Effect of Processing on Composition of Green Leafy Vegetables

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ABSTRACT

Green leafy vegetables are an important part of diet in many countries around the globe. The presence of nutrient content in the leaves is largely affected by the processing conducted in order to make it palatable. Hence the present study reviews the effect of processing on the composition of green leafy vegetables consumed around the globe.

Keywords Green leafy vegetable, processing, nutrient, composition

Vegetables and fruits, in particular, are very important for human health because they occur naturally as whole foods and are rich in a large variety of nutrients. Leafy vegetables are not only good sources of minerals but also contain vitamins, antioxidants and pigments. A large number of vegetables, such as spinach, brussel sprout, broccoli, onion etc are rich sources of antioxidants (Gazzani, et al., 1998; Velioglu et al., 1998; Vinson et al., 1998).

Green leafy vegetables (GLVs) are popular around the world, especially in Asia. The majority of the Indian population is vegetarian and daily intake of at least 100 g of fresh GLVs is recommended by nutrition experts (Reddy, 1999). India is endowed with an array of leafy vegetables suited for tropical, sub-tropical and temperate climates, which are grown throughout the year. Green leafy vegetables are store house of vitamins such as beta carotene, ascorbic acid, folic acid, and riboflavin as well minerals such as iron, calcium and phosphorous(Gupta et al., 2008). The commonly consumed GLVs in different parts of India are coriander, fenugreek, dill, amaranthus, mint, basella, lettuce, spinach, alteranthera, drumstick, etc (Hariprasad et al., 2012). Amongst several commonly consumed leafy vegetables, cabbage and amaranth were highest ranked on the basis of chemical composition and nutritional value (Awasthi & Tandon, 1987). It has been estimated that 100 g of tropical leafy vegetables can provide 60–140 mg of ascorbic acid, 100 mg of folic acid, 4–7 mg iron and 200–400 mg of calcium (Saxena, 1999).

Some GLVs are known to be rich in lysine, an essential amino acid that is lacking in diets based on cereal and fibres, while others are medicinal (Maundu, 1995), anticarcinogenic and antiarteriosclerotic (Imungi, 2002). Green leafy vegetables also contain polyphenols which have beneficial physiological effects on humans as antioxidants (Hariprasad et al., 2013). Research data support the recommendation of increased intake of a wide variety of vegetables, specifically dark green leafy cruciferous vegetables, which may reduce the risk of chronic diseases (Van Duyn and Pivonka, 2000). Leafy greens are economically affordable and represent an important source of nutrients for people in the lower income sector (Kawashima and Soares, 2003).

Amaranth is a multipurpose crop supplying high nutritional quality grains and leafy vegetables for food and animal feed; as possessing attractive inflorescence coloration, it also may be cultivated as an ornamental plant (Mlakar et al., 2009). Now a days amaranth could be classified as a new, forgotten, neglected, and alternative crop of great nutritional value; in fact, amaranth has gained increased attention only since the 1970’s (Lehmann, 1996). Amaranthus viridis L. (Amaranthaceae), commonly known as “Chowlai”, is a fast growing herb mainly cultivated in Asia, Africa and Latin America (Amin et al., 2006). Being resistant to drought, hot climate and pests, and with little requirements for its cultivation, this pseudocereal has attracted much attention as an important food commodity (Sexna et al., 2007). In the last decade, the use of amaranth has expanded not only in the common diet, but also in diet of people with celiac disease or allergies to typical cereals (Berti et al., 2005). Reactive oxygen species (ROS) and reactive nitrogen species produced as a result of oxidation have been shown to be linked with different degenerative disorders such as aging, inflammation, cancer, cardiovascular complications, and osteoporosis (Wilcox, 2004). Amaranth leaves contain 17.5 to 38.3% dry matter as protein of which 5% is lysine (Oliveira and De Carvallo, 1975). Vitamin A and C are also
present in significant levels. One hundred grams of the vegetable material cooked without oil can contribute 45% of daily Vitamin A requirement (Mulokozi et al., 2004 as quoted by FAO 2004). Compared to spinach, Amaranthus contains three times more vitamin C, calcium and niacin. Compared to lettuce, Amaranthus contains 18 times more vitamin A, 13 times more vitamin C, 20 times more calcium and 7 times more iron (Guillet, 2004). A study was done by Mnkeni et al.; in 2006 to compare the nutritional components in four different accessions Of amaranthus leaves(AMA 5,AMA17, AMA 18 and V2).It was found that Ascorbic acid content in the leaves varied between 630 and 496 mg/100g. V2 contained significantly higher amount of nitrates (1 474 mg/100g) while VOP and AMA17 had the lowest (729 mg/100g). AMA 17 leaves had the highest concentrations for all the minerals that were determined in leaves. As a member of the Brassicaceae (formerly Cruciferae) family (also known as the mustard family and cole crops), canola as a leafy green, may provide nutritional benefits similar to those of some traditional leafy greens as reported by Bhardwaj et al. (2003).The potential of canola (Brassica napus L.) leafy greens as a food source for human consumption is being considered to increase the variety of nutritious vegetables available to consumers. A study was done to compare the mineral composition of Five cultivars of canola leafy greens for comparison to those of collard greens (Brassica oleraceae var. viridis), kale (Brassica oleraceae L. acephala) and cabbage (Brassica oleraceae L. var. capitata). It was proved that collard greens were significantly higher in potassium (K) than the other crops tested; however, canola was significantly higher in K than cabbage and kale. The essential micronutrient, iron (Fe), (24.77 mg/ 100 g dry weight), was significantly higher in canola and lowest in cabbage (7.65 mg/100 g dry weight).Zinc (Zn) and manganese (Mn) contents of canola (3.00 and 16.40 g/100 g dry weight, respectively) were greater than cabbage and collard. Among the three canola harvest stages (rosette, budding and blooming), K content increased with growth, while Fe and aluminum (Al) decreased; sodium (Na) was lowest at the budding stage compared to the other two stages. Hence it can be an alternative for traditional green leafy vegetables. Leafy green products include romaine lettuce, green leaf lettuce, red leaf lettuce, butter lettuce, baby leaf lettuce, escarole, endive, spring mix, spinach, cabbage,kale, arugula, and chard.(Karl R. Matthews,Leafy Vegetables). Lettuce and escarole, belonging to the Asteraceae family, are the most popular vegetables in salads which are consumed in increasing amounts due to their perception as being “healthier” foods (Dupont, Mondi, Willamson, & Price, 2000).The healthy properties are attributed to a large supply of antioxidant compounds mainly vitamin C and polyphenols as well as the fibre content (Nicolle et al., 2004a; Serafini et al., 2002) Polyphenols (flavonols and anthocyanins) have been described to have greater antioxidant activity than vitamins C and E (Rice-Evans, Miller, & Paganga, 1997). Previous studies demonstrate the importance of the chemical nature of these conjugates and suggest that the degree of hydroxylation determines the antioxidant activity (Rice-Evans et al., 1997) and bioavailability (Hollman & Arts, 2000). Spinach is one important dietary vegetable usually consumed after cooking in boiling water either fresh or frozen. They are fair sources of protein and good sources of vitamins and also minerals. Some studies show that the leaves contain anti-nutrients that may interfere with the absorption of some nutrients in diet (Raheena, 2007). Green leafy vegetable acts as a buffer and maintains the proper alkalinity of the blood by balancing acid-producing foods like meats (Funke, 2011).

Outbreaks associated with leafy vegetables

Spoilage in Leafy vegetables is mainly associated with physiological spoilage such as enzymatic browning and respiration activity and also microbiological spoilage with the proliferation of gram negative bacteria. The main factors which influence spoilage are temperature, gas concentration, extent of mechanical damage and interaction physiology microbiology(Ragaert et al.;2010).In the United States, analysis of data from 1973 to 2006 indicates that about 5% of food borne outbreaks were associated with leafy greens (Smith et al., 2007). Outbreaks associated with Salmonella and E. coli O157:H7 tend to receive the most attention due to the severity of the illness.(Matthews, 2009). In 2005, bagged salad containing three basic ingredients, romaine lettuce, red cabbage, and carrots, were linked to an outbreak of E. coli O157:H7 foodborne illness (Smith DeWaal and Bhuiya, 2007). Spinach contaminated with E. coli O157:H7 was at the center of a large outbreak that resulted in 205 confirmed illnesses and three deaths in 2006 (Smith DeWaal and Bhuiya,
2007). This outbreak served as a catalyst for the development of more effective measures to ensure that fresh and fresh-cut leafy greens would be safe for human consumption. In September 2006, an E. coli O157:H7 outbreak affected 26 US States which involved about 200 cases of illness, including some of Hemolytic Uremic Syndrome (HUS) and resulted in three deaths (FDA, 2006). Data indicated that fresh spinach grown in three Californian countries was the source of the bacterium (Abadias et al., 2007).

In a study done by Abadias et al., 2007 to compare the microbiological quality of fresh, minimally-processed fruit and vegetables it was found out that in general the highest microorganism counts were associated with grated carrot, arugula and spinach (7.8, 7.5 and 7.4 log cfu g⁻¹ of aerobic mesophilic microorganisms. The lowest counts were generally associated with fresh-cut endive and lettuce (6.2 and 6.3 log cfu g⁻¹ of aerobic mesophilic microorganisms). Arugula and spinach are topsoil crops, but have open leaves that could be in contact with soil and irrigation water. Studies (Oliveira et al., 2011) have also shown that green leafy vegetables have poor microbiological quality when compared to other fresh cut fruits and vegetables. The widespread global contamination of leafy greens with E. coli O157 and subsequent outbreaks of food borne illness are difficult to explain. No specific genes are attributed to E. coli O157:H7 that would explain why the pathogen is so intricately associated with leafy greens outbreaks. Research demonstrates the ability of the pathogen to survive for extended periods in water, soil, and manure. The microbe is also capable of surviving shifts in temperature, exposure to sunlight (ultraviolet), moisture, and nutrients. (Karl R. Matthews, 2009). Differences in soil, climate, and cultivars independently or collectively impact microbial quality of the crops grown.

Growers must be aware of Good Agricultural Practices (GAPs) and be willing to implement GAPs to reduce the risk to human health associated with consumption of contaminated leafy greens (Jackson et al., 2007). Regardless of the target microbe, specific measures must be put into place to ensure the microbial safety of leafy vegetables during harvest (FDA/CFSAN, 2004, 2007). Sewage water containing a broad spectrum of pathogens, many that survive for several weeks in the field, is commonly used in urban areas (Amoah et al., 2006). The use of sewage or polluted water results in excessive accumulation of heavy metals in soils, which leads to elevated levels of heavy metal uptake by crops (Karanja et al., 2010). In addition, the demand by urban consumers for blemish-free and attractive produce encourages excessive use of pesticides and nitrate-rich chemical fertilizers (e.g., Okello and Swinton, 2010).

Wild green leafy vegetables

Wild vegetables are only seasonally available and highly perishable, and hence suitable processing and storage techniques need to be applied to conserve their micronutrients (Negi and Roy, 2000; Negi and Roy, 2001). Seasonality can be partly overcome by blanching, which is usually the primary step in the processing of vegetables, before drying and storage (Mulokazi and Svanberg, 2003). The multiple roles of wild traditional vegetables as both food and medicinal sources have been widely documented. These include: the listing of 28 medicinally important leafy vegetables by Ayodele, 2005, the reported medicinal uses of 24 indigenous leafy vegetables in south western Nigeria by Adebooye and Opabode, 2004, Wild vegetables, especially dark green leafy plants, are known to contain oxalates, phytates, nitrates, tannins and saponins known to reduce the absorption of certain micronutrients in the body (Guil et al., 1997; Wallace et al., 1998; Steyn et al., 2001; Gupta et al., 2005). The potentials of traditionally cooked green leafy vegetables to supply bioavailable iron, beta-carotene, riboflavin, thiamine, folic acid, ascorbic acid, zinc and copper for vegetarian diets have been investigated by Agte et al., 2000. He found that the vegetables cooked in this manner were adequate supplements for iron, beta-carotene and vitamin C, but not riboflavin, folic acid, zinc and copper.

Different methods of processing of leafy vegetables

The improper handling of product immediately after harvest can compromise the safety of leafy greens. Proper refrigeration is imperative to cool the product, thereby limiting or preventing growth of the pathogen. Cooling crops to 4°C or less will slow or prevent the growth of pathogens including Salmonella, E. coli O157:H7, and L. monocytogenes. Leafy greens are generally cooled under forced air, but passive storage under refrigeration is still a widely used method. Vacuum cooling is a common practice in the leafy greens industry. (Karl R. Matthews, 2009). A wealth of
Table 1. Effect of Processing on the Phytochemical content of leaves

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Type of vegetable</th>
<th>Leafy of processing</th>
<th>Treatment conditions</th>
<th>Effect on phytochemicals</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><em>Structium</em> sparejanophora</td>
<td>Blanching</td>
<td>100°C 5min</td>
<td>TP ↑ , vit C ↓</td>
<td>Oboh (2004)</td>
</tr>
<tr>
<td>2.</td>
<td><em>Amaranthus cruentus</em></td>
<td>Blanching</td>
<td>100°C 5min</td>
<td>TP ↔, vit C ↓</td>
<td>Oboh (2004)</td>
</tr>
<tr>
<td>5.</td>
<td><em>Solanum macrocarpon</em></td>
<td>Blanching</td>
<td>100°C 5min</td>
<td>TP ↑ , vit C ↓</td>
<td>Oboh (2004)</td>
</tr>
</tbody>
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Green variety: iceberg, romaine and continental
Red variety: red oak leaf and lollo rosso

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<th>References</th>
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<tbody>
<tr>
<td>Fresh sample (analysis of vitamin C)</td>
<td>Caffeic acid and vitamin C present in larger amounts in green variety</td>
<td>Llorach <em>et al</em>; (2007)</td>
<td></td>
</tr>
<tr>
<td>Freeze dried sample (analysis of antioxidant)</td>
<td>Flavonols present largely in red variety, anthocyanins present only in red variety</td>
<td>Funke (2011)</td>
<td></td>
</tr>
<tr>
<td>Steamed and then chopped</td>
<td>moisture (90.35) and ash content (1.36), Vitamin C (1.57 mg) and Iron (535.84 ppm)</td>
<td>crude fat per gram of sample (2.31), protein (4.35) and fibre (1.09), carbohydrate (4.89)</td>
<td></td>
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<tr>
<td>Blanching and then chopped</td>
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Where,
TP: total phenol
Vit C: vitamin C

Literature exists on the efficacy of various wash/sanitizing systems to remove or inactivate microbes associated with leafy greens (Doyle, 2005). Prior to bagging, leafy greens are dumped into water flumes containing sanitizing water. The total exposure time may range from 60 to 120 seconds. Leaves may float on the surface, a phenomenon often referred to as “lily padding,” which limits exposure of the entire leaf to the antimicrobial contained in the water which limits exposure of the entire leaf to the antimicrobial contained in the water. (Karl R. Matthews, 2009). Although every processor may have different procedures, leafy greens often go through a triple-wash process. The first wash occurs when product goes into an agitating tank containing weakly chlorinated water. This step is intended to remove gross physical debris (bugs, soil, stones). The major cleaning occurs in a second tank or flume containing chlorinated water. Although bacteria associated with the surface of a product may be killed, the chlorine in the water is intended to control bacterial numbers in the wash water and associated with equipment. The final wash is actually a rinse step that is intended to remove residual chlorine from the product.
Effect of processing on the mineral content of leafy vegetables

The basic functions of metals in biological systems have been known for many years, and it is currently accepted that several of them are indispensable for the normal functioning of living organisms. Relatively high levels of metals I and II of the main group (e.g. magnesium, sodium, potassium, calcium) are found in living organisms, while metals of the transitory groups (e.g. nickel, iron, copper, zinc, chromium, manganese or cobalt) occur in trace quantities. Particular attention should be paid to leafy vegetables because they contain more nutritionally important chemical constituents than other groups of vegetables (Kunachowicz et al., 2005; Souci et al., 2000), while their value as raw materials for freezing has been confirmed by numerous data in the literature (Jaworska and Kmiecik, 2000; Kmiecik and Lisiewska, 1999; Lisiewska and Kmiecik, 1997; Lisiewska et al., 2004; Supski et al., 2005). [Retention of mineral constituents in frozen leafy vegetables prepared for consumption]

Green leafy vegetables are known to be rich in iron, and are therefore, recommended as dietary supplements in case of iron deficiencies. However, GLV are known to contain some inhibitory factors like fibre reducing the availability of iron. In addition processing can have adverse effect on iron availability because of loss of ascorbic acid which acts as an enhancer for iron. It was found in a study (S.A. Chiplonkar et al; 1999) that open pan cooking resulted in a loss of bioavailable iron density of meals. Reduction of dialysable iron after blanching or squeeze washing of vegetables has been reported by others (Latunde-Dada, 1990). Green leafy vegetables are good sources of iron, providing around 5–10 mg per 100 g on an average (Gopalan et al., 1996). A daily intake of 100 g of greens is recommended in an adult’s diet (NIN, 1998). Though it is well established that iron availability is a function of the proportion of inhibitors and enhancers of a food material, a study done by Mamatha Kumari in 2003 have proved an increase in the total (1.2–10.8 times) and bioavailable iron (4 times) from greens cooked in an iron utensil compared to fresh and those cooked in other metallic utensils clearly indicates that the cooking utensil also has a role in determining the availability of iron. The total iron availability was higher (by 9%) in samples cooked in iron utensils than in samples cooked in non-iron utensils, while the averages of all other components were comparable (Mamatha Kumari, 2003).

Effect of processing on the vitamin content of leafy vegetables

Vitamin C is found in fruits, particularly fruits and juices and green leafy vegetables, they protect the body against cancer of the oesophagus, oral cavity and stomach, it also helps to maintain the blood vessel flexibility and improves circulation in the arteries of the smokers (Block, Patterson, & Subar, 1992; Nagy, 1980). Ascorbic acid losses from food items do not depend on temperature alone. In the case of cooked vegetables, apart from factors like light, pH, oxygen and the presence of trace metals (Eison-Perchonok & Downes, 1982). In Nigeria, green leafy vegetables are not usually consumed in their fresh form unlike fruits; however, they are usually blanched before consumption or preparation of soup (Akindahunsi & Oboh, 1999). Blanching could be briefly described as the process of heating vegetables to a temperature high enough to destroy enzymes present in the tissue. It stops the enzyme action, sets the colour, and shortens the drying and dehydration time. It is usually carried out in hot water or in steam; this technique is used by indigenous people to reduce or eliminate the bitterness of the vegetables and acid components that are common in leaves (Akindahunsi & Oboh, 1999). A study was conducted by Oboh (2004) to compare the antioxidant properties of blanched and unblanched green leafy vegetables such as Structium sparejanophora (Ewuro-odo), Amaranthus cruentus (Atetedaye), Telfairia occidentalis (Ugu), Baselia alba (Amunu tutu), Solanum macrocarpon (Igbagba), Corchorus olitorus (Ewedu), Vernonia amygdalina (Ewuro) and Ocimum gratissimum (Efinrin) [table 1]. It was revealed that blanching cause a significant (p<0.05) increase in the total phenol [fresh (0.1–0.3 g/100 g), blanched (0.2–0.6 g/100 g)] content of the green leafy vegetables except in Amaranthus cruentus and Vernonia amygdalina where there was no change. Conversely, there was a significant (p<0.05) decrease in the vitamin C [fresh (43.5–148.0 mg/100 g), blanched (15.8–27.3 mg/100 g), reducing property [fresh (0.5–1.5 absorbance), blanched (0.1–0.6 absorbance)] and free radical scavenging ability [fresh (20.0–51.4%), blanched (16.4–47.1%)] of the blanched green leafy vegetables except in Structium sparejanophora, where there was no change in the reducing property (0.6 absorbance) and free radical scavenging ability.
(59.8%) of the blanched vegetable (Oboh, 2004). The antioxidant compounds, polyphenols and vitamin C, have been determined in five varieties of lettuce (iceberg, romaine, continental, red oak leaf, lollo rosso) (Llorach et al., 2007; table 1). The polyphenol study identified two new compounds in lettuce namely quercetin and luteolin rhamnosylhexosides. Caffeic acid derivatives were the main phenolics in green varieties, and flavonols were detected in higher quantities in red varieties. Anthocyanins were only present in red-leafed varieties. The highest total phenolic content was observed in red-leafed varieties while the highest level of vitamin C was detected in the continental variety. Amaranth is a commonly consumed vegetable in households in Southwestern Nigeria. Raw amaranth is known to be rich in micronutrients particularly Iron and Vitamin C, which are lost during cooking due to the method of preparation. Hence, the study was conducted by Funke (2011) to determine the method of preparation that best retains nutrients (table 1). Sample A was prepared by chopping the leaves finely, sample B was prepared by steaming before chopping the leaves and Sample C was prepared by chopping the leaves prior to blanching. Result of proximate analysis showed that sample B method of preparation has highest percentage of crude fat per gram of sample (2.31 ± 0.45), protein (4.35 ± 0.15) and fibre (1.09 ± 0.06). Sample A has highest percentage of moisture (90.35 ± 0.27) and ash content (1.36 ± 0.28) while sample C has highest percentage per gram of sample in carbohydrate (4.89 ± 1.21) only. Micronutrient determination results showed that sample A was highest in Vitamin C (1.57 mg ± 0.06) and Iron (533.84 ppm ± 123.42), followed by sample C (1.21 ± 0.07) and (501.88 ± 215.19) respectively while sample B had the least vitamin C (0.79 ± 0.06) and Iron (354.18 ± 121.84). The study showed that sample A retained the maximum nutrient contents of Amaranth leaves after processing. Studies have done to compare the ascorbic acid present in six green leafy vegetables such as Vernonia amygdalina, Pterocarpus soyauxii, Manihot utilissima, Xanthosoma sagittifolium, Colocasia esculenta and Amaranthus hybridus during traditional West African cooking. The initial ascorbic acid levels were found to be 10.3-34.4 mg ascorbic acid/100g of fresh weight. It was found that 60-90% of ascorbic acid reduced in 15 min of cooking time. Here the loss of ascorbic acid was directly proportional to the time of cooking. The ascorbic acid of Vernonia amygdalina was lost about 50% during the squeezing and crushing in wash water. The vitamins present in Vernonia amygdalina was leached into the water and hence did not serve as a good source for ascorbic acid and vitamins (K.Oteng-Gyang & J. I. Mbachu, 1986). Studies done by Gupta et al.; in 2008 have shown that retention of ascorbic acid was reduced as the blanching time and temperature increased in all greens. It was noted that all greens blanched at 80°C for 1 min with chemical media retained maximum ascorbic acid. Studies done by Faboyia in 1990 showed that the ascorbic acid contents of leafy vegetables vary significantly with sampling sites and high proportion of the vitamin is rapidly lost from the vegetables on exposure to light. It is recommended to process leafy vegetables immediately after harvesting or purchasing as vitamin C content decreases on increasing of exposure time.

**Toxins**

The main problem in nutritional exploitation of green leafy vegetables is the presence of antinutritional and toxic principles (Gupta et al.; 1988). Leafy vegetables, such as amaranth, chenopodium, lettuce, spinach, etc., accumulate high concentrations of nitrate, oxalate and saponin (Pedersen & Wang, 1971; Cheeke & Bronson, 1980; Fenwick & Oakenfull, 1983). Aflatoxins are a group of mycotoxins produced mainly by Aspergillus flavus, A. parasiticus and A. nomius (Bayman & Cotty, 1993). Aflatoxin B1 is the most potent toxic metabolite that shows hepatotoxic, teratogenic and mutagenic properties, causing damage to mammals as toxic hepatitis, haemorrhage, oedema, immunosuppression and hepatic carcinoma. It has been classified as a Class 1 human carcinogen by the International Agency for Research on Cancer (IARC, 2002). Absorption of Aflatoxins by young germinating seedlings grown in contaminated soil could seriously affect the growth and development of plants (Ahmad & Sinha, 2002; Chatterjee, 1988; El-Naghy, Fadl-Allah, & Samhan, 1999).

However processing can have a significant impact on the toxin levels in the green leafy vegetables, a study conducted by Udousoro et al., 2013. They studied the effect of time and temperature on the levels of antinutrients in five popularly consumed green leafy vegetables in Nigeria. Utazi leaf (Gongronema latifolium), Bitter leaf (Vernonia amygdalina), Curry leaf (Ocimum canum sims) Bush apple leaf (Heinsia crinata) and

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Waterleaf (\textit{Talinum triangulare}) were used in the study. The vegetables were subjected to heating conditions of 50°C and 90°C for 5 minutes and 15 minutes, and the levels of selected anti-nutrients (phytate, cyanides, tannins, oxalates) were assessed. Reduction in the investigated anti-nutrients content in vegetables was observed. The greatest reduction in level was observed in oxalates. This study confirmed that thermal processing can have significant impact in reduction of antinutrient content in the leafy vegetables.

Heavy metals are known to pose a variety of health risks such as cancer, mutations or miscarriage (Weigert, 1991). A study was done by Itanna in 2002 in Ethiopia to compare the heavy metals present in cabbage, lettuce and swiss chard collected from three different farms which was irrigated near different river banks namely Kera river, Bulbula river and Kebena river. It was found that cabbage was least in heavy metals when compared to swiss chard and lettuce. The metal uptake by the leafy vegetable depends upon the tolerance of a plant to heavy metals. As the soil contamination increases metal contamination in the plants increases and hence the health of the consumers is at high risk.

Von Oettingen, 1958 stated that the ingestion of small doses of nitrate may cause cyanosis (methemoglobinemia) because of the reduction of nitrate to nitrite in the gastrointestinal tract. The toxicity of nitrites is due to their interaction with blood pigment to produce methemoglobinemia, and their presumptive toxicity is related to their possible reaction with amine or amides to form nitroso compounds (Wolff & Wasserman, 1972). Studies (Huissen, 1985) have shown that leafy vegetables (particularly spinach, roquette and chard) contained the highest concentration of nitrate when compared with root vegetables and pulses. It was also found that cooking and storage of leafy vegetables in frozen condition reduced the level of nitrate without any formation of nitrite. Abour-Arab & Abou-Donia, 2000 reported that thermal processing especially boiling the plant in water may cause leaching of heavy metals from plant leading to reduction of heavy metals in the plant itself.

Green leafy vegetables are important for a healthy balanced diet, processing do effect the nutrient and antinutrient content in the GLV. However different type of processing followed have varying effect, as such if the thermal processing involved hot water treatment, the nutrient as well as antinutrients and minerals content will be affected due to their leaching in water. Thermal processing will lead to degradation of heat sensitive nutrients and antinutrients, however the mineral contents as such are not much affected by thermal processing. More over the thermal processing may make some of the nutrient more bio available and easy to digest.

Hence processing have a significant impact on the quality, palatability and overall acceptability of the GLV, and it have various merits as well by decreasing the antinutrient content and heavy metals.

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