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Full Length Research Paper

Post harvest changes in physico-chemical properties and levels of some inorganic elements in off vine ripened orange (*Citrus sinensis*) fruits cv (Navel and Valencia) of Tanzania

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Two orange (*Citrus sinensis*) fruit varieties, Navel and Valencia, from Muheza in Tanga, were analyzed for their proximate composition (ash, acidity, crude fat, crude fibre, sugars and moisture content), ascorbic acid, sugars, concentrations of four macro elements (Ca, Mg, K, Na) and seven heavy metals (Al, Cd, Cu, Fe, Mn, Pb, Zn). The oranges had high moisture content (>68%), moderate titratable acidity (0.60 – 1.65% c.a.), low crude fat content (0.60 – 0.66 g/100 g-fresh weight (fw)), low crude fibre amounts (0.63 – 0.75 g/100 g-fw), low ash content (0.68 – 0.72 g/100 g-fw), high reducing sugars (6.6 – 13.1%), high total sugars (11.4 – 33.4%), high total soluble solids (11.5 – 31.8%) and high ascorbic acid (22.5 – 50.4%). Very low concentrations of the seven heavy metals were detected in the fruits. Ascorbic acid, moisture, titratable acidity, sugars content varied within the season and with storage-ripening time. The high moisture content suggests the usefulness of these fruits in the treatment of obesity. The citric acid which these fruits contain makes them to be used as acid foods when required. The value of ascorbic acid which is above 30 mg/day in these fruits allows them to be considered as good sources of ascorbic acid for human nutrition.

Key words: Orange, proximate composition, ascorbic acid, mineral elements, heavy metals.

INTRODUCTION

Muheza in Tanga region, Tanzania, is well known for its fruit cultivation. Mangoes, oranges and other delicious fruits are grown there. Navel and Valencia oranges are the most common and popular varieties found in the region. The oranges are normally eaten fresh and as orange juice. Orange fruits are excellent source of vitamins and minerals and supply arrays of colour, flavour and texture to the pleasure of eating. One healthy orange supplies about 116.2% of the daily requirement for vitamin C. Because of the importance of fruits as valuable food resources, many studies are being undertaken to establish the quality, physicochemical properties and seasonal variation in the properties of fruits. Physico-chemical properties of fruits such as mango (*Mangifera indica*), papaya (*Carica papaya*,), pineapple (*Ananas comosus*), medlar (*Mespilus germanica*), passion (*Passiflora edulis sims*), plum (*Vitex doniana*) and apple (*Malus domestica*) have been reported by Elahi and Khan (1983), Zaman et al. (2006), Shamsudin et al. (2007), Aydin and Kadioglu (2001), Egbekun et al. (1996) and Romero-Rodriguez et al. (1994), respectively. A few reports on physico-chemical properties of Tanzania fruits include those on mango (Mamiro et al., 2007) and pineapple (Mbogo, 1998).

Analysis of food and food products (Robinson et al., 1989) has revealed the presence of heavy metal in foods that may easily be taken up by persons from their diets. Heavy metals and other inorganic elements (Ca, P, Fe, Mg) have been found in green leafy vegetables (Bahemuka and Mubofu, 1999) and in some fruits (Saka et al., 2007, Mamiro et al., 2007). However information appears to be

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rather limited on many other foods (Aremu and Udoessien, 1990) especially in the developing world. Heavy metals in the environment are taken up by plants and fruits and end up in human diets. Other factors such as foliar sprays, irrigation practices (if plants are irrigated with water which contains these elements) may also cause contamination of fruits. Plants that are grown near motor ways have been shown to accumulate heavy metals especially lead (Chhatwal et al., 1989). The study aims at investigating the post harvest changes in physio-chemical properties and levels of inorganic elements in fresh orange fruits of the Navel and Valencia varieties from Muheza, eastern Tanzania.

MATERIALS AND METHODS

Sources of chemicals and equipment

Reagents

Analytical reagent (AR) grade sulphuric acid (assay 95 - 98%w/v) and Analar HCl acid (assay 37% w/v) were supplied by Aldrich Chemical Company Ltd. England. Analar copper sulphate (98.5-101%), AR grade NaOH pellets (assay 97%) and metaphosphoric acid (assay 88% w/w) were obtained from the British drug house (B.D.H.) Ltd. England. 2,6-dichlorophenol-indophenol A.C.S. reagent, were supplied by Sigma-Aldrich Chemical Company Ltd. England. Phenolphthalein indicator (pH range 8.3 - 10.0) was obtained from May & Baker Ltd. Dagenham, England. Citric acid (monohydrate) (assay 99.8%) and methylene blue indicator (pH range 7 + 0.01 volt) were supplied by Riedel - De Haën Ag Seelze-Hannover. Petroleum-ether (b.p 40-60˚C) was obtained from LAB-SCAN Analytical Sciences Ltd.

Equipment

A memmert oven, a muffle furnace Gallenkamp Rapid Model, Osterizer model 867-66A Waring blendor and Gallenkamp Centrifuge model 200 were from Gallenkamp Ltd.

Glassware

All glasswares were obtained from Gallenkamp Ltd. and Whatman filter papers, were supplied by Whatman Ltd. England.

Fruit sample collection

Samples of Valencia and Navel orange fruits were collected from Muheza farms during the early, mid and late orange fruiting season. Fully mature, ripe, green fruits were picked directly from trees in batches of five for the appropriate laboratory determinations. Fruit samples were transported to the Chemistry Department laboratory for room temperature storage-ripening and for further preparations.

Analysis

The determinations of the different parameters were done immediately on arrival and at intervals of two days from the day of harvesting of the fruits. These determinations were repeated for early, mid and late season fruits.

Moisture analysis

The moisture contents of fruits were determined according to standard methods (AOAC, 1990).

Titratable acidity

Minced fresh fruit samples (10 g) were mixed with 200 cm^3 distilled water and boiled for 1 h and then cooled, the mixture was then filtered. The filtrate (10 cm^3) was titrated with 0.1 M NaOH up to pH 8.1 measured with a RS pH meter. The results were expressed as % citric acid (g citric acid/100 g-fw) (Ranganna, 1977).

Crude fat

The weighed dried fruit sample was put into a thimble and covered with fat free cotton. The thimble was then put into the soxhlet apparatus. The flask was filled with 150 cm^3 petroleum ether and extraction was done for 16 h or longer on a water bath. At the end, the sample was dried at 100°C in the oven for 1 h, then cooled and re-weighed. The difference in the weights gave the fat-soluble material present in the sample. Determination was done in triplicate and the average value was recorded (Ranganna, 1977).

Crude fibre

Crude fibre is determined from the residue obtained from the crude fat determination. 200 cm^3 of the boiling sulphuric acid was added to 2 g of the residue in the digestion flask which was immediately connected to the condenser and then heated for 30 min. The wetted material was then filtered and washed thoroughly with boiling water until the washings were no longer acidic. NaOH solution was boiled under reflux and the washed material was added unto it. The contents in the flask was connected to the reflux condenser and boiled for 30 min. The material was then filtered and washed thoroughly with water followed by 15 cm^3 of alcohol. The contents were dried at 110°C to constant weight, cooled in the desiccators and weighed. The material was ashed in the muffle furnace at a dull-red heat for about 20 min then cooled and weighed. The loss in weight represented crude fibre amount (Ranganna, 1977).

Sugars and soluble solids

Total and reducing sugars, sucrose and total soluble solids content in the oranges were determined following the procedures of AOAC (1990).

Ash

The sample (5 g) was kept in a muffle furnace and ashed at a temperature not exceeding 525°C for 6 h. The ash was then cooled in a desiccator and weighed. The ash content was recorded as g per 100 g fresh weight (g/100 g-fw) (AOAC, 1990).

Ascorbic acid

Ascorbic acid content was obtained using the titration method involving 2,6-dichloroindophenol, that is, method 967.21 of AOAC (1990).

Table 1. Percentage moisture content and percent titratable acidity values (% c.a.) for oranges from Muheza, Tanga, Tanzania at different seasons.

Storage ripening days	Valencia Orange			Navel orange		
	Early	Mid	Late	Early	Mid	Late
Percent moisture content in oranges						
0	87.9 ± 2.6	88.1 ± 1.7	84.2 ± 2.3	80.2 ± 2.3	81.5 ± 2.1	70.7 ± 2.1
2	87.6 ± 3.2	88.5 ± 2.1	85.0 ± 2.3	80.6 ± 2.6	82.0 ± 2.3	71.3 ± 1.6
4	87.1 ± 2.6	89.0 ± 2.2	83.9 ± 3.1	81.1 ± 1.5	82.6 ± 1.9	70.1 ± 3.2
6	86.4 ± 2.3	88.4 ± 2.5	83.3 ± 2.9	79.6 ± 2.1	81.2 ± 2.0	69.4 ±2.7
8	85.8 ± 2.7	86.8 ± 2.1	82.6 ± 1.5	77.5 ± 1.6	78.7 ± 1.8	68.8 ± 1.1
Percent titratable acidity (% c.a.) in oranges						
0	1.05 ± 0.06	0.95 ± 0.06	0.94 ± 0.06	1.65 ± 0.13	1.55 ± 0.06	1.30 ± 0.15
2	1.00 ± 0.25	0.95 ± 0.13	0.90 ± 0.13	1.55 ± 0.06	1.50 ± 0.13	0.95 ± 0.06
4	0.95 ± 0.06	0.90 ± 0.25	0.85 ± 0.06	1.50 ± 0.25	1.45 ± 0.06	0.85 ± 0.06
6	0.90 ± 0.13	0.85 ± 0.06	0.80 ± 0.19	1.45 ± 0.13	1.35 ± 0.06	0.70 ± 0.13
8	0.85 ± 0.06	0.75 ± 0.06	0.80 ± 0.13	1.40 ± 0.06	1.20 ± 0.13	0.60 ± 0.13

All data are the mean of measurements for three samples ± average deviation.

Determination of metals

Sample preparation

To fresh fruit juice (20 cm^3) was added 10 cm^3 of concentrated HCl and the solution made up to a volume of 100 cm^3 with distilled water. The solution was then centrifuged and used for aspiration in the atomic absorption spectrophotometer (AAS). Appropriate dilution was done for elements present at high concentrations (McHard et al., 1976).

Atomic absorption spectrophotometric determinations

The above sample solution was aspirated into the instrument after all necessary set up and standardization procedures. All determinations of metals were performed with a Perkin Elmer Model Analyst 300 AAS using an air-acetylene flame (Perkin-Elmer 1994). For the determination of aluminum, a standard nitrous oxide-acetylene flame was used. All determinations were performed at the Department of Chemistry, University of Dar es Salaam.

RESULTS AND DISCUSSION

Moisture

The moisture content of orange fruits of Tanzania was always higher than 68.8% throughout the season and even after fully ripening (Table 1). High moisture content has also been reported for Nigerian oranges (Fasoyiro et al., 2005). The moisture content varied significantly with time of season, the content decreased during storage ripening under normal room temperature conditions. Valencia oranges had a decrease from 86.7 to 85.1% and Navel oranges from 80.2 to 69.4%. Similar observations have been reported for citrus fruits by Nagar (1993) and Sadashivan et al. (1972). The decrease is due to the evaporation of moisture from the surface of the fruit during the storage period while ripening (Inyang and Agbo, 1995; Sadashivan, 1972; Nagar, 1993). Moisture content determine the nutritional quality of various food materials; the high moisture contents (>80%) suggests a low energy value for these fruits. This suggests therefore that these fruits could be useful in the treatment of obesity as observed by other workers (Muller and Tobin, 1980). The moisture in fruits gives them a natural laxative property which is also important for human body nutrition.

Titratable acidity (TA) in orange

The TA values for the orange fruits are presented in Table 1. During the ripening of oranges under room temperature storage, a decrease in TA acidity was observed similar to that reported by Chen et al. (1992) for Valencia and 'Shamouti' oranges. Their values were comparable to what has been observed for Tanzania Navel oranges and higher than the values observed in Valencia oranges. The TA in Valencia oranges decreased from 1.05 to 0.85% c.a. while in Navel oranges the content decreased from 1.65to 1.40% c.a during the storage-ripening period. Nagar (1993) reported a TA decrease from 1.50 to 1.40% c.a. in ripening Kinnow citrus fruits. The TA of freshly harvested Valencia oranges decreased from 1.05to 0.94% c.a. from early to late season fruits while in Navel oranges this seasonal change in content showed a TA decrease from 1.65 to 1.30% c.a. Gepshtain, et al. (1970) studying the Israel 'Shamouti' oranges found that the concentration of citric acid decreased as the season progressed while that of malic acid remained constant. It has also been reported that during the season when fruits are harvested at different stages of maturity, the acid content decreased with increasing maturity (Lakshminarayana et al., 1979). In citrus fruits, citric acid

Table 2. Reducing sugars, total sugars and total soluble solids content of oranges of Muheza, Tanga, Tanzania at different seasons.

Storage ripening days	Valencia Orange			Navel orange		
	Early	Mid	Late	Early	Mid	Late
Reducing sugars content (% sugar ± 0.4)						
0	6.6	8.3	10.8	9.2	9.7	10.4
2	6.8	8.5	11.1	9.4	9.8	10.7
4	7.1	8.8	11.5	9.5	10.0	11.1
6	7.3	9.1	12.2	9.7	10.2	11.8
8	7.6	9.2	13.1	9.8	10.4	12.6
Total sugars content (% sugar ± 0.4)						
0	11.4	12.1	14.7	19.7	23.2	25.4
2	11.6	12.3	15.0	20.1	23.9	26.1
4	12.0	12.7	15.5	20.8	24.8	27.8
6	12.4	13.2	16.2	21.6	25.8	30.3
8	12.8	13.5	17.4	22.2	26.6	33.4
Total soluble solids (% solids ± 0.5)						
0	11.5	12.4	14.6	19.6	21.9	23.8
2	11.7	12.8	15.0	19.8	22.5	24.6
4	12.0	13.2	15.5	20.2	23.2	26.1
6	12.6	13.4	16.3	21.3	24.2	28.5
8	13.1	13.8	17.7	22.1	25.3	31.8

All data are the mean of measurements for three samples ± average deviation.

is the predominant acid though malic acid is also present in appreciable quantities (Echeverria and Ismail, 1987; Biale 1960). The loss in the dominant citric acid might be the cause for the decrease in acidity during the ripening of oranges as a direct relationship exists between the acidity of citrus fruit juices and the concentration of combined citric and malic acids (Chen et al., 1992). The reduction of TA might also be due to the utilization of these constituent acids in the fruit respiratory process (Nagar, 1993).

The nutritional value of fruit acids depends upon whether they are absorbed and oxidized in the body; citric acid is largely absorbed. It might be supposed that citrus fruits containing citric acid or its potassium salt would act as acid foods (Nitsch, 1965). A decrease in acidity and an increase in sugars are important parameters in flavour development. The sugar:acid ratio has been used as a maturity fruit index and has been found to increase with ripening (Medlicott and Thompson, 1985).

Sugars

Sugars in oranges consist mostly of glucose, fructose and sucrose in approximately a 1:1:2 ratios (Ting and Rouseff, 1986). The contents of the reducing sugars, total sugars and soluble solids in the orange varieties studied increased during ripening (Table 2). The reducing sugars in Valencia oranges increased from 8.6 to 9.7%, total sugars increased from 13.7 to 14.6% and soluble solids increased from 12.8 to 14.9%. Navel oranges showed an increase in reducing sugars from 9.8 to 10.9%, and that of total sugars from 22.8 to 27.4%. Soluble solids increased from 21.8 to 26.4%. The observed increase in the reducing sugars are higher than that of Nagar (1993) who reported for the Kinnow mandarin fruits (2.9 to 3.9 %). Such increase has been attributed to a concurrent increase in the sucrose contents which is then hydrolysed to simple sugars (Echeverria and Ismail, 1987). Increase in the concentration of juices as a result of dehydration might be another factor (Nagar, 1993; El-Zeftawi, 1976, Davis, et al 1973 and Biale, 1960). During the season, the reducing sugars, total sugars and soluble solids contents of the oranges were found to increase. Late-season fruits had the highest contents of these sugars. Mid-season fruits had moderate contents and early-season fruits had the lowest contents of sugar. These observations were similar to those of Ketsa et al. (1995).

Ascorbic acid

Ascorbic acid contents in the oranges studied decreased during ripening (Table 3). Navel oranges had an average value of 42.5 mg/100 g when harvested. Vinci et al. (1995) reported a value of 49.8 mg/100 g in oranges from Southern regions of Italy while West et al. (1988) reported a value of 48.0 mg/100 g for oranges from some

Table 3. Ascorbic acid content of oranges of Muheza, Tanga, Tanzania at different seasons.

Storage ripening days	Ascorbic acid content (mg/100 g-fw ± 3.2)					
	Valencia Orange			Navel orange		
	Early	Mid	Late	Early	Mid	Late
0	47.5	50.4	40.6	45.6	50.1	31.3
2	45.4	48.3	39.0	42.8	47.1	28.7
4	43.1	46.8	37.8	37.7	44.5	26.4
6	37.4	44.0	36.4	32.6	40.7	25.8
8	32.3	42.3	34.7	27.8	37.2	22.5

All data are the mean of measurements for three samples ± average deviation. Fw = Fresh weight.

parts of East Africa. Aydin and Kadioglu (2001) also reported similar observations for ripening in medlar (*Mespilus germanica* L.) fruits. The ascorbic acid contents of oranges during the season showed that the mid-season fruits of Valencia oranges and early-season fruits of Navel oranges had the highest contents. Late-season fruits of Valencia and Navel oranges had the lowest contents of ascorbic acid.

The recommended daily intake (RDI) of ascorbic acid is about 30 mg/day for adults and 17 mg/day for children. With these fruits therefore, Tanzanian could be considered as good sources of ascorbic acid for purposes of human nutrition.

Ash

The ash contents of oranges studied ranged between 0.68±0.06 to 0.72 ±0.06 g/100g (Table 4). West et al. (1988) found the ash contents of the orange as 0.50 g/100g. An ash content range of 0.30 to 0.70 g/100g was obtained by Romero-Rodriguez et al. (1994) for some fruits of Galicia (NorthWest Spain). The ash content decreased with ripeness of the fruit, that is, from 0.70 (at harvest) to 0.59 g/100g-fw after 8 days of storage-ripening. The main purpose of ash determination is to assess the quality of the food materials. A high total ash of a food material signifies the presence of adulterants (Ranganna, 1977). No significant variation in ash content was observed for early, mid and late season orange fruits.

The ash contents, in these fruits are not high; this implies low quantities of inorganic compounds in the fruits. Thus, to get higher quantities of such compounds in the body, repeated intake of the fruits is recommendable.

Crude fat

The crude fat content of the oranges studied ranged from 0.60 ± 0.06 g/100 g to 0.65 ± 0.06 g/100g of edible portion (Table 4). Fasoyiro et al. (2005) reported a low crude fat content of 0.03 g/100 g-fw for Nigerian oranges. These oranges were low in fat contents (Samson, 1980; Vickery and Vickery, 1979). The crude fat content results obtained agreed with those reported in the literature (West et al., 1988; Romero-Rodriguez et al., 1994). The low levels of fat in oranges agree with the observation that these fruit are not good sources of energy (Samson, 1980). Low values of fat contents imply that these substances are not good sources of fat and hence there is a need for supplementing these substances with other sources of fat for proper body nutrition.

Crude fibre

Oranges had average crude fibre content of 0.63 ± 0.01 g/100 g-fw (Table 4). This content is fair for body maintenance. West et al. (1988) reported a crude fibre content of 0.60 g/100 g-fw for oranges from east Africa while Fasoyiro et al. (2005) reported a crude fibre content of 0.55 g/100 g-fw for Nigerian oranges. Fibre helps to maintain the health of the gastrointestinal tract, but in excess it may bind trace elements, leading to deficiencies of iron and zinc in the body (Siddhuraju et al., 1996).

Metal contents

The contents of mineral elements and metals in the fruits are summarized in Table 4. Potassium was the predominant element of the mineral elements in the orange fruit. The highest value of potassium was 172.10-mg/100 g-fw found in the Valencia oranges and the lowest value was 162.00 mg/100 g-fw found in Navel oranges. The potassium content of the orange fruits herein reported were equivalent to the potassium contents reported for East Africa fruits by West et al. (1988) that is,150.0 - 280.0 mg/100 g-fw and for oranges from Nigeria by Aremu and Udoessien (1990).

The magnesium content in the orange fruits ranged from 42.32 mg/100g-fw in Valencia oranges to 48.24 mg/100g-fw observed in Navel oranges. These levels in Mg content are within the range, 7.7 to 118.0 mg/100 g-

Table 4. Ash, crude fat, crude fibre and metal elements and heavy metals contents in orange fruits from Muheza, Tanga, Tanzania.

Orange fruits	Valencia	Navel
Attributes (g/100 g-fw)		
Ash	0.68 ± 0.06	0.72 ± 0.06
Crude fat	0.60 ± 0.06	0.65 ± 0.06
Crude fibre	0.63 ± 0.01	0.66 ± 0.01
Metal elements (mg/100 g-fw)		
Potassium	172.10 ± 2.69	162.00 ± 4.00
Magnesium	42.32 ± 1.05	48.24 ± 0.38
Calcium	33.00 ± 1.29	30.25 ± 0.33
Sodium	3.30 ± 0.28	2.54 ± 0.05
Heavy metals (mg/100 g-fw)		
Copper	0.31 ± 0.04	0.44 ± 0.01
Iron	0.12 ± 0.01	0.31± 0.04
Zinc	0.16 ± 0.04	0.19 ± 0.03
Manganese	0.37 ± 0.09	0.85 ± 0.04
Aluminium	0.03 ± 0.02	0.05 ± 0.03
Lead	BD	BD
Cadmium	BD	BD

Values represent mean of three independent determinations ± average deviation. BD = Below detection limit of 1 µg/100 g.

fw, reported by Aremu and Udoessien (1990) for Nigerian oranges but higher than the range reported by Hunt et al. (1991) of 6 to 14 mg/100 g-fw for Galician fruits. The calcium levels observed in the oranges had a range from 30.25 mg/100g fw in Navel oranges to 33.00 mg/100g-fw in Valencia oranges (Table 2). This range was higher than that reported by West et al. (1988) (16.0 to 28.0 mg/100 g-fw.) for fruits in East Africa but was within the range (7.4 - 55.1 mg/100 g-fw) reported by Aremu and Udoessien (1990) for some Nigerian fruits. The amount of calcium present in the orange fruits was lower than the FAO value of 1.5 g/100 g.

Among the four mineral elements studied, sodium was the lowest in all the fruits. The amount ranged from 2.54 mg/100 g-fw observed in Navel oranges to 3.30 mg/100 g-fw in Valencia oranges. The sodium content of fruits herein reported was comparable to the sodium content reported for fruits of East Africa by West et al. (1988) of 2.0 to 4.0 mg/100 g-fw but was low when compared to reports on sodium content of some fruits of Galicia (Romero-Rodriguez et al., 1994) and of Nigeria by Aremu and Udoessien (1990). The levels of potassium (K), magnesium (Mg), calcium (Ca) and sodium (Na) reported in this study varied a bit (Table 4). The variations exhibited by the levels of these minerals could be due to differences in the levels of these metals present in the soil and different rates of absorption of these elements by plants which in turn is influenced by, among other factors, the pH of the soil and the organic matter content (Ifon and Bassir, 1979; Vogel, 1978).

The results showed that K was the chief mineral element. The levels of the above four mineral elements in the fruits were lower than those reported by FAO for such fruits. In comparison with the recommended dietary daily allowance (RDDA), the minerals elements levels were low, thus these fruits could not provide adequate amounts of these minerals except for K.

Heavy metals

The heavy metals levels measured in the Valencia and Navel oranges are summarized in Table 4. Valencia oranges had a manganese content of 0.37 mg/100 g-fw while Navel oranges had 0.85 mg/100 g-fw. These levels were higher than the values (0.02 to 0.39 mg/100 g-fw) reported for fruits by Ellen et al. (1990) and values (0.08 to 0.2 mg/100 g-fw) reported for Galician fruits by Romero-Rodriguez et al. (1994). The observed levels in Tanzania oranges were lower than the recommended daily intake (RDI) of manganese of 2-5 mg per day (Ellen et al., 1990).

The average amount of copper in the orange fruits ranged from 0.31 mg/100 g-fw found in Valencia oranges to 0.44 mg/100 g-fw found in Navel oranges. When the levels of copper were compared to the permissible level of 4 mg/100 g for copper in foods, all of these fruits had copper amounts well below this level. The copper contents were also lower than that found in some Nigerian fruits (Aremu and Udoessien, 1990) but higher than those reported by Hunt et al. (1991). The copper contents were comparable to those reported for Galician passion fruits by Romero-Rodriguez et al. (1994) (0.02 - 0.2 mg/100 g-fw). Ellen et al. (1990) reported a range of 0.034 to 0.23 mg/100 g-fw of copper in some Netherlands fruits.

The levels of iron in the Tanzania oranges ranged from 0.12 mg/100 g-fw in Valencia oranges to 0.31 mg/100 g-fw measured in Navel oranges. When compared to the levels of iron reported by Aremu and Udoessien (1990) for some fruits of Nigeria origin (that is, 2.1-11.5 mg/100 g-fw), the Tanzania oranges contained rather low amounts of iron. However the iron levels (0.07 - 0.37 mg/100 g-fw) reported by Hunt et al. (1991) and the level (0.3 - 0.6 mg/100 g-fw) reported by Romero-Rodriguez et al. (1994) for Galician fruits were lower.

The zinc levels in the Tanzania orange fruits ranged from 0.16 mg/100 g-fw observed in Valencia oranges to 0.19 mg/100 g-fw found in Navel oranges. Aremu and Udoessien (1990) reported a range of 0.89 - 46 mg/100 g-fw of zinc from some Nigerian fruits. The Tanzania oranges had zinc content well below the Food and Agricultural Organization (FAO) and World Health Organization (WHO) permissible level of zinc in foods, which is, 6 mg/100 g. However the levels of zinc in the Tanzania oranges were generally higher than those reported by Hunt et al. (1991), which is, 0.002-0.06 mg/100 g-fw, and were within the range, 0.035 to 0.41 mg/100 g-fw, reported by Ellen et al. (1990) for some fruits of Netherlands and the range, 0.08-0.5 mg/100 g-fw, reported by Romero-Rodriguez et al. (1994) of) for Galician fruits.

Valencia oranges had only 0.03 mg of aluminium per 100 g-fw while Navel oranges had 0.05 mg/100 g-fw of aluminium (Table 4). Lead and cadmium could not be detected in all the orange fruits. However Ellen et al. (1990) has reported a lead content of 10-29 µg per kg fruit and a cadmium content of 2-9 µg per kg for some fruits from the Netherlands. The heavy metal contents of the fruits were found to be very low, much lower than the permissible levels of such elements in foods. It was thus concluded that the exposure of these fruits to the toxic elements cadmium and lead was very minimal.

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