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Chemical Composition and *in vitro* Antioxidant Activities of Some Nigerian Vegetables

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Abstract: This study was designed to investigate the chemical composition of fourteen vegetables popularly consumed in the South Western part of Nigeria and also to evaluate some *in vitro* antioxidant activities of the selected vegetables. Ethanolic extracts of the vegetables were injected into GC-MS to investigate the presence of some chemical compounds and were also screened for their lipid peroxidation inhibitory potentials and free radical scavenging activities by two complementary. GC-MS studies showed that caffeic acid was present in all the vegetable samples with the exception of *Celocia argentia* and *Talinum triangulare* in addition to other compounds identified in some of the vegetables (phenylacetic acid, vanillic acid, genticic acid, protocatechuic acid, syringic acid, p-coumaric acid, garlic acid, ferulic acid, epicatechin and catechin. Lipid peroxidation inhibition studies revealed that lipid peroxide inhibition ranges from 3.59-69.47 (%) while conjugated diene inhibition ranges from 84.33-97.31 (%). Scavenging ability of the vegetables towards hydrogen peroxide ranges from 4.89±0.55-60.26±1.23 (%) while superoxide scavenging activities ranges from 75.62±1.42-97.01±1.32 (%). Total flavonoid mg mL^{-1} and total antioxidant activity (mg mL^{-1}) ranges from 0.12 to 3.08 and 0.13 to1.60, respectively. Results from conjugated diene formation and superoxide radical scavenging activity show that the evaluated vegetables exhibited a relatively high lipid peroxidation inhibitory potentials and free radical scavenging activity which could possibly be as a result of caffeic acid and other compounds present in the vegetables.

Key words: Antioxidant activities, vegetables, lipid peroxidation, free radical scavenging activity

Introduction

The role of oxygen and free radicals in tissue damage related to aging and other disease conditions are becoming increasingly recognized. Free radicals, having one or more unpaired electrons in the outer orbit, include superoxide anion ($O^{\cdot}_2$), hydroxyl ($HO^{\cdot}$), peroxyl ($ROO^{\cdot}$), alkoxyl ($RO^{\cdot}$) and nitric oxide, which are oxygen-centered free radicals sometimes known as Reactive Oxygen Species (ROS) (Squacrito and Peyer, 1998).

Modern theories of ROS have revealed that the oxygen centered free radicals play a dual role in organisms. ROS are not only strongly associated with lipid peroxidation, which lead to the deterioration of food but also involved in the development of a variety of diseases including cellular aging, mutagenesis, carcinogenesis, coronary heart disease, diabetes and neuro-degenerative

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disorders (Harman, 1980; Sasaki *et al*., 1996; Moskovitz *et al*., 2002). The efficiency of phenolic compounds as antioxidant is diverse and depends on many factors, such as the number of hydroxyl groups bonded to the aromatic ring, the site of bonding and mutual position of hydroxyls in the aromatic rings. The cell possesses a natural antioxidant defense mechanism that enables it to take care of these free radicals. However, when the free radicals outweigh the defense mechanism, the resulting effect is oxidative stress.

Recently, various phytochemicals and their effect on health, especially the suppression of free radicals by natural antioxidants have been studied (Ho *et al*., 1994). Increased intakes of dietary antioxidants may help to maintain an adequate antioxidant defense status, defined as the balance between oxidant and antioxidants in living organisms (Pulido *et al*., 2000; Halliwell *et al*., 1995). Food rich in antioxidants plays an essential role in the prevention of cardiovascular diseases and cancers (Gerber *et al*., 2002; Kris-Ethertn *et al*., 2002; Serafini *et al*., 2002), neurodegenerative diseases, as well as inflammation and problems caused by cell and cutaneous aging (Ames, 1983).

Many vegetables and fruits are potentially useful for decreasing the risks of several chronic diseases, such as coronary heart diseases and some cancers (Block *et al*., 1992; Hertog *et al*., 1995; Lampe, 1999). These protective effects have been particularly attributed to various antioxidant compounds such as vitamins C and E, β-carotene and polyphenolics (Diplock *et al*., 1998).

Recent investigation on the phytochemical screening and antioxidant indices of the selected tropical vegetables indicates that they could be potentially useful as natural antioxidants (Akindahunsi and Salawu, 2005a, b). However, detailed chemical composition and *in vitro* antioxidant studies is necessitated by lack of quantitative information to compare antioxidant activities of the vegetables. Therefore, this study was aimed to correlate the chemical composition of some Nigerian vegetables, mostly phenolic compounds with the *in vitro* antioxidant activities of the selected vegetables to provide useful information on their antioxidant potentials.

Materials and Methods

Collection of Plant Materials

Some popularly consumed green leafy vegetables in Nigeria namely: *Telfairia occidentalis* (Ugu), *Hibiscus esculentus* (Ewe Ila), *Crassocephalum crepidioides* (Worowo), *Occimum graticimum* (Efinrin), *Xanthosoma maffafa* (Ewe Koko), *Vernonia amygdalina* (Ewuro), *Solanum macrocarpon* (Igbagba), *Structium Sparejanophora* (Ewuro-Odo), *Celocia argentia* (Soko), *Talinium triangulare* (Gbure), *Corchorus olitorus* (Ewedu), *Amaranthus hybridus (Arowojeja)*, *Amaranthus caudatus* (Tete) and *Manihot utilisima* (Ewe Ege) were collected from a local market in Akure. The vegetables were rinsed with water and the edible portions were separated from the inedible portions. The edible portions were chopped into smaller pieces and air-dried, for further analysis.

Preparation of Samples for GC-MS Studies

Fifty milliliter of 96% ethanol was added to 5 g of the powdered vegetable materials in a pyrex tube and 500 μg g^{-1} (powdered vegetables in o-coumaric acid as internal standard) was added. The samples were extracted by sonication at room temperature for 2 h. The samples were then filtered using a Whatman No.1 filter paper. One milliliter each of filtered samples was evaporated by nitrogen flow and re-dissolved in 100 μL of ethyl acetate. The samples were added to 100 μL of BSTFA + TMCS (Supelco) and heated at 80°C for 20 min. One millilitre of derivatized samples were then injected into GC-MS.

Preparation of Methanol Extracts for Invitro Antioxidant Assay

The air-dried and finely ground vegetable samples (25 g) were extracted with 150 mL of methanol at 30°C for 5 h and mixed by using a magnetic stirrer. Each extract was filtered through Whatman

No. 4 filter paper and re-extracted with the same solvent for the extraction of antioxidant fractions. All extracts were pooled and concentrated under vacuum at 4°C and kept at +4°C prior to analysis.

Lipid Peroxidation Assay

Lipid peroxidation assay was carried out by measuring lipid peroxide content and the conjugated diene formation.

Lipid Peroxide Formation

A modified thiobarbituric acid reactive species (TBARS) assay (Okhawa *et al*., 1979) was used to measure the lipid peroxide formed using egg yolk homogenates as lipid rich media. Egg yolk homogenate was prepared according to a standard method (Wang *et al*., 1997). Malondialdehyde (MDA), a secondary end product of the oxidation of polyunsaturated fatty acids, reacts with two molecules of thiobarbituric acid (TBA) yielding a pinkish red chromogen with absorbance maximum at 532 nm (Janero, 1990). Egg homogenate (0.5 mL of 10% v/v) and 0.1 mL of each extract were added to a test tube and made up to 1 mL with distilled water. 0.05 mL of $FeSO_4$ (0.07 M) was added to induce lipid peroxidation and incubated for 30 min. Then 1.5 mL of 20% acetic acid (pH adjusted to 3.5 with NaOH) and 1.5 mL of 0.8% (w/v) TBA in 1.1% sodium deodecyl sulphate and 20% TCA were added and the resulting mixtures were vortexed and then heated at 95°C for 60 min. After cooling, 5.0 m of butan-1-ol was added to each tube and centrifuged at 3000 rpm for 10 min. The absorbance of the organic layer was measured at 532 nm. Inhibition of lipid peroxide formation (%) by the extract was calculated according to [(1-E/C) × 100] where C is the absorbance value of the fully oxidized control and E is ($Abs_{532+TBA}$-$Abs_{532-TBA}$).

Conjugated Diene Formation

1.8 mL of asolectin liposome (500 μM final concentration of phospotidylcholine equivalent) was incubated in a water bath at 37°C with 0.05 mL of the extract. Reaction was initiated with the addition of 200 μL of azo-initiator (5 mM AAPH final concentrations). Aliquots of liposome (60 μL) were dissolved with 940 μL of methanol directly in 1 cm quartz cell (Goncalves *et al*., 1998). The formation of conjugated diene was followed by comparing oxidation of liposome by AAPH with oxidation of AAPH-liposome-extract system.

Superoxide Radical (O_2^-) Scavenging Activity

The assay was based on the capacity of the extract to inhibit the photochemical reduction of nitroblue tetrazolium (NBT) in the presence of riboflavin-light-NBT system (Beauchamp and Fridovich, 1971). Superoxide dismutase was followed after modification of a standard method (Martinez *et al*., 2001). Each 3 mL reaction mixture contained 50 mM phosphate buffer (pH 7.8), 13 mM methionine, 2 μM riboflavin, 100 μM EDTA, NBT (75 μM) and 0.1 mL of the sample solution. The production of blue formazan was followed by monitoring the increase in absorbance at 560 nm after 10 min illumination. The entire reaction assembly was enclosed in a box lined with aluminium foil. Identical tubes with reaction mixture were kept in the dark and served as blanks. The percentage inhibition of superoxide generation was measured by comparing the absorbance value of the control and those of the reaction mixture containing sample solution.

Hydrogen Peroxide Scavenging Activity

The ability of extracts to scavenge hydrogen peroxide was determined according to a standard method (Ruch *et al*., 1989). Briefly, a solution of (40 mM) H_2O_2 was prepared in phosphate buffer (0.1 M, pH 7.4). 0.1 mL of the methanolic extracts of each vegetable was dissolved in 4 mL phosphate buffer and mixed with 600 μl of 40 mM hydrogen peroxide. Hydrogen peroxide concentration was determined spectrophotometrically at 230 nm in the presence and absence of the extract. For each

extract, a separate blank sample solution containing the extract in buffer solution without hydrogen peroxide was used. Percentage hydrogen peroxide scavenging activity was calculated as A_0-A_1/A_0 where A_0 is the absorbance of the control ($Abs_{230}.H_2O_2$) and A_1 is the absorbance in the presence of sample ($Abs_{230}.H_2O_{2+}$ sample).

Total Flavonoid

Total flavonoid content of the extracts was determined according to a colorimetric method with some modifications (Bao *et al*., 2005). One milliliter of methanolic extract were transferred into an Eppendorf tube containing 1 mL of distilled water and mixed with 75 µL of 5% $NaNO_2$. After 5 min, 75 µL of 10% $AlCl_3$ solution was added. The mixture was allowed to stand for another 5 min and then 0.5 mL of 1 M NaOH was added. The reaction solution was mixed and kept for 15 min. The increase in absorbance was measured at 510 nm. Total flavonoid content was calculated using a standard quercetin calibration curve. The results were expressed as milligram per ml of quercetin equivalent.

Total Antioxidant Activity

The assay was based on the reduction of Mo (VI)-Mo (V) by the extracts and the subsequent formation of a green phosphate/Mo (V) complex at acidic pH (Prieto *et al*., 1999). 0.1 mL of the extracts was combined with 3 mL of reagent solution (0.6 M sulphuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate). The tubes were incubated at 95°C for 90 min. After which the mixture had cooled to room temperature, the absorbance of the solution was measured at 695 nm against blank. The total antioxidant activity was expressed as gallic acid equivalent.

Results and Discussion

There are numerous antioxidant methods with modifications for the evaluation of antioxidant capacities of plant materials. Of these, total antioxidant activity, reducing power, DPPH assay, active oxygen species such as H_2O_2, $O^{\cdot-}_2$, $OH^{\cdot}$ quenching assay and lipid peroxidation are most commonly used for the determination of antioxidant activities of plant extracts (Amarowicz *et al*., 2000; Mitsuda *et al*., 1996).

Table 1 shows the GC-MS analysis of some phenolic compounds in the selected vegetables (*Telfairia occidentalis*, *Hibiscus esculentus*, *Crassocephalum*,*Occimum graticimum*, *Xanthosoma maffafa*, *Vernonia amygdalina*, *Solanum macrocarpon*, *Structium sparejanophora*, *Celocia argentia*, *Talinium triangulare*, *Corchorus olitorus*, *Amaranthus caudatus*,

Table 1: GC-MS analysis of some compounds (µg g^{-1}) in the selected tropical vegetables

Vegetable species	PHA	VA	GEA	PRA	SA	p-CA	GA	FA	CA	t-RES	(-)-EPI	(+)-CAT	QUE
Maniho tutilisima	20.2	7.6	Tr	10.7	10.0	13.2	Tr	16.1	21.5	ND	Tr	Tr	ND
Hibiscus esculentus	ND	4.0	ND	ND	ND	ND	ND	ND	8.1	ND	ND	ND	ND
Celocia argentia	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vernonia amygdalina	ND	ND	0.7	6.9	ND	2.7	ND	ND	69.2	ND	ND	ND	ND
Telfairia occidentalis	ND	ND	Tr	7.6	ND	Tr	ND	ND	36.0	ND	ND	ND	ND
Corchrous olitorus	ND	ND	ND	ND	ND	ND	ND	ND	37.0	ND	ND	ND	ND
Talinium triangulare	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Solanum macrocarpon	ND	Tr	ND	17.7	ND	ND	ND	3.2	Tr	ND	ND	ND	ND
Structium sparejanophora	ND	ND	ND	5.7	ND	5.8	ND	ND	16.7	ND	ND	ND	ND
Xanthosoma maffafa	23.6	7.2	4.6	3.4	ND	6.0	12.8	1.9	6.3	ND	ND	ND	ND
Crassocephalum crepidioides	14.8	1.7	ND	5.2	Tr	4.7	ND	2.5	6.7	ND	ND	ND	ND
Occimum graticimum	Tr	1.5	ND	12.1	ND	1.9	4.9	2.1	33.0	ND	ND	ND	ND
Amaranthus caudatus	8.2	6.9	ND	6.5	3.8	6.0	Tr	6.8	25.2	ND	14.7	17.0	ND
AmaranthusHybridus	12.6	7.6	ND	9.0	ND	13.2	ND	18.9	13.6	ND	26.0	26.5	ND

PHA = Phenylacetic acid, VA = Vanillic Acid, GEA = Gentisic acid, PRA = Protocatechiuc acid, SA = Siringic Acid, p-CA = p-Coumaric acid, GA = Gallic acid, FA = Ferulic Acid, CA = Caffeic Acid, t-RES = trans-resveratrol, (-)-EPI = (-)-Epicatechin, (+)-CAT = (+)-Catechin, QUE = Quercetin, ND = Not Detected, Tr = Trace

Amaranthus hybridus and *Manihot utilisima*). The results revealed that caffeic acid was the main phenolic compound present in all vegetables with the exception of *Celocia argentia* and *Talinum triangulare*. Caffeic acid is a phenolic compound widely present in the plant kingdom (Duke, 1992). It has been studied extensively and known to share a spectrum of physiological activities including anti-inflammatory (Taguchi *et al*., 1993; Moreira *et al*., 2000), anti-allergic (Murota and Koshihara, 1985; Kimata *et al*., 2000) and anti-tumour (Li, 1999; Hudson *et al*., 2000; Soleas *et al*., 2002). Other compounds includes; phenylacetic acid (*Manihot utilisim*, *Xanthosoma maffafa*, *Crassocephalum*, *Occimum graticimum, Amaranthus hybridus*) vanillic acid (*Manihot utilisima*, *Hibiscus esculentus*, *Xanthosoma maffafa*, *Crassocephalum* crepidiodes, *Occimum graticimum*, *Amaranthus caudatus*, *Amaranthus hybridus*), gentisic acid (*Manihot utilisima*, *Vernonia amygdalina*, *Telfairia occidentalis* and *Xanthosoma maffafa*), protocatechuic acid (*Manihot utilisima*, *Vernonia amygdalina*, *Telfairia occidentalis*, *Solanum macrocarpon*, *Structium sparejanophora*, *Amaranthus caudatus*, *Amaranthus hybridus* and *Occimum graticimum*), syringic acid (*Manihot utilisima* and *Crassocephalum* crepidiodes), p-coumaric acid (*Manihot utilisima*, *Vernonia amygdalina*, *Telfairia occidentalis*, *Structium sparejanophora*, *Xanthosoma maffafa*, *Crassocephalum* crepidiodes, *Amaranthus caudatus*, *Amaranthus hybridus* and *Occimum graticimum*), garlic acid (*Manihot utilisima*, *Xanthosoma maffafa*, *Amaranthus hybridus* and *Occimum graticimum*), ferulic acid (*Manihot utilisima*, *Solanum macrocarpon*, *Xanthosoma maffafa*, *Crassocephalum* crepidiodes, *Amaranthus caudatus*, *Amaranthus hybridus* and *Occimum graticimum*) epicatechin (*Manihot utilisima*, *Amaranthus caudatus* and *Amaranthus hybridus*) and catechin (*Manihot utilisima*, *Amaranthus caudatus* and *Amaranthus hybridus*) most of which shared some physiological properties.

The peroxidation inhibitory capacities of the selected vegetables were shown on Table 2 by measuring the lipid peroxide content and conjugated diene formation. The results of the investigation indicates that all the evaluated vegetables were able to inhibit lipid peroxidation but at different rates. The inhibition of lipid peroxide formation ranges from 4.70-69.46 with *Vernonia amygdalina* having the highest inhibitory tendency while the least was recorded for *Crasscocphalum crepidiodes*. Lipid peroxides are likely involved in numerous pathological events, including inflammations, metabolic disorders and cellular aging (Ames, 1983; Wiseman and Halliwell, 1996). The result suggests that the consumption of the vegetables, most especially *Vernonia amygdalina* and *Corchorous olitorus* may afford a better cytoprotective effects. The inhibition of conjugated diene formation as presented on Table 2 indicates that all the evaluated vegetables possess a relatively high inhibitory activity (84.33-99.73%). This implies that most of the evaluated vegetables could protect lipids in the presence of extracts by decreasing the induction rates of oxidation. Thereby, predicting the high potency

Table 2: Lipid peroxidation inhibitory activity of the selected vegetables

	Inhibition (%)	
Samples	Lipid peroxide	Conjugated diene
Telfairia occidentalis	31.74	93.26
Hibiscus esculentus	30.54	88.99
Crassocephalum crepidioides	4.70	97.31
Occimum graticimum	35.92	92.65
Xanthosoma maffafa	5.40	90.78
Vernonia amygdalina	69.46	97.38
Solanum macrocarpon	26.94	96.03
Structium sparejanophora	7.78	99.73
Celocia argentia	13.77	84.33
Talinium triangulare	43.11	88.53
Corchrous olitorus	68.26	94.92
Amaranthus caudatus	34.73	91.62
Manihot utilisima	3.59	95.23
Amaranthus Hybridus	14.97	92.31

of the selected vegetables as good natural antioxidants. *Structium sparejanophora* was reported to exhibit the highest ability to inhibit conjugated diene formation while *Celocia argentia* has the least inhibitory activity.

Radical scavenging activities (H_2O_2, O^{-}_2 scavenging activity) of the selected vegetables were presented on Table 3. The H_2O_2 scavenging activities (%) ranges from 4.89±0.55- 60.91±1.11, while superoxide scavenging activity (%) ranges from 75.62±1.42-95.28±1.33. The results of the investigation show that *Vernonia amygdalina* has the highest hydrogen peroxide scavenging activity while the least was recorded for *Xanthosoma maffafa*. The H_2O_2 scavenging activity of an extract may be attributed to the structural features of their active components, which determines their electron donating ability (Wettasingbe and Shahidi, 2000).

Results from the investigation revealed that all the evaluated vegetables possess a relatively high superoxide scavenging activity (75.62±1.42-97.01±1.32) with *Manihot utilisima* having as high as 97.01±1.32 scavenging ability while the least, though, a relatively high value was recorded for *Talinium triangulare*. Superoxide radicals (O^{-}_2) also known as superoxide anion is produced in the body during aerobic respiration, enzymatic reactions and drug metabolism (Fridovich, 1972; Halliwell and Gutteridge, 1989). Although a superoxide radical itself is not so reactive to biomolecules, it helps in the generation of more powerful hydroxyl radicals through the Haber-Weiss reaction (Halliwell and Gutteridge, 1989). The toxicity of superoxide radicals and its role in deleterious processes in biology are well established. Hence the ability of plant food stuff to inhibit the formation of such toxic species is a good index for measuring antioxidant activities.

Total antioxidant activity is a measure of the capacity of substances extracted from the food matrix to delay oxidation process in a controlled system, (Cao *et al*., 1996; Fogliano *et al*., 1999; Miller and Rice-Evans, 1997; Pellegrini *et al*., 2000). Rather than determining the concentration of each antioxidant molecule individually, evaluation of total antioxidant activity, using different model assay systems has become increasingly important.

Total antioxidant capacity of the tropical vegetables is expressed as the number of equivalents of gallic acid (Table 4). The assay is based on the reduction of Mo (VI)-Mo (V) by the extract and subsequent formation of green phosphate/Mo (V) complex at acid pH. The result of the study shows that total antioxidant activity was in the following order: *Solanum macrocarpon*>*Telfairia occidentalis*>*Xanthosoma maffafa*>*Manihot utilisima*>*Corchorus olitorus*> *Occimum graticimum*>Amaranthus hyhbridus>*Amaranthus caudatus*>*Structium sparejanophora*> *Crassocephalum*>*Talinium triangulare*>*Hibiscus esculentus*>*Celocia argentia*>*Vernonia amygdalina.* Table 4 equally shows the total flavonoid content (mg mL^{-1} quercetin equivalent) of the selected vegetables. Flavonoids are one of the most powerful antioxidants found in plants. Typically, they

Table 3: Radical scavenging activities of the selected vegetables

	Scavenging activity	
Samples	H_2O_2 (%)	% O^{-}_2 (%)
Telfairia occidentalis	15.96±0.97	95.28±1.10
Hibiscus esculentus	34.85±1.24	91.98±1.35
Crassocephalum crepidioides	40.39±1.20	95.28±1.33
Occimum graticimum	24.43±1.42	86.00±1.24
Xanthosoma maffafa	4.89±0.55	86.48±1.32
Vernonia amygdalina	60.91±1.11	91.35±1.24
Solanum macrocarpon	28.34±1.16	93.24±1.05
Structium sparejanophora	8.79±0.62	94.18±2.11
Celocia argentia	12.05±0.87	94.97±1.45
Talinium triangulare	10.42±1.00	75.62±1.42
Corchrous olitorus	60.26±1.23	79.87±1.30
Amaranthus caudatus	31.27±1.23	86.16±1.45
Manihot utilisima	40.39±1.50	97.01±1.32
Amaranthus hybridus	7.92 ±1.12	95.28±1.62

Table 4: Total flavonoid and total antioxidant activity of the selected vegetables

Samples	Total flavonoid (mg mL^{-1}) Quercetin equivalent	Total antioxidant (mg mL^{-1}) Gallic acid equivalent
Telfairia occidentalis	0.77	1.50
Hibiscus esculentus	0.27	0.18
Crassocephalum crepidioides	1.10	0.25
Occimum graticimum	1.16	0.70
Xanthosoma maffafa	0.87	1.40
Vernonia amygdalina	1.67	0.13
Solanum macrocarpon	3.08	1.60
Structium sparejanophora	0.37	0.26
Celocia argentia	0.29	0.14
Talinium triangulare	0.12	0.20
Corchrous olitorus	1.24	1.10
Amaranthus caudatus	0.79	0.45
Manihot utilisima	1.82	1.30
Amaranthus hybridus	0.33	0.55

possess one or more of the elements that are considered important to the antioxidant potential of plant materials. *Solanum macrocarpon* have the highest flavonoid content (3.08) while the least content was recorded for *Amaranthus hybridus*. The result is in agreement with the result of an investigation (Takeoka *et al*., 2001), antioxidant activity in methanolic fraction is due to the presence of phenolic compounds, such as cafeic acid and chlorogenic acid as this could be the reason why *solanum macrocarpon* with the highest total flavonoid content is equally having the highest total antioxidant activity.

Based on the data obtained from this study, the selected vegetables exhibit free radical and lipid peroxidation inhibitory or scavenging activity which may limit free radical damage occurring in the human body. However, this reveals that consumption of the selected vegetables may supply substantial antioxidant by synergy and may provide health promoting and disease preventing effect. This study could be considered as a new report and could be a starting point for further investigations.

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References

Akindahunsi, A.A and S.O. Salawu, 2005a. Antioxidant indices of some green leafy vegetables. Trop. Sci. (UK), 45: 33-35.

Akindahunsi, A.A and S.O. Salawu, 2005b. Phytochemical screening and nutrient- ntinutrient composition of selected tropical green leafy vegetables. Afr. J. Biotechnol., 4: 497-501.

Amarowicz, R., M. Naczk and F. Shahidi, 2000 Antioxidant activity of crude tannins of canola and rapeseed hulls. J. Am. Oil Chem. Soc., 77: 957-961.

Ames, B.N., 1983. Dietary carcinogens and anticarcinogens-oxygen radicals and degenerative disease. Science, 221: 1256-1264.

Bao, J., Y. Cai, M. Sun, G. Wang and H. Corke, 2005. Anthocyanins, flavonols and free radical scavenging activity of Chines bayberry (*Myrica rubra*) extracts and their color properties and stability. J. Agric. Food. Chem., 53: 2327-2332.

Beauchamp, C. and I. Fridovich, 1971. Superoxide dismutase: Improved assays and an assay applicable to acrylamide gels. Anal. Biochem., 44: 276-287.

Block, G., B. Patterson and G.M. Sapers, 1992. Varietal differences in distribution of quercetin and Kaempferol in onion (*Allium cepa*) tissue. J. Agric. Food Chem., 32: 274-276.

Cao, G., E. Srfie and R.L. Prior, 1996. Antioxidant capacity of tea and common vegetables. J. Agric. Food Chem., 44: 3425-3431.

Diplock, A.T., J.L. Charleux, G. Crozier-Willi, F.J. Kok, C. Rice-Evans and M. Roberfroid, 1998. Functional food science and defense against reactive oxidative species. Br. J. Nutr., 80: 77-112.

Duke, J.A, 1992. Handbook of Phytochemical Constituents of Gras Herbs and Other Economical Plants. CRC Press, Boca Raton, FL.

Fogliano, V., V. Verde, G. Randazzo and A. Ritieni, 1999. Method of measuring antioxidant activity and its application to monitoring the antioxidants capacity of wines. J. Agric. Food Chem., 47: 1035-1040.

Fridovich, I., 1972. Superoxide radical and superoxide dismutase. Acc Chem. Res., 5: 321-322.

Gerber, M., M.C. Boutron-Rault, S. Herberg, E. Riboli, A. Scalbert and M.H. Siess, 2002. Food and cancer: State of the art about the protective effect of fruits and vegetables. Bull. Cancer, 89: 293-312.

Goncalves, E., L.M. Almeida and T. Dinnis, 1998. Antioxidant activity of 5-aminosalicylic acid against lipid peroxidation in the presence of vitamin C and E. Intl. J. Pharmacol., 172: 219-228.

Halliwell, B., J.M.C. Gutteridge, 1989. Free Radicals in Biology and Medicine. 2nd Edn. Oxford: Clarendon.

Halliwell, B., M.A. Murcia, S. Chirico and O.I. Aruoma, 1995. Free radicals and antioxidants in food and *in vivo*: What they do and how they work. Crit. Rev. Food Sci. Nutr., 35: 7-20.

Harman, D., 1980. Free radical theory of aging: Origin of life, evolution and aging. Age, 3: 100-102.

Hertog, M.G.L., D. Kromhout, C. Aravanis, N. Blackborn, R. Buzina and F. Fidanza, 1995. Flavonoid intake and long term risk of coronary heart disease and cancer in The seven countries study. Arch. Intl. Med., 155: 381-386.

Ho, C.T., T.Ferraro, Q. Chen, R.T. Rosen, 1994. Phytochemical in Teas and Rosemary and Their Cancer Preventive Properties. In: Food Phtochemicals for Cancer Prevention II, Spices and Herbs. Ho, C.T., T. Osawa, M.T., Huang, and R.T. Rosen (Eds.), ACS Symposium series 547. Am. Chem. Soc. Washington, DC., pp: 2-9.

Hudson, E.A., P.A. Dinh, T. Kokubun, M.S. Simmonds and A. Gescher, 2000. Characterization of potentially chemopreventive phenols in extracts of brown rice that inhibit the growth of human breast and colon cancer cells. Cancer Epidemiol. Biomark. Prev., 9: 1163-1170.

Janero, D.R, 1990. Malondialdehyde and thobarbituric acid reactivity as diagnostic indices of lipid peroxidation and peroxidative tissue injury. Free Rad. Biol. Med., 9: 513-540.

Kimata, M., N. Inagaki and H. Nagai, 2000. Effect of luteolin and other flavonoids on IgE_mediated allergic reactions. Planta Med., 66: 25-29.

Kris-Ethertn, P.M., K.D. Hecker, A. Bonanome, S.M. Coval, A.E. Binkosi, K.F. Hilpert, A.E. Griel and T.D. Eterton, 2002. Bioactive compounds in foods: Their role in The prevention of cardiovascular disease and cancer. Am. J. Med., 113: 71S-88S.

Lampe, J.W, 1999. Health effects of vegetables and fruits: Assessing mechanisms of action in human experimental studies. Am. J. Clin. Nut., 70: 475S-490S.

Li, W., F. Shen and G. Weber, 1999. Ribavirin and quercetin synergistically downregulate signal transduction and are cytotoxic in human ovarian carcinoma cells. Oncol. Res., 11: 243-247.

Martinez, C.A., E. Louriero and M.A. Oliva, 2001. Differential responses of Superoxide dismutase in freezing resistant *Solanum curtibolum* and freezing sensitive *Solanum tuberosum* subjected to oxidative stress. Plant Sci., 160: 505-515.

Miller, N.J. and C.A. Rice-Evans, 1997. The relative contributions of ascorbic acid and phenolic antioxidants to the antioxidant activity of orange and apple fruit juices and blackcurrant drink. Food Chem., 60: 331-337.

Mitsuda, H., K. Yausumoto and K. Iwami, 1996. Antioxidation action of indole Compounds during the auto-oxidation of linoleic acid. Eiyo to Shokuryo, 19: 210-214.

Moreira, A.S., V. Spitzer, E.E. Schapoval and E.P. Schenkel, 2000. Anti-inflammatory activity of extracts and fractions from the leaves of *Gochnatia polymorpha*. Phytother. Res., 14: 638-640.

Moskovitz, J., K.A. Yim and P.B. Choke, 2002. Free radicals and disease. Arch. Biochem. Biophys., 397: 354-359.

Murota, S. and Y. Koshihara, 1985. New lipoxygenase inhibitors isolated from Chinese plants. Development of new anti-allergic drugs. Drugs Exp. Clin. Res., 11: 641-644.

Okhawa, H., N. Ohisi and K. Yagi, 1979. Assay for lipid peroxides in animal tissue by thiobarbituric acid reaction. Anal. Biochem., 95: 351-358.

Pellegrini, N., P. Riso and M. Porrini, 2000. Tomato consumption does not affect thetotal antioxidant capacity of plasma. Nutrition, 16: 268-271.

Prieto, P., M. Pineda and M. Aguilar, 1999. Spectrophotometric quantitation of antioxidant capacity through the formation of phosphomolybdenum complex: Specific application to the determination of vitamin E. Anal. Biochem., 269: 337-341.

Pulido, R., L. Bravo and F. Saura-Calixto, 2000. Antioxidant activity of dietary polyphenols as determined by a modified ferric reducing/antioxidant power assay. J. Agric. Food Chem., 48: 3396-3402.

Ruch, R.J., S.J. Cheng and J.E. Klavning, 1989. Prevention of cytotoxicity and inhibition of intercellular communication by antioxidant catechins isolated from Chinese green tea. Carcinogens, 10: 1003-1008.

Sasaki, S., T. Ohta and E.A. Decber, 1996. Antioxidant activity of water soluble fraction of *Solanum spremary* tissue. J. Agric. Food Chem., 44: 1682-1686.

Serafini, M., R. Bellocco, A. Wolk, A.M. Ekstorm, 2002. Total antioxidant potentials of fruit and vegetables and risk of gastric cancer. Gastroenterology, 123: 985-991.

Soleas, G.J., L.Grass, P.D. Josphy, D.M. Goldberg and E.P. Diamandis, 2002. A comparison of the anticarcinogenic properties of four red wine polyphenols. Clin. Biochem., 35: 119-124.

Squacrito, G.L. and W.A. Peyer, 1998. Oxidative chemistry of nitric oxide: The role of superoxide, peroxynitrite and carbon dioxide. Free Rad. Biol. Med., 25: 392-403.

Taguchi, K., Y. Hagiwara, K. Kajiyama and Y. Suzuki, 1993. Pharmacological studies of *Houttuyniae herba:* The anti-inflammatory effect of quercetin. Yakuga Zasshi, 113: 327-333.

Takeoka, G.R., L. Dao, S. Flessa, D.M. Gillepsie, W.T. Jewell, B. Heupner, D. Bertow and S.E. Ebeler, 2001. Processing effects on lycopene content and antioxidant activity of tomatoes. J. Agric. Food Chem., 49: 3713-3717.

Wang, H., G. Cao and R. Prior, 1997. Oxygen radical absorbing capacity of anthocyanins. J. Agric. Food Chem., 45: 304-309.

Wettasinghe, M. and F. Shahidi, 2000. Scavenging of reactive-oxygen species and DPPH free radicals by extracts of borage and evening primrose meals. Food Chem., 70: 17-26.

Wiseman, H. and B. Halliwell, 1996. Damage to DNA by reactive oxygen species: Role of inflammatory disease and progression to cancer. Biochem. J., 313: 17-29.