



Bioavailability of vitamins C, E and pro-vitamin A in extracts of fluted pumpkin (*Telfairia occidentalis*), tomato (*Lycopersicum esculentum*) and eggplant (*Solanum melongena*)

Madukwe, E. U., Nwabunze, A. M^{*}, Onyibalu, L.

Department of Home Science, Nutrition and Dietetics, University of Nigeria, Nsukka

*Corresponding author E-mail: adaobi.nwabunze@unn.edu.ng

Abstract

Background: Vegetables, an important source of our diet contain some beneficial antioxidants.

Objectives: This study evaluated pro-vitamin A, vitamins E and C content of extracts of tomato, fluted pumpkin and eggplant and bioavailability of these antioxidants in rats.

Methods: The antioxidant content of the vegetable aqueous extracts, serum, liver, faecal and urinary antioxidants were determined using standard procedures.

Results: The aqueous extract of tomato had the highest pro-vitamin A content (0.33 ± 0.01 mg/100ml) and fluted pumpkin extract had the highest vitamins E and C (5.07 ± 0.04 mg/100ml) and (40 ± 0.02 mg/100ml) respectively. The faecal and urinary vitamin A for the rats fed vegetable extracts was higher than their intake. Rats fed tomato extract consumed more (0.09 ± 0.02 mg) pro-vitamin A and had the highest liver vitamin A (2.33 ± 0.01 mg). This group of rats also had the least vitamin E intake (0.20 ± 0.00 mg) with high urinary (0.34 ± 0.01 mg) and faecal (0.65 ± 0.01 mg) excretions leading to negative vitamin E retention. In addition, rats fed tomato extracts consumed highest vitamin C (10.10 ± 0.80 mg) which contributed to the high serum concentration of vitamin C (0.85 ± 0.00 mg).

Conclusion: Further studies on the specific bioavailability of vitamin A and vitamin E (α -, β -, γ - and δ - tocopherols) differentials in the vegetable extracts should be carried out.

Keywords: antioxidants, pro-vitamin A, vegetable extract, vitamin C, vitamin E

1 Introduction

The protection fruits and vegetables provide against diseases are attributed to the various antioxidants they contain [1]. Antioxidants are compounds that inhibit or delay the oxidation of other molecules by inhibiting the initiation or propagation of oxidizing chain reactions [2]. They neutralize free radical reactive species that are generated endogenously through aerobic metabolism [3]. Vegetables and fruits are therefore valuable components of the daily diets contributing carbohydrates in form of dietary fibre, vitamins and minerals to the body [4]. Consumption of fruits and vegetables has been associated with the maintenance of health and prevention of numerous chronic diseases including cancer, cardio- and cerebro-vascular, ocular and neurological diseases [5,6,7]. Vitamin C, vitamin E, and beta carotene are among the most widely studied dietary antioxidants. It is believed that antioxidants exert their protective effect by decreasing oxidative damage to deoxyribonucleic acid and by decreasing abnormal increases in cell division [8]. Bioavailability is defined as the proportion of an antioxidant that is digested, absorbed, and utilized in normal metabolism; however, measurement of bioavailability relies heavily upon estimates of amounts of antioxidant absorbed. Fluted pumpkin, tomato and eggplant are amongst the commonly consumed vegetable in the eastern part of Nigeria. However, enough is not known about the actual amount of the individual antioxidants in the vegetables and the actual amount absorbed and utilized by the body. The thrust of this work was to determine the antioxidant content of aqueous extracts of fluted pumpkin, tomato and eggplant and their bioavailability.

2 Materials and method

2.1 Materials

Fluted pumpkin leaves (*Telfairia occidentalis*), tomatoes (*Lycopersicon esculentum*) and eggplant (*Solanum melongena*) were purchased from Ogige market in Nsukka, Enugu State, Nigeria for the investigation.

2.2 Method

2.2.1 Sample preparation

Four hundred grammes (400g) of *Telfairia occidentalis* leaves and *Lycopersicon esculentum* and six hundred grammes (600g) of *Solanum melongena* leaves were washed, blended separately to produce their juice extracts using a juice extractor. The juice extracts were 200ml, 250ml and 150ml for *Telfairia occidentalis*, *Lycopersicon esculentum* and *Solanum melongena* juices. The extracts were bottled and labeled for chemical analysis.

2.2.2 Vitamin A determination

This was determined using the method of Pearson (1976). Two grammes (2g) of each sample was put into a film container containing 20ml of petroleum ether. Each extract was filtered separately through Whatman filter paper No 42 (125mm). The filtrate was evaporated to dryness using rotary evaporator. After this, the dry sample was dissolved in 0.2ml chloroform acetic anhydride. Two millilitres (2ml) of TCA chloroform was added and read at 620nm using a spectrophotometer (Spectro 21D).

2.2.3 Vitamin C determination

This was determined using AOAC (2010) procedure.

Preparation of reagents

Extraction solution: Fifteen grammes (15g) of trichloroacetic was dissolved in forty millilitres (40ml) acetic acid and two hundred millilitres (200ml) of distilled water and diluted to 500ml and filtered.

Standard solution: 0.05g of ascorbic acid was dissolved in sixty millilitres (60ml) of the extract and made up to two hundred and fifty millilitres (250ml) with distilled water.

Indophenol standard solution: 0.05g of 2, 6-dichloro-phenolindophenol (sodium salt) was dissolved in one hundred millilitres (100ml) of distilled water and filtered.

The 2, 6-dichloro-phenolindophenol was standardized by titrating against ten millilitres (10ml) of acid stock solution until a faint pink colour was obtained. The concentration of ascorbic acid in mg was expressed as equivalent to 1ml of the dye solution. Five grammes (5g) of each of the fresh samples were added to 60ml of the extract. The mixture was homogenized with an electric high speed homogenizer. The mixture was filtered under suction, the filtrate was poured into two hundred and fifty millilitres (250ml) volumetric flask and made up with distilled water. Ten millilitres (10ml) of the resulting solution was pipetted into a conical flask, titrated against the standard indophenols solution and the titre value (Y) was recorded. This procedure was repeated four times for each sample.

$$10\text{ml of sample solution} = Y = \frac{0.05}{V}$$

100ml of sample contained K mg of ascorbic acid

100g of sample contained 20Kmg ascorbic acid

if 100g leaf sample = 20Kmg ascorbic acid

$$K(\text{mg}) = Y \times \frac{0.05}{V} \times \frac{250}{10} \times \frac{100\text{mg}/100\text{g}}{W}$$

2.2.4 Vitamin E determination

This was determined using the method of Pearson (1976). One gramme (1g) of the sample was extracted with 50ml of petroleum ether and concentrated to dryness. The residue was saponified with 5ml of 0.1M of potassium hydroxide under reflux. Twenty millilitres (20ml) of petroleum ether was used to extract the unsaponifiable matter and concentrated to dryness. Twenty millilitres (20ml) of ethanol was added to dissolve the residue. One millilitre (1ml) was transferred into three test tubes, 1ml of 0.2% ferric chloride in ethanol and 1ml of 0.5% α -dipyridyl in ethanol were added and made up to 5ml with ethanol. The absorbance was read at 520nm using spectrophotometer 21D.

2.2.5 Animal study

Animal and housing: Twenty-four adult male albino rats (95- 150g) were purchased from the Department of Veterinary Pathology, University of Nigeria, Nsukka. The rats were divided into four groups of six each on the basis of body weight. They were housed in individual stainless steel metabolism cages equipped with screen bottom to separate the faeces and urine of the animals. A 5-day adjustment period was adopted to acclimatize the rats to diet and environment. The rats were fed rat chow and the respective extracts as source of fluid *ad-libitum* for a period of 7 days. Fresh extracts were fed each morning and water was fed the control rat daily. Fluid intakes were calculated on daily basis.

2.2.6 Laboratory analysis

Carmines red was added to the rat chow on day 5 to mark the beginning of the balance period and on the morning of day 11 to mark the end of the 7-day balance study. The coloured faeces excreted on day 6 were included in the pooled faecal sample and those on day 12 were excluded. Urine was collected from 7:00am of day 5 through the morning of day 12 (7days). Hydrochloric acid (HCl) (0.1N) was used to preserve individual urine samples. One millilitre (1ml) of 0.1N of HCl was added to each pooled urine of each group. Individual faecal collections were dried and weighed before being ground into fine powder.

Blood composition: Blood was collected from the control and test groups and analyzed for vitamin C.

Liver composition: The control and the test groups were sacrificed, their liver were weighed ready and analyzed for vitamin A and E using the standard methods.

2.2.7 Vitamin C determination

The method described by Pearson (1976) was used. One gramme (1g) of the sample (serum and urine) was weighed and homogenized (macerated in the case of faeces) with 20ml of oxalic acid. The mixture was filtered. Nine millilitres (9ml) of indophenol reagent was added to 1ml of the filtrate. The absorbance read at 520nm using spectrophotometer 21D).

Statistical analysis

All results were analyzed statistically using the computer programme Statistical Package for Social Sciences (SPSS) for windows version 16. Main analysis included means and standard error of mean.

3 Results

Table 1: Pro-vitamin A, vitamins C and E composition of fluted pumpkin (*Telfairia occidentalis*), tomato (*Lycopersicum esculentum*) and eggplant (*Solanum melongena*) extracts (mg/100ml and µg beta-carotene/100ml for pro-vitamin A).

Antioxidants	Fluted pumpkin extract	Tomato extract	Eggplant extract
Pro-vitamin A	0.27±0.1	0.33±0.01	0.25±0.00
Vitamin C	40.76±0.02	37.85±0.06	18.12±0.03
Vitamin E	5.07 ±0.04	0.75±0.06	2.08±0.06

Mean ± standard error of means of three determinations

Table 1 presents antioxidant composition of fluted pumpkin, tomato and eggplant extract (mg/100ml and µg beta-carotene /100ml for pro-vitamin A). The pro-vitamin A value for the three extracts varied. The variation was from 0.25 to 0.33. Vitamin C value ranged from 18.12 to 40.76mg. Fluted pumpkin had the highest vitamin C followed by tomato extract, 40.76 and 37.85mg/100ml. Eggplant extract had the least value for pro-vitamin A and vitamin C, 0.25 µg beta-carotene and 18.12mg/100ml respectively. Vitamin E value for the three extracts differed. The range was from 0.75 to 5.07mg/100ml. tomato extract had the least (0.75mg/100ml) and eggplant extract had the second least (2.08mg/100ml). Fluted pumpkin extract had the highest (5.07mg/100ml).

Table 2: Vitamin A retention for rats fed the experimental extract and water (µg)

Variables	Fluted pumpkin extract	Tomato extract	Eggplant extract	Water (control)
Fluid intake (ml)	27.76±5.96	26.69±11.41	24.24±7.79	15.46±3.22
Pro-vitamin A intake (µg beta-carotene)	0.06±0.010	0.09±0.0200	0.06±0.010	-
Faecal vitamin A excretion	0.56±0.010	0.62±0.0000	0.30±0.010	0.27±0.000
Absorbed vitamin A	-0.50±0.00	-0.53±0.000	-0.24±0.00	-0.27±0.00
Urinary vitamin A	0.57±0.010	0.74±0.0000	0.50±0.010	0.39±0.000
Retained Vitamin A	-1.07±0.00	-1.27±0.000	-0.74±0.00	-0.66±0.00
Liver vitamin A	1.60±0.00	2.33±0.0100	0.78±0.010	0.32±0.000
Tissue store	-2.67±0.00	-3.60±0.000	-1.52±0.00	-0.98±0.00

Mean±standard error of means of six rats

Table 2 presents vitamin A retention for rats fed experimental fluids and water (µg/kg body weight). The fluid intake of the four groups of rats differed. The range was from 15.46 to 27.76ml. The rats fed fluted pumpkin extract had the highest followed by those fed tomato extract (27.76 and 26.69 ml respectively). The control had the least fluid intake (15.46ml) and those fed eggplant extract had 24.24ml. The pro-vitamin A intake for the three extracts was from 0.00 to

0.09 μ g. The rats fed tomato extracts had higher pro-vitamin A intake (0.09 μ g) relative to the other two groups of rats. It had comparable intake (0.06 μ g). The faecal vitamin A excretion for the groups of rats were high (0.27 to 0.62 μ g) relative to the intake (0.06 to 0.09). The absorbed vitamin A were negative which ranged from -0.24 to -0.53 μ g. Equally, the urinary vitamin A excretion was high for all the four groups of rats. It ranged from 0.39 to 0.74 μ g.

The retained vitamin A values were also negative. The rats had the highest faecal and urinary excretions and also high levels of vitamin A retention (Table 2). Surprisingly, the liver vitamin A values were positive. The rats fed tomato extract had the highest liver vitamin A (2.33 μ g). On the other hand, the rats fed pumpkin extracts had 1.6 μ g. The rats fed eggplant extract and water (control) had 0.78 and 0.32 μ g each respectively. The tissue storage of rats fed both the extracts and water (control) had negative vitamin A stores. The control had the least tissue storage (-0.98 μ g). The rats fed tomato and fluted pumpkin extracts had first and second vitamin A tissue stores (-3.60 and -2.67 μ g respectively). The rats fed eggplant extract had the highest negative tissue storage of vitamin A.

Table 3: Vitamin C retention for rats fed the experimental extract and water (mg)

Variables	Fluted pumpkin extract	Tomato extract	Eggplant extract	Water (control)
Vitamin C intake (mg)	8.87 \pm 0.61	10.10 \pm 0.80	4.39 \pm 0.71	-
Faecal vitamin C	0.28 \pm 0.01	0.41 \pm 0.01	0.33 \pm 0.00	0.23 \pm 0.00
Absorbed vitamin C	8.59 \pm 0.60	9.69 \pm 0.79	4.06 \pm 0.70	-0.23 \pm 0.00
Urinary vitamin C	0.38 \pm 0.01	0.44 \pm 0.01	0.39 \pm 0.01	0.24 \pm 0.00
Retained vitamin C	8.21 \pm 0.59	9.25 \pm 0.78	3.67 \pm 0.69	-0.47 \pm 0.00
Serum vitamin C	0.76 \pm 0.01	0.85 \pm 0.00	0.41 \pm 0.01	0.29 \pm 0.00
Tissue store	7.45 \pm 0.58	8.40 \pm 0.77	3.26 \pm 0.68	-0.76 \pm 0.00

Mean \pm standard error of means of six rats

Table 3 presents vitamin C retention for the rats fed the experimental extracts and water. The rats fed control (water) had zero vitamin C intake. The three test groups had 8.87, 10.10 and 4.39mg vitamin C for fluted pumpkin, tomato and eggplant extracts each. The faecal vitamin C output ranged from 0.23 to 0.41mg. The rats fed tomato extracts had the highest faecal excretion (0.41mg) relative to others whose values ranged from 0.23 to 0.33mg. The absorbed vitamin C varied and was a function of faecal values. The rats fed fluted pumpkin and tomato extract had highest intake (8.87 and 10.10mg) also had the highest absorbed vitamin C, 8.59 and 9.69mg each. The control group had a negative absorbed vitamin C (-0.23mg). The urinary excretion for the three test groups ranged from 0.38-0.44mg. The control has the least (0.24mg). Vitamin C retention was controlled by both faecal and urinary excretion values. The rats fed tomato extracts had higher intake (10.10mg) as well as retained vitamin C (9.25mg) relative to the other groups of rats. The control rats had also negative retained vitamin C (0.47mg).

The serum vitamin C concentration for the group of rats differed. The values followed the same trend as the retained values. The rats fed tomato and fluted pumpkin extracts had first and second serum vitamin C values (0.85 and 0.76mg respectively). On the other hand, the rats fed eggplant extract and water had first and least values (0.41 and 0.29mg) each. The vitamin C tissue storage for rats fed tomato extracts was 8.4mg and 7.45mg for those rats fed fluted pumpkin extracts. As one would expect, the control group of rats had negative value (-0.76mg, Table 3). The rats fed eggplant extract had the least vitamin C tissue storage (3.26mg).

Table 4: Vitamin E retention for rats fed the experimental extracts and water (mg)

Variables	Fluted pumpkin extract	Tomato extract	Eggplant extract	Water (control)
Vitamin E intake (mg)	1.10 \pm 0.00	0.20 \pm 0.00	0.50 \pm 0.00	-
Faecal vitamin E	0.55 \pm 0.01	0.65 \pm 0.01	0.10 \pm 0.01	0.05 \pm 0.00
Absorbed vitamin E	0.55 \pm 0.01	-0.45 \pm 0.01	0.40 \pm 0.01	-0.05 \pm 0.00
Urinary vitamin E	0.29 \pm 0.01	0.34 \pm 0.01	0.38 \pm 0.00	0.11 \pm 0.00
Retained vitamin E	0.26 \pm 0.00	-0.79 \pm 0.00	0.02 \pm 0.01	-0.16 \pm 0.00
Liver vitamin E	0.49 \pm 0.01	0.88 \pm 0.00	0.68 \pm 0.01	0.46 \pm 0.00
Tissue store	-0.23 \pm 0.00	-1.69 \pm 0.00	-0.66 \pm 0.00	-0.62 \pm 0.00

Mean \pm standard error of means of six rats

Table 4 presents vitamin E retention for rats fed experimental fluids and water (ml). The rats fed control as expected had no vitamin E intake. The rats fed pumpkin extract had the highest value (1.1mg) relative to 0.20 and 0.50mg for those fed tomato and eggplant extracts. The faecal vitamin E excretion varied. The control group had the least followed by those fed eggplant extracts (0.05 and 0.10mg). The rats fed tomato extract had more faecal vitamin E than the rats

fed fluted pumpkin extracts (0.65 and 0.55mg respectively). The rats fed tomato extract and water (control) had negative vitamin E absorption (-0.45 and -0.05mg each). The urinary vitamin E excretion followed the same trend as the faecal. The rats fed tomato had first and second values (0.38 and 0.34mg each). The control group had the least (0.11mg) and those fed fluted pumpkin extract had 0.29mg. The retained vitamin E values followed the same trend as the absorbed. The groups fed tomato extracts and the control had negative retention values. The negative value for retained vitamin E was much higher than the absorbed vitamin E. The liver vitamin E content of the rats varied. The rats fed tomato and eggplant extracts had the first and second highest values (0.88 and 0.62mg respectively). The liver vitamin E concentration for rats fed fluted pumpkin and water were 0.49 and 0.46mg each. Surprisingly, tissue storage of vitamin E values was negative. The values ranged from -0.23 to -1.69mg. The rats fed fluted pumpkin extract had the least (-0.23mg). The rats fed tomato extract had the highest negative value (-1.69mg). The rats fed eggplant extract and water had each -0.66 and -0.62mg.

Table 5: Absorption of antioxidants in rats fed the experimental extracts and water (%)

Vitamins (mg/100g)	Fluted pumpkin extract	Tomato extract	Eggplant extract	Water (control)
Pro-vitamin A intake	0.06±0.01	0.09±0.02	0.06±0.01	-
Faecal vitamin A	0.56±0.01	0.62±0.00	0.30±0.01	0.27±0.00
Absorbed vitamin A	-0.50±0.00	-0.53±0.00	-0.24±0.00	-0.27±0.00
Percentage absorbed (%)	-	-	-	-
Vitamin C intake	8.87±0.61	10.10±0.80	4.39±0.71	-
Faecal vitamin C	0.28±0.01	0.41±0.01	0.33±0.00	0.23±0.00
Absorbed vitamin C	8.59±0.60	9.69±0.79	4.06±0.70	-0.23±0.00
Percentage absorbed (%)	96.84	95.94	92.48	-
Vitamin E intake	1.10±0.00	0.20±0.00	0.50±0.00	-
Faecal vitamin E	0.55±0.01	0.65±0.01	0.10±0.01	0.05
Absorbed vitamin E	0.55±0.01	-0.45±0.01	0.40±0.01	-0.05±0.00
Absorbed (%)	50	-	80	-

Mean±standard error of mean of six rats

Table 5 presents absorption and antioxidants in rats fed experimental fluids and water (%). The ascorbate intake of rats fed fluted pumpkin, tomato and eggplant extracts was 8.87 10.10 and 4.39mg. The control group had no value. The faecal values ranged from 0.23 to 0.41mg. It is only the control that has negative absorption value (-0.23mg). The rats fed tomato and fluted pumpkin extracts had first and second absorbed ascorbate (9.69 and 5.59mg each). The rats fed eggplant extract had the least 4.06mg. The percentage absorbed ascorbate was high for the three extracts. The rats fed eggplant extract had lower values relative to those of tomato and fluted pumpkin extracts (92.48 versus 95.94 and 96.84% each). Vitamin E intake was negative for the control group. The control group also had the least faecal output (0.05mg) relative to those of other three groups (0.05 versus 0.10, 0.65 and 0.55mg each). The rats fed tomato extract and water had negative absorbed vitamin E (-0.45 and -0.05mg). On the other hand, the rats fed fluted pumpkin and eggplant extracts had each 0.55 and 0.40mg. The percent absorption for rats fed tomato extracts and water (control) had negative values. The rats fed fluted pumpkin and eggplant extracts had each 50 and 80% respectively.

4 Discussion

Tomato extract had comparable pro-vitamin A with the other two extracts 0.33µg, 0.27µg and 0.25µg, each which meant that any of them is good as the other in antioxidant levels. Tomato and its products are important dietary sources of antioxidants such as α-tocopherol and the carotenoids beta-carotene, phytoene and phytofluene [9]. Fluted pumpkin extract had the highest vitamin E content (5.07±0.04mg/100ml), and vitamin E is considered the 'standard antioxidant' to which other compounds with antioxidant activities are compared, especially in terms of its biological activity and clinical relevance [10]. The vitamin C value for fluted pumpkin was the highest (40±0.02mg/100ml). According to [11] ascorbic acid is an antioxidant that directly eliminates superoxide, hydroxyl radicals and singlet oxygen radicals as well reduces hydrogen peroxide.

The high pro-vitamin A intake for rats fed tomato extract (0.09±0.02µg beta carotene) as well as their high liver vitamin A (2.33±0.01µg) was attributed to low faecal and urinary vitamin A (Table 2). The liver serves as the primary storage depot for vitamin A and contains more than 90% of total vitamin A in the body [12]. The rats fed the three extracts had high faecal and urinary vitamin A output. They had liver vitamin A that ranged from 0.78 to 2.33µg. This shows that liver vitamin A is not influenced by both faecal and urinary output. It is known that the relative amount of vitamin A metabolites in both urine and faeces vary with intake and hepatic stores [13]. Vitamin A is excreted in various forms in both urine and faeces [13]. It leaves the body in urine as inactive metabolites due to tissue utilization and as potentially recyclable active glucuronide conjugates of retinol in bile secretions [14]. It has been shown that vitamin A metabolites

that had intact carbon chains are excreted in faeces and the chain-shortened, acidic metabolites are excreted in urine [13].

The highest vitamin E intake ($1.10 \pm 0.00 \text{mg}$) for rats fed fluted pumpkin extract might be due to its high level in the fluted pumpkin extract or that the fluted pumpkin extract was highly palatable to the rats. Rats are known to consume more food when it is palatable. The group of rats fed tomato extract had the least intake ($0.20 \pm 0.00 \text{mg}$) and had high urinary ($0.34 \pm 0.01 \text{mg}$) and faecal ($0.65 \pm 0.01 \text{mg}$) vitamin E excretions relative to other groups of rats. The higher faecal and urinary output and least intake led to negative vitamin E retention. This might be due to the type of tocopherol in tomato. According to [15] leaves and other green (chloroplasts) portions of plants contain mostly α -tocopherol and smaller amounts of γ -tocopherol. The main sources of β -, γ - and δ - tocopherols are nonchloroplast regions of plants. Most of the ingested β -, γ - and δ - tocopherol are secreted into bile for excretion in the faeces [16]. A specific protein known as (α -tocopherol transfer protein, α -TTP) is predominantly expressed in liver and its expression appears to depend on dietary tocopherols themselves [17]. The rats fed fluted pumpkin extract had the least liver vitamin E ($0.49 \pm 0.01 \text{mg}$) storage relative to those of rats fed other vegetable extracts. According to [18] vitamin E is absorbed in the intestine and enters the circulation via the lymphatic system to be absorbed together with lipids, packed into chylomicrons for transportation to the liver along with the chylomicrons and other lipid remnants. Release of absorbed vitamin E into circulation was reported to occur through chylomicrons [17]. The low liver vitamin E storage in rats fed fluted pumpkin extract confirmed earlier report. Only after passage through the liver does α -tocopherol preferentially appear in the plasma [18]. The reason for this plasma preference for α -tocopherol is its specific selection by the hepatic α -tocopherol transfer protein (α -TTP) [19]. This might have led to the low liver vitamin E storage in this group of rats. Rats and mice do not need vitamin C in their diet because they are able to synthesize it. Fluted pumpkin extract had the highest vitamin C, however, rats fed tomato extract consumed much more vitamin C ($10.10 \pm 0.80 \text{mg}$). This might be associated with high serum concentration of vitamin C in group of rats fed tomato extract ($0.85 \pm 0.00 \text{mg}$). The higher vitamin C serum profile for rats fed tomato extract as well as the control ($0.29 \pm 0.00 \text{mg}$) might be a function of intake – a commonly observed phenomenon.

5 Conclusion

The three antioxidant vitamins (vitamins C and E and pro-vitamin A) were contained in the extracts. Vitamin E and pro-vitamin A had negative tissue retention due to high faecal and urinary output, the reverse was that of vitamin C. There is therefore need for further studies on the vitamin A and vitamin E (α -, β -, γ - and δ - tocopherols) differentials in the vegetable extracts so as to determine their specific bioavailability *in vivo*.

References

- [1] Azeez, L., Adeoye, M. D., Majolagbe, T. A., Lawal, A. T. and Badiru, R. Antioxidant activity and phytochemical contents of some selected Nigerian fruits and vegetables. American Journal of Chemistry, 2, 4, (2012), pp.209-213.
- [2] Henriques, F., Guiné, R. and Barroca, M. J. Chemical properties of pumpkin dried by different methods. Croatian Journal of Food Technology, Biotechnology and Nutrition, 7, 1-2, (2012), pp.98-105.
- [3] Bennett, L. E., Jegasothy, H., Konczak, I., Frank, D., Sudharmanarajan, S. and Clingeleffer, P. R. Total polyphenolics and anti-oxidant properties of selected dried fruits and relationships to drying conditions. Journal of Functional Foods, 3, (2011), pp.115-124.
- [4] Babalola, O. O., Tugbobo, O. S. and Daramola, A. S. Effect of processing on the vitamin C content of seven Nigerian green leafy vegetables. Advance Journal of Food Science and Technology, 2, 6, (2010), pp.303-305.
- [5] Rao, A.V. and Agarwal, S. Role of lycopene as antioxidant carotenoid in the prevention of chronic diseases: a review. Nutrition Research, 19, (1999), pp.305-323.
- [6] Giovannucci, E. Tomatoes, Tomato based product, Lycopene and cancer. Review of the epidemiologic Literature. Journal of National Cancer Institute, 91, (1999), pp.317-31.
- [7] Barber, N.J. and J. Barber. Lycopene and prostate cancer. Prostate Cancer and Prostatic Diseases, 5, (2002), pp.6-12.
- [8] Percival, M. Antioxidants. Clinical nutrition insights. Advanced Nutrition Publications, Inc. (1996).
- [9] Paran, E., Novack, V., Engelhard, Y. N. and Hazan-Halevy, I. The effect of natural antioxidants from tomato extract in treated but uncontrolled hypertensive patients. Cardiovascular Drugs and Therapy, 23, 2, (2008), pp.107-8.
- [10] Devasagayam, T. P. A., Tilak, J. C., Bloor, K. K., Sane, K. S., Ghaskadbi, S.S. and Lele, R. D. Free radicals and antioxidants in human health: current status and future prospects (Review article). Journal of the Association of Physicians of India, 52, (2004), pp.794-804.
- [11] Khan, A., M.S. Akeel, H.U. Akhtar and M. Asraf.. Interactive effect of foliarly applied acid and salt stress on wheat (*Triticum aestivum*) at seed ling stage. Pakistan Journal of Botany, 38, 5, (2006), pp.1407-1414.
- [12] Panel of Micronutrients, Food and Nutrition Board. Dietary reference intakes for vitamin A, vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium and Zinc. Washington D.C. National Academy Press, (2002).
- [13] Combs, G. F. The vitamins: fundamental aspects in nutrition and health, 3rd ed. Elsevier Academic Press, USA. (2008).
- [14] Green, M. H. and Green, J. B. Dynamics and control of plasma retinol. In: Blomhoff R. (Ed.). Vitamin A in health and disease, New York, Marcel Dekker, Inc. (1994), pp.119-133.
- [15] Gropper, S.S., Smith, J.L. and Groff, J.L. Advanced Nutrition and Human Metabolism (14th ed.). USA, Marshall, (2005).
- [16] Drevon, C. A. Absorption, transport and metabolism of vitamin E. Free Radical Research Communications, 14, (1991), 229-249.

- [17] Brigelius-Flohé, R., Kelly, F. J., Salonen, J. T., Neuzil, J., Zingg, J. and Azzi, A. The European perspective on vitamin E: current knowledge and future research. *American Society for Clinical Nutrition*, 76, 4, (2002), pp. 703-716.
- [18] Traber, M. G. and Sies, H. Vitamin E in humans: demand and delivery. *Annual Review of Nutrition*, 16, (1996), pp.321-347.
- [19] Hosomi, A., Arita, M., Sato, Y., Kiyose, C., Ueda, T., Igarashi, O., Arai, H., Inoue, K. Affinity for alpha-tocopherol transfer protein as a determinant of the biological activities of vitamin E analogs. *Federation of European Biochemical Societies Letters*, 409, (1997), pp.105-108.