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Dietary Fibre and Mineral Availability in Some Nigerian Fruit-Vegetable and Fruit-Legume Composite Diets

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ABSTRACT

Soluble Dietary Fibre (SDF), Insoluble Dietary Fibre (IDF) and Total Dietary Fibre (TDF) were determined by the gravimetric method in some fruits (Banana, Grapefruit, Orange and Pineapple), amaranthus vegetable and a legume (Vigna unguiculata). The availability of some minerals (Fe, Zn, Mg and Cu) in the whole fruits was investigated using ICP – OES after enzymatic digestion as well as their possible effect in composite amaranthus-fruit and legume-fruit meals. The different types of fibres were low in all the fruit samples but relatively high in amaranthus and cowpea. Banana and orange enhanced Fe availability from amaranthus but grapefruit and pineapple impaired Fe availability. All the fruits impaired Fe availability from cowpea. There was a strong correlation between DF and Iron Availability. All the fruits enhanced Zn availability from amaranthus but only grapefruit and orange enhanced it from cowpea. There was no correlation between Mg and DF. All the fruits impaired Cu availability with the exception of orange with 100 % enhancement from amaranthus and pineapple with 25 % enhancement from cowpea.

INTRODUCTION

Mineral deficiency (especially iron) is still a public health issue in West African countries where the population depends mainly on carbohydrate foods, vegetables and very little animal protein. Iron deficiency causes anaemia and other related diseases (Punnonen, Irjala & Rajamaki, 1997). Deficiency of copper has been reported to cause cardiovascular disorders as well as anaemia and disorders of the bone and nervous system (Mielcarz *et al.*, 1997). Deficiency of magnesium in man is responsible for severe diarrhoea, migraines, hypertension, cardiomyopathy, atherosclerosis and stroke (Mark, Kokke & Saidi 1995; Mauskop & Altura 1998; Appel 1999) while zinc deficiency is a common feature of inherited diseases such as *Acrodermatitis enteropathica* growth retardation and testicular hypofunction (Prasad, 2003; Brown *et al.*, 2002).

Mineral availability from plant food sources is usually low (Adewusi, Falade & Harwood, 2003) but some food constituents could either enhance or inhibit mineral availability; those that enhance mineral availability include ascorbic acid, lactic acid and some amino acids

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(Adewusi, Ojumu & Falade 1999; Oladipo *et al*., 2004; Falade *et al*., 2003). Plant anti-nutritive components such as phytate, tannin and oxalate have been implicated to impair mineral availability (Adewusi & Falade, 1996; Osuntogun *et al*., 2004).

In a recent dietary survey of adolescent university students (Obafemi Awolowo University, Ile-Ife, Nigeria) aged between 18 and 25 (Sample size - 174) and adults (Sample size - 225), it was found that 41.3 and 49 % of the adolescent and adult groups consumed fruits on a regular basis, satisfying the RDA (Dare *et al*., unpublished results). In addition, most of the adults consumed packaged fruit drinks during social occasions while the adolescents preferred soft drinks. 60 and 53 % of the adolescent and adult groups consumed whole fruits especially oranges, grapes, pineapple and banana, all of which contain dietary fibre.

Dietary fibre, defined as that portion of plant foods that cannot be digested by the nonmicrobial enzymes in the digestive tract (Deis, 1999), has been reported to impair mineral availability (Fernandez & Phillips, 1982), though the positive effect of dietary fibre include the reduction of blood cholesterol and the glycaemic index of carbohydrate sources (Murray *et al.,* 1999; Kurowska, 2000; Liu *et al* ., 2000) Fruits contain appreciable amounts of dietary fibre, especially soluble fibres. They are also well known sources of dietary ascorbic acid - vitamin C (Shaw & Wilson, 1982). However vegetables and cowpeas contain high levels of minerals, a greater percentage of which is not available (Adewusi & Osuntogun, 1991; Adewusi & Falade, 1996).

This present study was designed to examine the effects of adding some selected whole fruits to either vegetable (amaranthus) or cowpea on their mineral availability and also to examine any correlation between DF and mineral availability.

MATERIALS AND METHODS

Ripe fruits (orange, grapefruit, pineapple and banana) and amaranthus vegetable (*Amaranthus esculentus* L.) were bought in a local market in Ile-Ife. Cowpea (*Vigna unguiculata* L. Walp IT82D-699) was obtained from IITA, Ibadan. The fruits were washed with distilled water, peeled and seeds, where present, were removed. The fruits, thus prepared, were blended into a creamy consistency using Kenwood KW10 food blender and frozen until used.

The amaranthus vegetable was cleaned of foreign matter, diced and blanched with hot water for 20 minutes, cooled and also stored in the freezer until used. The cowpea (IT 82D-699) seeds were cleaned, cooked and processed into powdery form as previously described (Adewusi *et al.,* 1999).

Chemical analysis

Moisture content was determined according to the AOAC method (AOAC, 1984). Total, soluble and insoluble dietary fibres were determined by Enzymatic-Gravimetric method. 2 g each of the fruit and amaranthus samples on wet weight basis and 1g of cowpea were analysed as described by Lee, Prosky & DeVries (1992). The analysis was carried out in quadruplicate.

Total mineral content was determined from 4 g of the fresh fruits each, and blanched vegetable samples and 0.5 g of the cowpea weighed in triplicate. 10 ml conc. HNO_3 was added to each sample in a digestion flask and allowed to stand overnight. The samples were heated carefully until the production of brown nitrogen (iv) oxide fume ceased. The flasks were cooled and (2-4 ml) of 70 % perchloric acid was added. Heating was continued until the solutions turned colourless. The solutions were transferred into 50ml standard flasks and diluted to mark with distilled water. Total mineral content was then analysed by ALPHA 4 Atomic absorption spectrophotometer.

Available mineral content was determined as follows by the method of Miller *et al.* (1981) as modified by Falade *et al*. (2003).

Preparation of test meals: 20 g fresh sample was mixed with 80 g water to make 100 g meal (fruits and amaranthus) while 10 g of cowpea (dry weight) was mixed with 90 g of water to make a 100 g meal. The mixture was homogenised in a Kenwood KW10 food blender to a creamy consistency, adjusted to 40 g meal aliquots and frozen until used.

Simulated digestion of test meals: Pepsin-HCl digestion: The frozen meal from (i) above was thawed at 37^{o}C and divided into 20 g aliquots. Pepsin was then added to provide 0.1 g per 20 g meal and incubated in a water bath for 2 hours at 37^{o}C. After the incubation period, one of the 20 g portions was analysed for titratable acidity while the other portion was frozen until used.

Pancreatin digestion: The frozen 20 g-pepsin digest from (b) above was thawed and placed into a 100 ml beaker. Dialysis tubing (12,400 molecular weight cut off obtained from Sigma), which contained 10 ml distilled water and an amount of $NaHCO_3$ equivalent to the measured titratable acidity, was placed into the beaker containing 20 g pepsin digest sample. The beaker was sealed with parafilm and incubated in a Buchi water bath model No 887196, type B 465 at 37^{o}C with continuous agitation until pH was about 5 (approx. 30min). Pancreatin-bile extract mixture (6.25 ml) was then added to the beaker and incubated for 2 hours with gentle shaking. The volume of the dialysate was noted and then frozen until used.

Preparation of composite test meals was carried out by mixing 16 g fruit (wet weight) with 4 g (dry weight) of vegetable or cowpea. Water was added to the mixture to make a 100 g meal and then blended to a creamy consistency. The resulting mixture was treated as in (a) and (b) above.

Determination of titratable acidity was carried out as described by Miller *et al.*, 1981.

Estimation of available mineral: Protein from the dialysate was precipitated as previously described (Miller *et al.*, 1981) and the supernatant was diluted as required for available mineral determination using ALPHA 4 Atomic Absorption Spectrophotometer.

Statistical Analyses

The results were expressed as a mean of three determinations with the exception of dietary fibre and available minerals that were presented as the mean of four determinations ± SD. Correlation analysis was carried out using the Pearson test.

RESULTS

The moisture content presented in Table 1 ranged between 71 and 89 % for fruit samples. The moisture content of amaranthus was equally high (85.4 %).

Total Dietary fibre (TDF) was very low in all the fruit samples. It ranged between 1.3 and 1.7 g/100 g FW (fresh weight) samples. SDF for all samples was lower than the respective IDF. SDF ranged between 0.2 g/100 g for banana and 0.8 g /100 g for orange and pineapple. IDF range of 0.5 to 1.3 g/100 g was obtained for fruit samples while amaranthus and cowpea had IDF content of 3.3 g/100 g and 13.3 g/100 g FW respectively.

Iron content

Individual samples. Total iron content presented in Table 2 ranged between 10.9 mg and 12.1 mg/kg for fruit samples while amaranthus and cowpea recorded

Table 1. Percentage moisture and dietary fibre values of fruits, amaranthus vegetable and cowpea

Sample	% Moisture	*Dietary fibre g/100g*			
		IDF[1] basis	*SDF[2]*	*TDF[3]*	*TDF on dry wt basis*
Banana	71.4 ± 0.2	1.1 ± 0.03	0.2 ± 0.05	1.3 ± 0.1	4.5%
Grape fruit	82.4 ± 0.1	1.3 ± 0.3	0.5 ± 0.15	1.7 ± 0.2	9.7%
Orange	88.9 ± 0.3	0.7 ± 0.3	0.8 ± 0.16	1.5 ± 0.1	13.5%
Pineapple	88.1 ± 1.0	0.5 ± 0.01	0.8 ± 0.00	1.3 ± 0.01	10.9%
Amaranthus[4]	85.4 ± 1.2	3.3 ± 0.3	0.3 ± 0.05	3.6 ± 0.3	24.7%
Cowpea[5]	10.6 ± 0.4	13.3 ± 2.2	1.4 ± 0.87	14.7 ± 1.4	16.4%

*mean ± standard deviation of quadruplicate analysis expressed on wet weight basis

[1] Insoluble dietary fibre
[2] Soluble dietary fibre
[3] Total dietary fibre
[4] Values are on wet weight basis (Blanched vegetable)
[5] The samples were dried at 50^{o}C prior to analysis.

46.3 mg and 178.5 mg/kg respectively. Banana recorded the highest value of 39.4% availability of iron, while orange had the least value of 10.7% among the fruit samples. Amaranthus and cowpea recorded very low percent availability (1.7 and 2.2% respectively).

Composite meals: When each of the fruit samples was mixed separately with amaranthus and cowpea in ratio 4:1 and 9:1 respectively, banana and orange enhanced iron availability from amaranthus by 13.9% and 16.7% respectively. On the other hand, grapefruit and pineapple reduced iron availability by 27.3% and 28.6% respectively. All the fruit samples impaired iron availability from cowpea by between 21.1% and 93.3%.

Magnesium content

Individual samples. Total magnesium content of the fruits presented in Table 3 showed a range between 180 and 1670 mg/kg. Amaranthus and cowpea had the highest total magnesium content (1024 and 1665 mg/kg respectively). Percent available magnesium ranged between 25.3% and 44.4% while the percent available magnesium for amaranthus and cowpea samples (Table 3) was 8.8 and 25.7% respectively.

Composite Meals: When fruit samples and the foodstuffs were mixed as described earlier, all the fruit samples, especially orange and grapefruit, enhanced magnesium availability. The enhancement was between 14.3 and 62.2%. On the other hand, all the fruits samples impaired magnesium availability from cowpea.

Zinc content

Individual Samples. Total zinc presented in Table 4 ranged between 2.7 mg and 11.1 mg/kg for the fruit samples, 23 mg/kg for amaranthus and 50 mg/kg for cowpea. Percent available zinc for fruits samples ranged between 0.3 and 89%. The

Table 2. Total percent available iron content of fruits, amaranthus vegetable, cowpea together with the theoretical and experimental available iron values of the composite diets[1]

Sample	*Total iron (mg/kg)*	*% available iron*	*Available iron (mg/kg) in fruit-amaranthus and fruit-cowpea composite diets*					
			Fruit + amaranthus[2]			*Fruit + cowpea*[3]		
			Theoretical	*Exptal*	*%DF*[4]	*Theoretical*	*Exptal*	*%DF*[4]
Banana	10.9 ± 0.3	39.4	3.6 ± 0.0	4.1 ± 2.6	+ 13.9	4.3 ± 0.0	1.0 ± 1.1	- 76.7
Grape fruit	11.1 ± 0.2	22.5	2.2 ± 1.1	1.6 ± 1.0	- 27.3	2.7 ± 1.1	0.6 ± 0.2	- 77.8
Orange	12.1 ± 0.5	10.7	1.2 ± 0.1	1.4 ± 0.2	+ 16.7	1.5 ± 0.1	0.1 ± 0.2	- 93.3
Pineapple	12 ± 2.7	13.8	1.4 ± 0.9	1.0 ± 0.1	- 28.6	1.9 ± 0.9	1.5 ± 0.9	- 21.1
Amaranthus	46 ± 9.0	1.7	-	-	-	-	-	-
Cowpea	179 ± 5.0	2.2	-	-	-	-	-	-

[1] mean ± standard deviation of quadruplicate analysis
[2] composite diet = fruit and amaranthus mixed in ration 4:1
[3] composite diet =fruit and cowpea mixed in ration 9:1
[4] DF = difference between theoretical and experimental values

Table 3. Total percent available magnesium content of fruits, amaranthus vegetable, cowpea together with the theoretical and experimental available magnesium values of the composite diets[1]

Sample	*Total iron magnesium (mg/kg)*	*% available magnesium*	*Available magnesium (mg/kg) in fruit-amaranthus and fruit-cowpea composite diets*					
			Fruit + amaranthus[2]			*Fruit + cowpea*[3]		
			Theoretical	*Exptal*	*%DF*[4]	*Theoretical*	*Exptal*	*%DF*[4]
Banana	455 ± 45	28.7	126 ± 3.6	144 ± 26	+ 14.3	172 ± 12.5	165 ± 10.4	-4.2
Grapefruit	178 ± 25	44.4	87 ± 10	141 ± 5.1	+ 62.2	133 ± 24.4	110 ± 6.8	- 17.3
Orange	180 ± 36	29.9	61 ± 6.4	85 ± 10.8	+ 39.8	95 ± 7.1	95 ± 18.4	- 0.1
Pineapple	398 ± 31	25.3	104 ± 12	120 ± 15	+ 14.7	152 ± 20.7	135 ± 9.9	- 11.0
Amaranthus	1024 ± 84	8.8	-	-	-	-	-	-
Cowpea	1665 ± 35	25.7	-	-	-	-	-	-

[1] mean ± standard deviation of quadruplicate analysis
[2] composite diet = fruit and amaranthus mixed in ration 4:1
[3] composite diet =fruit and cowpea mixed in ration 9:1
[4] DF = difference between theoretical and experimental values

Table 4. Total percent available zinc content of fruits, amaranthus vegetable, cowpea together with the theoretical and experimental available zinc values of the composite diets[1]

Sample	*Total zinc (mg/kg)*	*% available zinc*	*Available zinc (mg/kg) in fruit-amaranthus and fruit-cowpea composite diets*					
			Fruit + amaranthus[2]			*Fruit + cowpea*[3]		
			Theoretical	*Exptal*	*%DF*[4]	*Theoretical*	*Exptal*	*%DF*[4]
Banana	11.1 ± 0.1	10.8	1.5 ± 0.0	1.9 ± 0.9	+ 26.7	2.4 ± 0.4	2.2 ± 0.6	- 4.3
Grape fruit	2.9 ± 0.0	82.8	2.4 ± 0.9	4.2 ± 0.4	+ 7.5	3.1 ± 0.9	3.2 ± 0.5	+ 3.2
Orange	9.6 ± 0.5	0.3	0.5 ± 0.0	0.9 ± 0.1	+ 80.0	1.0 ± 0.0	2.2 ± 0.2	+ 120
Pineapple	2.7 ± 0.2	88.9	2.4 ± 0.6	3.3 ± 1.1	+ 37.5	3.3 ± 0.3	2.9 ± 0.5	- 12.1
Amaranthus	23 ± 3.7	10.1	-	-	-	-	-	-
Cowpea	50 ± 0.0	16.7	-	-	-	-	-	-

[1] mean ± standard deviation of quadruplicate analysis
[2] composite diet = fruit and amaranthus mixed in ration 4:1
[3] composite diet =fruit and cowpea mixed in ration 9:1
[4] DF = difference between theoretical and experimental values

Table 5. Total percent available copper content of fruits, amaranthus vegetable, cowpea together with the theoretical and experimental available copper values of the composite diets[1]

Sample	*Total copper (mg/kg)*	*% available copper*	*Available copper (mg/kg) in fruit-amaranthus and fruit-cowpea composite diets*					
			Fruit + amaranthus[2]			*Fruit + cowpea*[3]		
			Theoretical	*Exptal*	*%DF*[4]	*Theoretical*	*Exptal*	*%DF*[4]
Banana	1.6 ± 0.8	18.8	0.3 ± 0.1	0.1 ± 0.0	- 66.7	0.5 ± 0.0	0.2 ± 0.1	- 60.0
Grape fruit	0.8 ± 0.0	25.0	0.4 ± 0.0	0.2±0.1	- 50.0	0.5 ± 0.0	0.2 ± 0.2	- 60.0
Orange	0.7 ± 0.04	42.9	0.3 ± 0.1	0.6 ± 0.1	+ 100.0	0.5 ± 0.2	0.2 ± 0.0	- 60.0
Pineapple	1.2 ± 0.1	25.0	0.3 ± 0.1	0.2± 0.1	- 33.3	0.4 ± 0.1	0.5 ± 0.1	+ 25.0
Amaranthus	1.1 ± 0.4	36.4	-	-	-	-	-	-
Cowpea	17 ± 6.0	12.0	-	-	-	-	-	-

[1] mean ± standard deviation of quadruplicate analysis
[2] composite diet = fruit and amaranthus mixed in ration 4:1
[3] composite diet =fruit and cowpea mixed in ration 9:1
[4] DF = difference between theoretical and experimental values

result showed that availability of zinc from orange was very low. Grapefruit and pineapple are the same in percent availability while banana and amaranthus are also similar in percent available zinc. Amaranthus and cowpea recorded percent available zinc of 10.1 and 16.7% respectively.

Composite Meals: All the fruit samples enhanced Zinc availability from amaranthus (7.5% to 80.0%), but grape fruit enhanced it only marginally while orange enhancement was very high (80.0%). Grapefruit does not seem to affect zinc availability but orange enhanced zinc from cowpea by 120% while the other two fruits impaired it.

Copper content

Individual Samples. Total copper ranged between 0.7 mg/kg and 1.6 mg/kg for fruits, 1.1 mg/kg for amaranthus vegetable and 16.7 mg/kg for cowpea (Table 5). Percent available copper ranged between 18.8 and 42.9%.

Composite meals: Copper availability was not enhanced from both foodstuffs by all the fruit samples investigated, with the exception of orange that enhanced copper availability from amaranthus by 100% and pineapple with 25.0% enhancement from cowpea. Surprisingly, all the fruits with exception of pineapple recorded the same level of impairment of copper availability from cowpea (60%).

DISCUSSION

The moisture content of amaranthus agreed with 86.7% reported for amaranthus (Awoyinka *et al*., 1995).

Fruits can be consumed in two main forms; the juice can be extracted and taken or just sucked out of the fruit as in oranges. On the other hand, the whole fruit minus the peel and the seeds can be eaten. About 40 – 50% of the population consume their oranges in this latter form that would no doubt increase their intake of total dietary fibre, hence the need to measure the level of dietary fibre and assess their influence on mineral uptake. TDF in amaranthus (3.6 g/100 g FW) was higher than the 1.6 g/100 g wet weight reported for lettuce (Marlett & Vollendorf, 1993). TDF in amaranthus corresponded to 24.7 g/100 g on dry weight basis and agreed with 26.9 g/100 g reported for some cassava leaves but this value was lower than 39 g/100 g reported for amaranthus (Awoyinka *et al*., 1995). The difference could be due to the age of the vegetable samples used and the quantity of the stalk included in each sample. The TDF of cowpea was 14.7 g/100 g FW or 16.4% on dry weight basis. This was however greater than the 9.8 g/100 g reported for cooked bean (Marlett & Vollendorf, 1993). The difference could be due to retrogradation since the cowpea used in this work was cooked, dried and then milled.

SDF (and not IDF) has been reported to be responsible for impairing mineral availability (Fernandez & Phillips 1982). All the SDF values reported here were lower than 3.1 g/100 g SDF reported for tomato (Marlett & Vollendorf, 1993). SDF for amaranthus (0.3 g/100 g) was lower than 1.2 g/100 g reported for lettuce but agreed with the SDF (0.3 g/100 g) reported for cooked corn (Marlett & Vollendorf, 1993). Cowpea on the other hand recorded the highest value of 1.4 g/100 g. This was higher than 1.1 g/100 g reported for the cooked bean but lower than 3.5 g/100 g for fresh raw bean (Marlett & Vollendorf, 1993). The range of IDF for fruit samples is lower than 11.4 to 12.7 g/100 g reported for tomato (Marlett & Vollendorf, 1993).

The range of total iron content is lower than 30-60 mg/kg reported by Oyenuga (1968). Variation in mineral content is known to exist in fruits and vegetables as a result of time of harvest, level of maturity, environmental stress such as tropical heat and humidity, and nature of soil from where they were harvested. The value obtained for amaranthus agreed with 46 mg/kg reported earlier (Oyenuga 1968), but lower than 102 mg/kg (Adewusi *et al.*, 1999).

The highest level of percent iron availability in banana could be attributed to the lowest level of SDF in the fruit while orange and pineapple with the highest SDF recorded the lowest values of 10.7 and 13.8% respectively. As stated earlier (Fernandez & Phillips 1982), SDF impairs mineral availability and indeed, there was a negative correlation (-0.53 at $P \leq 0.05$) between SDF and iron availability. The SDF of amaranthus was lower than those for orange and pineapple and was therefore expected to translate to higher iron availability in amaranthus compared to the two fruits. However, this was not so probably due to the high levels of ascorbic acid as well as the presence of other organic acids (Table 6) in these fruits (Oladipo *et al.*, 2004).

The observations on the composite meals could only be explained on the basis of the high DF content of cowpea. Interestingly, statistical treatment showed that there was a negative correlation between percent available iron and each of the three types of DF (r = - 0.52, -0.58 and – 0.53 for IDF, SDF and TDF $p \leq 0.05$ respectively).

The total magnesium values obtained in this study were lower than 6851 mg/kg recorded for blanched amaranthus (Adewusi *et al.*, 1999) and 2270 mg/kg for cowpea (Adewusi & Falade 1996). Unlike iron, DF seems not to play any role in magnesium availability (r = -0.19, 0.09 and –0.18 for IDF, SDF and TDF respectively). The percent available magnesium for amaranthus and cowpea samples were lower than those reported earlier for amaranthus and cowpea (Adewusi & Falade 1996; Adewusi *et al.*, 1999).

The enhancement of magnesium availability by all the fruits in the composite meals was unlike the situation whereby only banana and orange had an enhancing effect on iron availability. Vegetables, unlike cowpea, contain a high level of ascorbic acid (Table 6) that could complement the enhancing power of the fruit samples. This could account for enhancement of magnesium in fruits-vegetable composite meals compared to the fruits-cowpea composite meals.

Total zinc value recorded for amaranthus agreed with the 24 mg/kg reported earlier (Adewusi *et al.*, 1999) but that of cowpea was higher than the 32 mg/kg reported for a similar sample (Adewusi & Falade 1996). However, it was still lower than 60 mg/kg sample published in 1968 (Oyenuga, 1968). Just as observed in mag-

Table 6. Ascorbic, citric and total organic acids (mg/100g) content of fruit juice, and amaranthus vegetable

Sample	*Ascorbic acid*[1]	*Citric acid*[2]	*Total organic acid*[3]
Grape fruit	45.4 ± 1.2	1312 ± 18	1382 ± 39.4
Orange	55.3 ± 1.5	452 ± 31	497 ± 5.2
Pineapple	11.7 ± 1.5	218 ± 4.0	246 ± 6.3
Amaranthus*	386 ± 11.4	-	-

Source: Falade *et al.* (2003)
* Source: Falade *et al.* (2004)
[1] expressed in mg/100g
[2] expressed in mg/100g (expressed as anhydrous citric acid)
[3] Total organic acid expressed as anhydrous citric acid mg/100g juice

nesium, none of the three DF seems to correlate with zinc availability (r = 0.29, 0.02, and - 0.27 for IDF, SDF, and TDF respectively at $P \leq 0.05$).

The observations on the zinc availability in the composite meals could also be due to the high content of ascorbic acid (Table 6) in fruits-vegetable composite meals compared to fruits-cowpea composite meals as pointed out earlier.

The total copper value here reported for fruits agreed with 2.0 mg/kg recorded for banana. The value obtained for cowpea in this study was twice that reported earlier (Oyenuga, 1968).

There was a negative correlation between percent available copper and IDF and TDF (-0.58 and –0.57 respectively at $p \leq 0.05$), but there was no significant correlation between copper and SDF (-0.34 at $p \geq 0.05$). The mode of Fe enhancement is through the reduction of the insoluble Fe^{3+} to Fe^{2+} (soluble). A similar reduction of Cu (II) to Cu (I) ion would result in the precipitation of copper as Cu_2O. This may be the mechanism of copper inhibition by ascorbic acid and other organic acids.

CONCLUSION

The enhancing power of ascorbate and other organic acids in fruits on mineral availability seem to be antagonised by the dietary fibre content when the whole fruit is eaten. This antagonism seems to depend on the source of minerals as demonstrated in this study. The consumption of fruit juice rather than the whole fruit should therefore be encouraged in populations at risk. Dietary fibre, though an essential component of food, could be obtained from many sources in the tropical world without necessarily loading that of fruits onto it.

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