0.10 bc	0.60 ± 0.07 a	0.43 ± 0.05 d	0.23 ± 0.04 de	ND
Jega	0.83 ± 0.06 defg	0.57 ± 0.05 ab	0.62 ± 0.05 c	0.30 ± 0.05 bc	ND
Jos	0.81 ± 0.03 defg	0.42 ± 0.05 d	0.35 ± 0.09 d	0.16 ± 0.05 efg	ND
Kaduna	0.77 ± 0.05 fg	0.45 ± 0.03 cd	0.23 ± 0.04 e	0.15 ± 0.04 fgh	ND
Kano	0.77 ± 0.07 fg	0.40 ± 0.02 d	0.23 ± 0.03 e	0.15 ± 0.04 fgh	ND
Kastina	0.99 ± 0.09 bc	0.51 ± 0.04 bc	0.43 ± 0.05 d	0.15 ± 0.04 fgh	ND
Langtang	0.86 ± 0.08 def	0.54 ± 0.03 ab	0.42 ± 0.04 d	0.16 ± 0.02 efg	ND
Maiduguri	0.71 ± 0.05 g	0.40 ± 0.05 d	0.23 ± 0.05 e	0.09 ± 0.03 hi	ND
Mallamsidi	0.42 ± 0.04 h	0.28 ± 0.05 f	0.36 ± 0.03 d	0.21 ± 0.04 def	ND
Minna	0.90 ± 0.05 cde	0.53 ± 0.02 ab	0.24 ± 0.03 e	0.14 ± 0.04 ghi	ND
Oyo	0.24 ± 0.04 i	0.32 ± 0.02 ef	0.71 ± 0.03 b	0.08 ± 0.04 i	ND
Sokoto	0.80 ± 0.05 efg	0.58 ± 0.07 ab	0.26 ± 0.04 e	0.24 ± 0.02 cd	ND

Location	P (%)	Fe (%)	Zn (%)	Cu (%)	Na/K	Ca/P
Abuja	0.37 ± 0.05 a	0.23 ± 0.02 a	0.03 ± 0.02 a	0.02 ± 0.02 a	0.6	3.0
Azare	0.31 ± 0.02 abcde	0.16 ± 0.04 b	0.03 ± 0.04 a	0.02 ± 0.02 a	0.6	3.0
Bauchi	0.26 ± 0.02 cde	0.15 ± 0.04 bc	ND	0.03 ± 0.02 a	0.5	3.8
Bichi	0.24 ± 0.04 e	0.12 ± 0.03 bcd	ND	0.02 ± 0.02 a	0.7	3.8
Birni Kebbi	0.27 ± 0.06 bcde	0.16 ± 0.02 b	0.01 ± 0.01 a	ND	0.5	3.4
Funtua	0.33 ± 0.05 abc	0.11 ± 0.02 cde	0.03 ± 0.02 a	ND	0.4	3.9
Gombe	0.27 ± 0.05 cde	0.15 ± 0.02 bc	0.03 ± 0.02 a	0.02 ± 0.02 a	0.1	2.6
Gwarzo	0.30 ± 0.02 bcde	0.12 ± 0.03 bcd	0.02 ± 0.02 a	ND	0.5	3.3
Jega	0.31 ± 0.04 abcde	0.14 ± 0.02 bc	0.03 ± 0.02 a	0.03 ± 0.02 a	0.5	2.7
Jos	0.34 ± 0.03 ab	0.14 ± 0.02 bc	0.02 ± 0.02 a	0.02 ± 0.02 a	0.5	2.4
Kaduna	0.28 ± 0.03 bcde	0.07 ± 0.02 fg	0.02 ± 0.02 a	ND	0.7	2.8
Kano	0.28 ± 0.05 bcde	0.07 ± 0.02 ef	0.03 ± 0.02 a	ND	0.7	2.8
Kastina	0.31 ± 0.04 abcde	0.11 ± 0.02 cde	0.01 ± 0.01 a	ND	0.4	3.2
Langtang	0.31 ± 0.04 abcde	0.14 ± 0.00 bc	0.02 ± 0.02 a	ND	0.4	2.8
Maiduguri	0.32 ± 0.03 abcd	0.09 ± 0.02 def	0.02 ± 0.02 a	ND	0.4	2.2
Mallamsidi	0.31 ± 0.03 abcde	0.06 ± 0.01 fg	0.03 ± 0.03 a	0.03 ± 0.02 a	0.6	1.4
Minna	0.30 ± 0.05 bcde	0.03 ± 0.01 gh	0.02 ± 0.02 a	ND	0.6	3.0
Oyo	0.25 ± 0.04 de	0.03 ± 0.02 gh	ND	0.02 ± 0.01 a	0.1	1.0
Sokoto	0.34 ± 0.04 ab	ND	0.02 ± 0.02 a	ND	0.9	2.4

Means in the same column with the same letter are not significantly different ($P \leq 0.05$)
ND, Not detected

Mineral composition of tamarind fruits

The mineral contents of tamarind pulp are as shown in **Table 4**. The tamarind pulp samples exhibited wide variations in the content of several of the mineral. For example, Ca values increased from about 0.24% in the sample obtained from Oyo town to 1.28% in the sample obtained from Funtua. Mg, on the other hand, ranged from 0.28% in the Mallamsidi sample to 0.61% in the Funtua sample. The trace elements Pb, Cu and Zn varied in content among the tamarind samples within much narrower limits. No definite pattern of differences was seen in mineral contents of a particular source of tamarind sample as compared with other sources of tamarind samples, that is, no one source of tamarind was consistently higher or lower in mineral element content than other sources. Ca and Na were the most abundant macro- and micro-minerals, respectively, although all the samples of tamarind pulp recorded very low values of micro-minerals. Maiduguri and Bichi respectively contained the lowest quantities of potassium (0.23%) and phosphorus (0.24%). The macro-mineral contents of the tamarind pulp samples in this study are higher than those reported by Morton (1987), Maragoni *et al.* (1988), Ishola *et al.* (1990) and Bhattacharya *et al.* (1994). However, the report of Kuhnlein (1989) on wild fruit berries is corroborated by the results in **Table 4** in terms of Ca, Mg, Na, Fe, Zn and Cu contents. When compared with the report of previous workers (**Table 5**), tamarind fruits obtainable in Nigeria are fairly rich in minerals, a fact which is further corroborated by Food and Nutrition Board (2011) which stated that the recommended daily intake (RDI) for calcium, iron, magnesium and potassium for a healthy male is 1000, 8, 420 and 4.7 mg, respectively.

Ketiku and Adepoju (2005) had earlier reported that pulp of shear butter contained 0.17-0.21% Ca, 0.17-0.22% Mg, 0.28-0.37% K, 0.37-0.39% Na, 0.40-0.45% P and 0.00-0.01% Fe with insignificant levels of manganese (Mn), Cu and Zn. Thus, tamarind pulp is richer in mineral than shear butter pulp. Most of these mineral elements are essential activators for enzyme-catalysing reactions. Ca, like P, plays a major role in teeth and development and its deficiency can cause osteomalacia, depraved appetite or *pica*, poor fertility, subnormal growth and low live weight gain (Ezeagu *et al.* 1997). Hence, Ca and P are very necessary for growing children, pregnant and lactating women. Calcium and magnesium are important in photosynthesis, carbohydrate metabolism and nucleic acid, and serve as binding agents of cell walls (Ayaz *et al.* 2006). Iron plays a major role in the synthesis of amino acids and protein, and it is an essential activator for enzyme-catalysing reactions involving chlorophyll synthesis and ferrodoxin nitrate reductase. Iron and copper may exist as iron-copper proteins (Ayaz *et al.* 2006). Zinc is an essential micronutrient, which is associated with a number of enzymes, especially those for synthesis of ribonucleic acids. Trace elements are also essential for biological activities of the body, and the formation of mineral complexes enhances the biological activity of trace elements (Shkolnik 1984). The Na/K ratio in the body is of great concern for prevention of high blood pressure (Aremu *et al.* 2006). Na/K ratio less than 1 is recommended. The ratios of sodium

Table 5 Literature values for the mineral composition of tamarind pulp, mg/100 g dry weight.

Minerals	A	B	C	D	E	F
Al	-	-	-	1.84	-	-
Ba	-	-	-	0.20	-	-
Ca	465.75	17.10	240.00	0.19	74.00	106.88
Cu	21.83	-	-	0.91	0.09	0.29
Co	-	-	-	0.01	-	0.05
Cr	-	-	-	0.29	-	-
Fe	8.49	6.80	14.00	3.17	2.80	1.69
K	62.00	1226.90	-	0.65	628.00	790.11
Mg	72.03	128.20	-	0.12	92.00	53.28
Mn	-	-	-	21.50	-	0.06
Mo	-	-	-	0.01	-	-
Na	76.66	11.10	-	6.21	28.00	13.95
Ni	0.52	-	-	0.13	-	0.08
P	91.00	108.10	-	0.12	113.00	99.49
Pb	-	-	-	0.01	-	-
St	-	-	-	0.28	-	-
Ti	-	-	-	0.02	-	-
Zn	1.06	-	2.30	1.32	0.10	0.09

A: Leung and Flores (1961); B: Wenkam and Miller (1965); C: Hassan and Ijaz (1972); D: Purseglove (1987); E: FAO (1988); F: Saka and Msonthi (1994); G: Ishola *et al.* (1990); H: Nordeide *et al.* (1996); Source: A-H: De Caluwe *et al.* (2010)

Table 6 Total carotenoids content of tamarind (*Tamarindus indica* L.) pulp (µg/100 g).

Sample	Total carotenoids
Abuja	16.01 ± 0.19 i
Azare	18.09 ± 0.32 fg
Bauchi	19.06 ± 0.15 ef
Bichi	22.18 ±1.44 b
Birni-Kebbi	19.65 ± 0.69 de
Funtua	21.56 ± 0.83 bc
Gombe	19.02 ± 0.09 ef
Gwarzo	21.03 ± 0.24 bc
Jega	20.75 ± 1.25 cd
Jos	16.25 ± 0.93 i
Kaduna	16.50 ± 0.64 hi
Kano	20.67 ± 0.52 cd
Katsina	20.32 ± 0.73 cd
Langtang	15.67 ± 0.46 i
Maiduguri	15.54 ± 0.60 i
Mallam-sidi	18.28 ± 0.40 fg
Minna	17.67 ± 0.54 gh
Oyo	25.38 ± 1.12 a
Sokoto	18.08 ± 0.19 fg

Means in the same column with the same letter are not significantly different ($P \leq 0.05$)

to potassium (Na/K) as shown in **Table 4** suggest that tamarind fruits could probably be used to reduce coronary heart disease. According to Martinello *et al.* (2006), tamarinds have the potential of controlling the risk of arteriosclerosis developments in humans. Furthermore, modern diets which are rich in animal proteins and phosphorus may promote the loss of calcium in the urine (Aremu *et al.* 2006) and this has lead to the concept of Ca/P ratio. If the Ca/P ratio is low (low calcium, high phosphorus intake), more than the normal amount of calcium may be lost in the urine thereby decreasing the calcium levels in the bones. A food is considered 'good' if the Ca/P ratio is above one and 'poor' if the ratio is less than 0.5 (Nieman *et al.* 1992). The Ca/P ratio in the present study ranged between 1.0 in Oyo sample and 3.8 in Bauchi and Bichi samples, indicating that tamarind foods would serve as good sources of minerals for bone formation.

Total carotenoids content of tamarind pulp

Table 6 shows that the tamarind fruit samples were low in total carotenoids (15.54-25.38 µg/100 g). This result is similar to the earlier reports of Gunasena and Hughes (2000) on tamarind pulp. Gaziano *et al.* (1995) reported that carotene-containing fruits and vegetables reduce the risk of cardiovascular disease. Tamarind fruits, as a result of being consumed in large quantity by indigenous people, are therefore capable of reducing the risk of cardiovascular disease and providing a substantial contribution to vitamin A requirement. Tamarind pulp sample from the Sudan savannah contained the highest amount of carotenoids. The carotenoids contents of tamarind fruits were found to be much lower than those from other tropical fruits, such as carrots (*Daucus carota*), which contained 58,200-103,500 µg/100 g (Arya *et al.* 1979; Ogunlesi and Lee 1979; Sims *et al.* 1993); acreola (*Malpighia emarginata*), which contained 940 µg/100 g (Lima *et al.* 2005); pawpaw (*Carica papaya*), containing 16,600 µg/100 g (Arya *et al.* 1979) and pulp of Mineiro tomato (*Cyphomanra betacea*), which contained 2,430 µg/100 g (Rodríguez-Amaya *et al.* 1983). The low value of carotenoids obtained for the samples supports the claims of Gunasena and Hughes (2000) and Krithika and Radhai Sri (2007) that the colour of tamarind fruit is due mainly to the anthocyanin pigments. The variation in total carotenoids observed among the sources of tamarind pulp may also be attributed to genetic factors (Lima *et al.* 2005). The regulation of carotenoid biosynthesis is complex and restricted to specific plant tissues where they are used. Enzymes of carotenoid biosynthesis, such as geranylgeranyl pyrophosphate (GGPP) synthase are functional in chloroplast/chromoplast but are codified by nuclear genes (Delgado-Vargas *et al.* 2000).

Antinutritional contents of tamarind pulp

The knowledge of antinutritional factors of tamarind is of great significance because the nutritional values of legumes are limited by the presence of certain antinutritional components (Nowacki 1980; Liener 1994). Data on antinutritional factors of tamarind pulps are presented in **Table 7**. The tamarind pulp samples were particularly low (0.02-0.52%) in tannin. The phytate, oxalate and trypsin inhibitor ranged respectively from 0.31% (Oyo sample) to 1.42% (Langtang sample), 0.24 (Azaresample) to 0.47% (Abuja sample) and 0.06% (Oyo sample) to 0.75% (Gwarzo sample). The levels of tannin and oxalate in the tamarind pulp samples are lower than in some of the commonly cultivated pulse crops (Khan *et al.* 1979; Singh and Jamburathan 1981; Al-Bakir *et al.* 1982; Rao and Deosthale 1982; Giami 1993) and underexploited legumes (Siddhuraju *et al.* 1995; Vijayakumari *et al.* 1997). The phytic acid content of tamarind pulps is similar to those of commonly consumed legumes like *P. tetragonolubus* (Tan *et al.* 1983), *V. mungo* (Kataria *et al.* 1989), *V. radiata* (Kataria *et al.* 1989) and lima bean (Egbe and Akinyele 1990). The values of tannin and trypsin obtained in this work are lower than those found in tamarind seeds (Siddhuraju *et al.* 1995).

Tannins are water-soluble compounds (Uzogara *et al.* 1990; Rehman and Shah 2005; Uzoechina 2009) and they can be eliminated by decortication, soaking, heat treatment or cooking (Singh 1988). Kanwar *et al.* (1991) also reported that cooking eliminates more than 98% of trypsin inhibitor activity. The reduction of trypsin inhibitor may be due to denaturation under heat treatment (Vijayakumari *et al.* 1997). Ishola *et al*. (1990) however reported that tamarind pulps do not contain any detectable amount of phytic acid. Phytic acid is known to decrease the bioavailability of certain minerals and may interfere with the utilisation of proteins due to the formation of phytate-protein and phytate-mineral-protein complexes, and also inhibits the digestive enzymes (Reddy *et al.* 1982). Phytates could, however, be substantially eliminated by processing methods such as soaking and heat treatment (Reddy *et al.* 1982).

Generally, differences occurred in the physical and chemical attributes of the tamarind pulp samples. Balogun and Fetuga (1986) reported that agronomic practices, inclu-

Table 7 Antinutritional factors of tamarind (*Tamarindus indica* L.) pulp.

Location	Tannin (%)	Phytate (%)	Oxalate (%)	Trypsin inhibitor µg/mg protein
Abuja	0.07 ± 0.02 cdef	1.30 ± 0.05 b	0.47 ± 0.06 a	0.71 ± 0.03 a
Azare	0.04 ± 0.01 def	0.52 ± 0.04 e	0.24 ± 0.04 j	0.35 ± 0.03 efg
Bauchi	0.04 ± 0.02 def	0.54 ± 0.05 e	0.29 ± 0.02 ghij	0.33 ± 0.05 fg
Bichi	0.05 ± 0.02 def	0.43 ± 0.05 fg	0.35 ± 0.04 def	0.73 ± 0.06 a
Birni kebbi	0.42 ± 0.04 b	1.33 ± 0.05 b	0.41 ± 0.03 abcd	0.40 ± 0.03 def
Funtua	0.07 ± 0.02 cdef	0.51 ± 0.03 ef	0.39 ± 0.04 bcd	0.35 ± 0.03 efg
Gombe	0.07 ± 0.01 cdef	0.54 ± 0.03 e	0.35 ± 0.04 defg	0.33 ± 0.05 fg
Gwarzo	0.03 ± 0.01 ef	0.48 ± 0.05 efg	0.31 ± 0.04 fghi	0.75 ± 0.07 a
Jega	0.41 ± 0.01 b	1.33 ± 0.05 b	0.45 ± 0.04 ab	0.39 ± 0.03 def
Jos	0.07 ± 0.02 cdef	1.43 ± 0.04 a	0.40 ± 0.02 bcd	0.60 ± 0.03 b
Kaduna	0.03 ± 0.02 ef	1.22 ± 0.02 c	0.26 ± 0.02 ij	0.41 ± 0.04 de
Kano	0.09 ± 0.02 cd	0.46 ± 0.03 efg	0.38 ± 0.04 cdef	0.72 ± 0.06 a
Katsina	0.06 ± 0.02 cdef	0.41 ± 0.04 g	0.44 ± 0.04 abc	0.31 ± 0.03 g
Langtang	0.08 ± 0.01 cde	1.42 ± 0.03 a	0.45 ± 0.04 ab	0.61 ± 0.04 b
Maiduguri	0.52 ± 0.08 a	1.16 ± 0.07 c	0.39 ± 0.02 bcd	0.53 ± 0.05 c
Mallamsidi	0.07 ± 0.02 cdef	0.52 ± 0.02 e	0.32 ± 0.04 efgh	0.37 ± 0.03 defg
Minna	0.11 ± 0.03 c	0.47 ± 0.05 efg	0.44 ± 0.05 abc	0.43 ± 0.04 d
Oyo	0.06 ± 0.03 def	0.31 ± 0.02 h	0.26 ± 0.03 hij	0.06 ± 0.01 i
Sokoto	0.02 ± 0.01 f	0.77 ± 0.10 d	0.35 ± 0.01 defg	0.15 ± 0.03 h

Means in the same column with the same letter are not significantly different ($P \leq 0.05$)

ding burning in the savannah, and the combined effects of climatic factors (rainfall, sunshine and temperature) in all the vegetation zones influenced the edaphic conditions, and consequently, the compositional properties of plant species in Nigeria. Globally, climatic conditions have also been known to influence the chemical composition of food crops (Gunasena and Hughes 2000; Wilkes *et al*. 2010). The wide differences in the physical and chemical properties of tamarind pulp may therefore, be due to the fact that the samples were obtained from different geographical zones within the country. Tamarind fruits contained essential chemical substances which could be employed in alleviating problem of food insecurity and malnutrition in developing countries. Tamarind fruits could also be utilised in new product development, thereby increasing the food choices of citizens in sub-Saharan countries.

REFERENCES

A.A.C.C. (1983) *American Association of Cereal Chemists' Approved Methods*, American Association of Cereal Chemists, St Paul MN

A.O.A.C. (1995) *Official Methods of Analysis*, Association of Analytical Chemists, Washington, DC

Abdullahi SA, Abdullahi GM (2005) Effect of boiling on the proximate, antinutrients and amino acid composition of raw *Delonix regia* seeds. *Nigerian Food Journal* **23**, 128-132

Achoba II, Lori JA, Elegbede JA, Kagbu JA (1993) Nutrient composition of black (African) velvet tamarind (*Dialium guineense* wild) seed and pulp from Nigeria. *Journal of Food Biochemistry* **16**, 229-233

Adekunle VAJ, Ojerinde OV (2004) Food potentials of some indigenous wild fruit in lowland rain forests ecosystems of south west Nigeria. *Journal of Food Technology* **2**, 125-130

Adeola AA, Adeola OO, Dosumu OO (2010) Comparative analyses of phytochemical and antimicrobial properties of extracts of wild *Tamarindus indica* pulps. *African Journal of Microbiology Research* **4**, 2769-2779

Adeola AA, Aworh OC (2010) Development and sensory evaluation of an improved beverage from Nigeria's tamarind (*Tamarindus indica* L.) fruit. *African Journal of Food Agriculture Nutrition and Development* **10**, 4079-4092

Arya SS, Natesan V, Parihar DB and Vijayaraghavan PK (1979) Stability of carotenoid in dehydrated carrots. *Journal of Food Technology* **14**, 579-586

Anhwange BA, Ajibola VO, Oniye SJ (2004) Chemical studies of the seeds of *Moringa oleifera* (Lam)' and *Deuterium microcarpum* (Guill and Sperr). *Journal of Biological Science* **4**, 711-715

Afolabi OA, Osuntogun BA, Adewusi SRA, Fapojuwo FO, Ayorinde FO, Grisson FE, Oke LE (1985) Preliminary nutritional and chemical evaluation of raw seeds *Mucuna solanei*: an underutilised food source. *Journal of Agricultural and Food Chemistry* **33**, 122-124

Akinyele IO, Keshinro OO (1980) Tropical fruits as sources of vitamin C. *Food Chemistry* **5**, 163-167

Al-Bakir AY, Sachde AG, Neacon IE (1982) Occurrence and stability of trypsin inhibitor in Iraqi local legumes. *Journal of Agricultural and Food Chemistry* **30**, 1184-1185

Arogba SS, Ajiboro AA, Odukwe IJ (2006) A physico-chemical study of Nigerian velvet tamarind (*Dialium guineense* wild) fruit. *Journal of the Science of Food and Agriculture* **66**, 533-534

Aremu MO, Olaofe O, Akintayo TE (2006) A Comparative study of the chemical and amino acid composition of some Nigerian underutilised legume flours. *Pakistan Journal of Nutrition* **5**, 34-38

Aworh OC, Olorunda AO, Akhuemonkhan IA (1983) Effects of post-harvest handling on qualify attributes of tomatoes in the Nigerian marketing system. *Food Chemistry* **10**, 225-230

Ayaz FA, Glew RH, Millson M, Huang HS, Chuang LT, Sanz C, Hayirlioglu-Ayaz S (2006) Nutrient contents of Kale (*Brassica oleraceae* L. var. *acephala* DC). *Food Chemistry* **96**, 572-579

BAIF (2002) Fruit for the future: Tamarind. *Messages Programme and Technologies on sustainability newsletter* No. 25. Available online: www.baif.com/mpts6.htm

Balogun AM, Fetuga BL (1986) Chemical composition of some under-exploited leguminous crop seeds in Nigeria. *Journal of Agricultural and Food Chemistry* **34**, 189-192

Bello MO, Falade OS, Adewusi SRA, Olawore NO (2008) Studies on the chemical compositions and antinutrients of some lesser known Nigeria fruits. *African Journal of Biotechnology* **7**, 3972-3979

Benero JR, Collazo de Rivera AL, Georage LMI (1974) Studies on the preparation and shelf life of soursop, tamarind and blended soursop-tamarind soft drinks. *Journal of the Agricultural University (Puerto Rico)* **58**, 58-99

Bhattacharya S, Bal S, Mukherjee RK (1994) Studies on the characteristics of some products from tamarind (*Tamarindus indica* L.) kernels. *Journal of Food Science and Technology (India)* **31**, 372-376

Chan HT Jr., Cavaletto CG (1982) Aspetically packaged papaya and guava puree: Changes in chemical and sensory quality during processing and storage. *Journal of Food Science* **47**, 1164-1169, 1174

Coronel RE (1991) *Tamarindus indica* L. In: Verheij EWM, Coronel RE (Eds) *Plant Resources of South East Asia*, PROSEA Foundation, Bogor, pp 298-301

De Caluwe E, Halamova K, Van Damme P (2009) Tamarind (*Tamarindus indica* L.): a review of traditional uses, phytochemistry and pharmacology. In: Juliani HR, Simon JE, Ho C (Eds) *African Natural Plant Products: New Discoveries and Challenges in Chemistry and Quality,* American Chemical Society, Washingto DC, pp 85-110

Delgado-Vargas F, Jiménez AR, Parades-Lopez O (2000) Natural pigments: Carotenoids, anthocyanins and betalains-characteristics, biosynthesis, processing and stability. *Critical Reviews in Food Science and Nutrition* **40**, 173-289

Edem DO, Eka OU, Ifon ET (1984) Chemical evaluation of the value of the fruit of African Star apple (*Chrysophyllum albidum*). *Food Chemistry* **14**, 303-311

Egbe IA, Akinyele IO (1990) Effect of cooking on the antinutritional factors of lima beans (*Phaseolus lunatus*). *Food Chemistry* **35**, 81-88

Essien AI, Ebana RUB, Udo HB (1992) Chemical evaluation of pod and pulp of the fluted pumpkin (*Telfaira occidentalis*) fruit. *Food Chemistry* **45**, 175-178

El-Siddig K, Gunasena HPM, Prasad BA, Pushpakumara DKNG, Ramana KVR, Vijayanand P, Williams JT (2006) *Tamarind, 'Tamarindus indica L.'*, International Centre for Underutilised Crops, Southampton, 188 pp

Ezeagu IE, Metges CC, Proll J, Petze KJ, Akinyosinu AO (1997) Chemical composition and nutritive value of some wild-gathered tropical plant seeds. Available online: http://www.unu.edu/unupress/food/8F173e/*F173EOo.htm

FAO (2007) Low-income Food-Deficit Countries (LIFDC). Available online: www.fao.org/countryprofiles/lifdc.asp?lang=en

Feungchan S, Yimsawat T, Chindapraseat S, Kitpowsong P (1996) Evaluation of tamarind cultivars on the chemical composition of pulp. *Thai Journal of Agricultural Science* **(Special Issue No. 1)**, 28-33
Food and Nutrition Board USA (2011) Dietary reference intakes. Available online: www.nap.edu
Gaziano JM, Manson JE, Branch LG, Colditz GA, Willett WC, Buring JE (1995) A prospective study of consumption of carotenoids in fruits and vegetables and decreased cardiovascular mortality in the elderly. *Annals of Epidemiology* **5**, 333-335
Giami SY (1993) Effect of processing on the proximate composition and functional properties of cowpea (*Vigna unguiculata*) flour. *Food Chemistry* **47**, 153-158
Glew RH, Dorothy JV, Cassius L, Louis GE, Garrett SC, Andrzej P, Mark M (1997) Amino acid, fatty acid and mineral composition of 24 indigenous plants of Burkina Faso. *Journal of Food Composition and Analysis* **10**, 205-217
Gunasena HPM, Hughes A (2000) *Tamarind*, International Centre for Underutilised Crops, Southampton, 182 pp
Grela ER (1996) Nutrient composition and content of antinutritional factors in spelt (*Triticum spelta* L.). *Journal of the science of Food and Agriculture* **71**, 399-404
Griffiths DW, Jones DIH (1977) Cellulase inhibition by tannins in the testa of field beans (*Vicia faba*). *Journal of the Science of Food and Agriculture* **28**, 938-989
Hamerstrand GE, Black LT, Glover JD (1981) Trypsin inhibitors in soy products: Modification of the standard analytical procedure. *Cereal Chemistry* **58**, 42-45
Hassan SK, Ijaz S (1972) Tamarind - A review. *Science Industry (Karachi)* **9**, 131-137
I.I.T.A. (1991) Selected methods for soil and plant analysis. Manual serie No. 1, International Institute of Tropical Agriculture, Ibadan
Ishola MM, Agbaji EB, Agbaji AS (1990) A chemical study of *Tamarindus indica* L. (*Tsamiya*) fruits grown in Nigeria. *Journal of the Science of Food and Agriculture* **51**, 141-143
Jadhav Y, Sahoo AK, Ghosh JA (2010) Phytochemical detection and *in vitro* evaluation of tamarind fruit pulp for potential antimicrobial activity. *International Journal of Tropical Medicine* **5**, 68-72
Kakade ML, Rackies JJ, McGhee JE, Puski G (1974) Determination of trypsin inhibitor activity of soy products: A collaborative analysis of an improved procedure. *Cereal Chemistry* **51**, 376-382
Kamel BA, Dawson H (1985) Characteristics and composition of melon and grape seed oils and cakes. *Journal of the American Oil Chemists' Society* **62**, 881-883
Kanwar JR, Sharma PB, Kanwar SS (1991) Biochemical and nutritional characteristics of non-conventional protein sources. *Journal of the Science of Food and Agriculture* **55**, 141-151
Kataria A, Chauhan BM, Punia D (1989) Antinutrients as affected by domestic processing and cooking. *Food Chemistry* **32**, 9-17
Ketiku AO, Adepoju OT (2004) Protein quality, dietary fibre components and anti-nutritional factors of shea butter (*Butyrospermum paradoxum* Gaertn. f) fruit pulp. *Nigerian Journal of Nutritional Sciences* **25**, 28-33
Khan AM, Jacobsen I, Eggum BO (1979) Nutritive value of some improved varieties of legumes. *Journal of the Science of Food and Agriculture* **30**, 390-400
Khandare AL, Kumar UP, Shanker RG, Venkaiah K, Lakshmaiah N (2004) Additional beneficial effect of tamarind ingestion over defluoridated water supply. *Nutrition* **20**, 433-436
Krithika V, Radhai Sri S (2007) Value added products from tamarind. Available online: www.techno-preneur.net/information_desk/sciencetech-magazine/2007/nov 07/Value.pdf
Kuhnlein HV (1989) Nutrient values in indigenous wild berries used by the Nuxalk people of Bella Coola, British Columbia. *Journal of Food Composition and Analysis* **2**, 28-36
Liener IE (1994) Implication of antinutritional components in soyabean foods. *Critical Reviews in Food Science and Nutrition* **34**, 31-67
Lima VLAG, Melo EA, Maciel MIS, Prazeres FG, Musser RS, Lima DES (2005) Total phenolic and carotenoid contents in acreola genotypes harvested at three ripening stages. *Food Chemistry* **90**, 565-568
Maragoni A, Alli I, Kermasha S (1988) Composition and properties of seeds of the true legume *Tamarindus indica* L. *Journal of Food Science* **53**, 1452-1455
Martinello F, Soares SM, Franco JJ, Santos AC, Sugohara A, Garcia SB, Curti C, Uyemura SA (2006) Hypolipemic and antioxidant activities from *Tamarindus india* L. pulp fruit extract in hypercholesterolemic hamsters. *Food Chemical Toxicology* **44**, 810-818
Morton J (1987) *Tamarind*. Available online: www.hort.purdue.edu/newcrop/morton/tamarind.htm
Nahar N, Rahman S, Mosiihuzzaman M (1990) Analysis of carbohydrates in seven edible fruits of Bangladesh. *Journal of the Science of Food and Agriculture* **51**, 185-192
Nieman DC, Butterworth DE, Nieman CN (1992) *Nutrition*, WMC Brown Publishers, Dubugye, 323 pp
Nowacki E (1980) Heat stable antinutritional factors in leguminous plants. In: Summerfield RJ, Bunting AH (Eds) *Advances in Legume Science*, Royal Botanical Gardens, Kew, pp 171-177
Ogunlesi AT, Lee CY (1979) Effect of thermal processing on the stereoisomerisation of major carotenoids and vitamin A value of carrots. *Food Chemistry* **4**, 311-318
Okigbo BN (1986) Broadening the food base in Africa: The potential of traditional properties of cowpea (*Vigna unguiculata*) flour. *Food Chemistry* **47**, 153-158
Omobuwajo T (1998) New technologies and products development and evaluation of lemon-based soft drink. *Discovery and Innovation* **10**, 12-14
Parvez S, Parvez M, Fujii Y, Gemma H (2003) Analysis of chemical components and oxygen radical absorbance of *Tamarindus indica* L. *Japanese Journal of Tropical Agriculture* **47 (4)**, 243-249
Rao PU, Deosthale YG (1982) Tannin content of pulses, varietal differences, effect of germination and cooking. *Journal of the Science of Food and Agriculture* **33**, 1013-1016
Reddy NR, Salunkhe DK (1980) Effects of fermentation on phytate, phosphorus and mineral content in black gram, rice, and black gram rice blends. *Journal of Food Science* **45**, 1708-1712
Reddy NR, Sathe SK, Salunkhe DK (1982) Phytates in legumes and cereals. *Advances in Food Research* **28**, 1-92
Rehman Z, Shah WH (2005) Thermal heat processing effects on antinutrients, protein and starch digestibility of food legumes. *Food Chemistry* **91**, 327-331
Rodríguez-Amaya DB, Kimura M (2004) *Harvestplus Handbook for Carotenoid Analysis*. Technical monograph 2. International Food Policy Research Institute, Washington DC, 57 pp
Rodríguez-Amaya DB, Bobbio PA, Bobbio FO (1983) Carotenoid composition and vitamin A value of the Brazilian fruit, *Cyphomandra betacea. Food Chemistry* **12**, 61-65
Sadik HA (2011) The nutritional value of *Poha Beer* (Tamarind fruit drink) and its social usage in Tamale metropolis. *Pakistan Journal of Nutrition* **9**, 797-805
Salem SA, Hegazi SM (1973) Chemical changes occurring during the processing of sun-dried apricot juice. *Journal of the Science of Food and Agriculture* **24**, 123-126
Salunkhe DK, Kadam SS (1995) *Handbook of Fruit Science and Technology: Production, Composition, Storage and Processing*, Marcel Dekker, New York, 611 pp
Sánchez PA (2005) Reducing hunger in tropical Africa while coping with climate change. In: Lal R, Uphoff N, Stewart BA, Hansen DO (Eds) *Climate Change and Global Food Security*, Taylor & Francis, New York, pp 3-19
SAS (1995) SAS User's Guide. Statistical Analysis System Institute Inc Cary
Sawaya WW, Khatchadourian HA, Safi WM, Al-Muhammad HM (1983) Chemical Characterization of prickly pear pulp, *Opuntia ficus-indica*, and the manufacturing of prickly pear jam. *Journal of Food Technology* **18**, 183-193
Schoenemann DR, Lopez A, Cooler FW (1974) pH and acidic stability during storage of acidified and non-acidified canned tomatoes. *Journal of Food Science* **39**, 257-259
Siddhuraju P, Vijayakumari K, Janardhanan K (1995) Nutritional and antinutritional properties of the under-exploited legumes *Cassia laevigata* Willd and *Tamarindus indica* L. *Journal of Food Composition and Analysis* **8**, 351-362
Shkolnik MY (1984) The chemical and prediction of calcium content in apple. *Acta Horticulturae* **383**, 463-466
Sims BA, Balaban MO, Mathews RF (1993) Optimisation of carrot juice colour and cloud stability. *Journal of Food Science* **58**, 1129-1131
Singh U (1988) Antinutritional factors of chickpea and pigeon pea and their removal by processing. *Plant Foods for Human Nutrition* **38**, 251-261
Singh U, Jambunathan R (1981) Protease inhibitors and *in vitro* protein digestibility of pigeon pea (*Cajanus cajan* (L) Millsp.) and its wild relatives. *Journal of Food Science and Technology* **18**, 246-247
Spore (2010) Population and agriculture. Special Issue (August), pp 3-6. Available online: http://spore.cta.int
Tan N, Rahim ZHA, Khor H, Wong K (1983) Winged bean (*Psophocarpus tetraganolobus*) tannin level, phytate content and haemagglutinating activity. *Journal of Agricultural and Food Chemistry* **31**, 916-917
Uzoechina OB (2009) Nutrient and antinutrients potentials of brown pigeon pea (*Cajanus cajan var bicolor*) seed flours. *Nigerian Food Journal* **27**, 10-12
Uzogara SS, Morton ID, Daniel JW (1990) Changes in some antinutrients of cowpea (*Vigna unguiculata*) processed with 'kanwa' alkaline salt. *Plant Foods for Human Nutrition* **40**, 249-258
Vadivel V, Pugalenthi M (2010) Evaluation of nutritional value and protein quality of an underutilised tribal food legume. *Indian Journal of Traditional Knowledge* **9**, 791-797
Vijayakumari K, Siddhuraju P, Janardhanan K (1997) Chemical composition, amino acid content and protein quality of the little-known legume *Bauhinia purpurea* L. *Journal of the Science of Food and Agriculture* **73**, 279-286
Wenkam NS, Miller CD (1965) Composition of Hawaii fruits. *Hawaii Agriculture Experimental Station Bulletin* **135**, 65-75
Wheeler EL, Ferrel RE (1971) A method for phytic acid determination in wheat and wheat fraction. *Cereal Chemistry* **48**, 312-316

Wilkes MA, Seung D, Levavasseur G, Trethowan RM, Copeland L (2010) Effects of soil type and tillage on protein and starch quality in three related wheat genotypes. *Cereal Chemistry* **87**, 95-99

Yusof S, Ibrahim N (1994) Quality of soursop juice after pectinase enzyme treatment. *Food Chemistry* **51**, 83-88

Yusuf AA, Mofio BM, Ahmed AB (2007) Proximate and mineral composition of *Tamarindus indica* Linn 1753 seeds. *Science World Journal* **2**, 1-4