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Production and Quality Evaluation of Green and Black Herbal Teas from *Moringa oleifera* Leaf

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ABSTRACT

Freshly plucked *Moringa oleifera* leaves were processed into green and black herbal teas, due to its nutritional, pharmacological and medicinal properties. The unit operations were plucking, destalking and steaming for green tea or withering, grinding, fermentation for black tea prior to drying, milling, grading and packing. The tea samples were subjected to chemical and microbial load analyses, using standard methods. The results revealed the following ranges: proximate parameters; crude protein (7.25-26.62%), moisture content (10.37-70.48%), crude fat (1.82-2.74%), crude fibre (1.09-19.37%), ash content (0.94-9.75%), carbohydrate (15.31-44.93%); phytochemicals; saponins (2.25-5.50%), flavonoid (6.0-16.50%), steroid (1.05-5.05%) and terpenoid (0.70-1.23%) and anti-nutritional factors; tannin (0.23-1.32%), phytate (5.5-18.75%), cyanide (2.55-12.00%) and alkaloid (0.65-2.20%). The ranges of vitamins detected were; vitamins A (7-35-20.37 mg), B_1 (0.11-2.85 mg), B_2 (0.07-21.46 mg) and C (8.25-213 mg), while minerals included calcium (465.5-2057.5 mg), phosphorus (74.80-225.00 mg) and iron (8.23-32.15 mg). The microbial profile of green tea revealed 8.34×10^2 CFU g^{-1} total viable count, whereas no mould growth was observed in both green and black *Moringa* tea leaves.

Key words: Steaming, fermentation, proximate, micronutrients, phytochemicals, antinutrients

INTRODUCTION

Tea is the processed leaves of *Camellia sinensis* which upon infusion with cold or hot water, gives a non-alcoholic beverage (Sharma *et al.,* 2005). Tea consumption is a very ancient habit, with legends from China and India indicating that it was initiated about five thousand years ago (Dufresne and Franworth, 2001). Traditionally, tea was consumed to improve blood flow, eliminate toxins and improve resistance to diseases (Balentine *et al.*,1997). According to Hertog *et al.* (1993), numerous epidemiological studies linked tea consumption to reduction of the risk of cardio vascular diseases, high cholesterol levels, diabetes (Vinson *et al.*, 2001), arthritis (Haqqi *et al.*, 1999), osteoporosis (Hegarty *et al.*, 2000) and dental carries. Polyphenols are the most biologically active group of tea components (Park *et al.*, 2012), which possesses antioxidative, antimutagenic and anticarcinogenic effects (Yao *et al.*, 2004). Valerga *et al.* (2012) modified polyphenol content and composition of yerba mate as well as the capacity of its extracts to inhibit the oxidation of β-carotene/linoleic acid system, after industrial processing. These beneficial effects of tea have been attributed to the antioxidant properties of polyphenolic compounds, particularly the catechin derivatives (Horzic *et al.*, 2009). According to Gill *et al.* (2011), factors that determine the quality of made tea include the plucking method, fermentation time, sorting and particle size among others. Horzic *et al*. (2009) reported that four types of teas are produced; white tea, green tea (both unfermented), oolong tea (semi-fermented) and black tea (fully fermented). Other classes of teas include puerrh tea, scented teas, flavoured teas and herbal teas.

Herbal tea also known as tisane, or herbal infusion is simply the combination of boiling water and dried leaves, flowers, fruits or herbs, often consumed for their physical or medicinal effects (Kara, 2009). Herbal teas can be made with fresh or dried flowers, leaves, seeds or roots, generally known to posses medicinal values by pouring boiling water over the plant parts and letting them steep for a few minutes. In Nigeria, leaves such as bitter leaf (Okafor *et al*., 2009), "Utazi" and "Uziza" have been successfully used for production of herbal teas, due to their medicinal properties. *Moringa oleifera* has so many attributes such as the green nature of the leaves, the antioxidant properties, polyphenol content, phytochemicals properties among others (Fahey, 2005), which makes it similar to the leaves of *Camellia sinensis* and useful for tea manufacturing. They also form the basis for the name "Herbal tea" often given to teas other than from the leaves of *Camellia sinensis*, because they are associated with management of different ailments. The use of herbal remedies especially in the form of teas for management of various diseases is gaining increasing popularity, making them the main stay of health care system, especially among the rural populace in the developing countries (Ogbonnia *et al*., 2011).

Nutrient enrichment with *Moringa oleifera* represents a superior option for mitigating the effects of micronutrient deficiency in impoverished areas. According to De Saint Sauveur and Broin (2010), *Moringa* leaf powder is highly concentrated with micronutrients, that a few grams a day can help to combat vitamin, mineral and protein deficiencies. They equally reported that eating 100 g fresh *Moringa oleifera* leaves provide as much protein as an egg, as much calcium as a big glass of milk, as much iron as a 200 g beef steak, as much vitamin A as a carrot and as much vitamin C as an orange. Its leaves are used as nutritional supplement and growth promoters (Sanchez-Machado *et al.,* 2006), antiulcer, diuretic, anti-inflammatory agent and for enhancing wound healing (Udupa *et al*., 1994; Pal *et al*., 1995). Prakash (1998) demonstrated that the aqueous extract of the leaves has antifertility activity, while Tahiliani and Kar (2000) used it in regulating adult Swiss rat's thyroid hormone status. *Moringa* is not used as a stimulant because it contains no caffeine. Different processing steps such as fermentation, steaming, among others help to remove the anti-nutrients present in *Moringa* leaves. The aim of processing *Moringa oleifera* leaves into green and black teas is to process them into convenient shelf stable forms and to preserve the products, thus helping to increase food security, create employment opportunities and generate income.

MATERIALS AND METHODS

Raw materials procurement: Fresh green leaves of *Moringa oleifera* were plucked from a garden at Orba in Nsukka local government area, Enugu State, Nigeria.

Method of producing green tea from the leaf of *Moringa oleifera*: The flowchart for production of green tea from *Moringa oleifera* leaves is presented in Fig. 1. Freshly plucked leaves of *Moringa oleifera* weighing 1000 g were washed using pipe borne water. An electric steamer (John Lewis model) was plugged to an electric socket and the water reservoir filled with cold water until the maximum level was reached. The timer was set for 60 min count down. The steamer was switched on and water was allowed to reach boiling point temperature of 100°C using inserted thermometer. The washed leaves were weighed in batches of 92 g using a digital weighing balance (Camry 302), placed in the plastic containers of the steamer and allowed to steam for 3 min. After

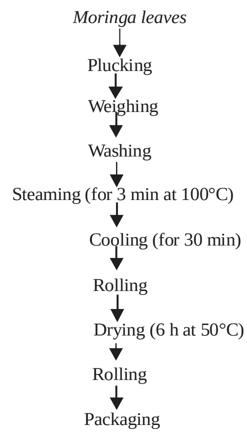

Fig. 1: Production of green herbal tea from *Moringa* leaf

the steaming process, the leaves were allowed to cool at room temperature for 30 min prior to rolling, using a manual plate mill (Corona) to disrupt the leaf cells and increase their surface area, in order to enhance the drying rate. The rolled leaves were spread on trays and dried immediately in a hot air oven for 6 h at 50°C till the product became crispy. After drying, the products were coarsely milled using a manual plate corona mill to obtain a coarse product which was sieved using a USA standard testing sieve No. 30 and packed in an air tight container and stored at room temperature.

Method of producing black tea from the leaves of *Moringa oleifera*: The flowchart for production of black tea from *Moringa oleifera* leaves is presented in Fig. 2. *Moringa oleifera* leaves (1 kg) were washed with tap water and allowed to drain. The drained leaves were thinly spread on jute bags and withered under shade for 3 h. The leaves were allowed to lose about 60% of their moisture in order to make them pliable for rolling. This was done by weighing at intervals of 30 min. The withered leaves were rolled using a manual corona plate mill. Rolling was done to disrupt the leaf cells and expose some of the essential oils and juice necessary for fermentation. After rolling, the leaves were thinly spread on trays and left at room temperature for 3 h for fermentation to take place. The colour of the leaves darkened as a result of fermentation/oxidation. The fermented leaves were dried in a hot air oven at the temperature of 50°C for 4 h, cooled and coarsely milled using a manual corona plate mill in order to obtain a coarse product, which was sieved using a USA standard testing sieve No. 30 and packaged into an air tight container.

Determination of proximate composition: The proximate analysis (moisture, fat, ash, protein, carbohydrate and fibre) of the fresh leaves and products was carried out using AOAC (2010) method. However, carbohydrate content was determined by the difference in the sum of all other proximate content from 100.

$$\text{Percentage carbohydrate} = 100\text{-}(\text{Moisture (\%)}+\text{Ash (\%)}+\text{Protein (\%)}+\text{Fibre(\%)}+\text{fat (\%)})$$

Determination of phytochemical composition: The steroid content of the samples was carried out using the method of Subhadhirasakul and Pechpongs (2005). Terpenoid was determined using

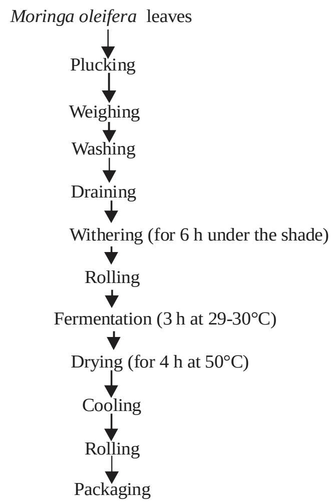

Fig. 2: Production of black herbal tea from *Moringa oleifera* leaf

the same procedure with steroid. The only difference was that methanol was used in terpenoid determination instead of chloroform. Flavonoid was determined using the method of Boham and Kocipai-Abyazan (1974) while, saponin was determined using method of Obadeni and Ochuko (2002).

Determination of anti-nutrients: The anti-nutrients were determined as follows: phytate was determined using method of Oberlase (1973). Tannin was determined using the method of Pearson (1976). The gravimetric method of Harbone (1973) was adopted in determining the alkaloid content of the samples. Cyanide content was determined using the method of Onwuka (2005).

Determination of mineral elements: Minerals occur in foods in both organic and inorganic compounds of the nutrients essential for human nutrition. Some minerals such as calcium, iron and phosphorous considered to be among the top mineral elements were analyzed as follows; the phenanthroline method described by Pearson (1976) was used to determine the iron content of the samples. Calcium was determined using the method described by Harbone (1973), while the spectrophotometer molybdate method as described by Pearson (1976) was used to determine phosphorous content.

Determination of vitamin composition: Provitamin A was determined using the method of Pearson (1976). Vitamin C was determined using method of Barakat *et al.* (1973), while determination of thiamin was done using the method described by Pearson (1976). Niacin content of the sample was determined using AOAC (2010).

Microbial analysis: The total viable and mould counts were carried out on the *Moringa* leaf tea samples. The total viable count of each sample was determined by pouring plate method using nutrient agar as described by Prescott *et al.* (2005), while mould count was done according to method of Prescott *et al.* (2005) on Potato Dextrose Agar (PDA).

Statistical analysis: Data analysis was carried out using one-way analysis of variance (ANOVA) based on completely randomized design and mean separation was by Duncan's New Multiple Range Test (DNMRT). Significance was accepted at $p<0.05$.

RESULTS AND DISCUSSION

Proximate composition of fresh and powdered *Moringa oleifera* leaves, black and green teas: The proximate composition of the *Moringa* black tea, green tea, powdered and fresh leaves is shown in Table 1. The moisture content of the samples, ranged from 8.76-70.48%. Powdered *Moringa* leaves had the lowest moisture content of 8.76%, while fresh *Moringa* leaves had the highest moisture content of 70.4%. The moisture content of green and black teas did not fall within the suggested limit (below 6.5%) of Owuor (2003). The high moisture content of *Moringa* tea samples could be attributed to improper packaging, making the samples to reabsorb moisture from the humid environment, after processing. Controlling the moisture content of tea products is an important factor in tea preservation, particularly for inhibition of microbial growth (Heong *et al*., 2011). According to Mohammed and Sulaiman (2009), high moisture content aids fungal growth. The ash content of a sample, which is an indication of its mineral content, does not necessarily indicate high quality, except when there is a favourable balance of the essential minerals (Ahmed *et al*., 1989). The ash content of these samples ranged from 4.04-9.75%, which could be attributed to the different processing methods used for the teas. *Moringa* leaf powder was found to have the lowest ash content (4.04%), while black tea had the highest ash content (9.75%). These high ash contents suggest that the samples are good sources of minerals (Mohammed and Suleiman, 2009). There were significant ($p<0.05$) differences between the crude fibre content of all the samples. The powdered *Moringa* leaves had the highest crude fibre content (18.64%), which is in agreement with the crude fiber content (18.82%) reported for Srilanka tea (Mohammed and Sulaiman, 2009), while the fresh leaf had 1.09% crude fibre content. Crude fibre stimulates the movement of the bowel and helps to prevent constipation (Okanlawon, 2000).

The fat content of the samples that ranged from 1.82-2.72% were significantly ($p<0.05$) different from each other. Fresh *Moringa* leaf had the least fat content (1.82%), while green tea had highest content followed by *Moringa* leaf powder and black tea. The disparity between the fat content of the processed samples could be due to drying which concentrated nutrients, steaming or withering processes that contributed to loss of moisture (Jabeen *et al*., 2015). The protein content of the samples which ranged from 7.25-26.65% were significantly ($p<0.05$) different from each other, with *Moringa* leaf powder being the highest (26.62%) followed by green and black *Moringa* teas, while fresh *Moringa* leaf had the least protein content (7.25%) probably due to its high percentage of moisture content. The carbohydrate content of the powdered *Moringa* leaf sample was highest (26.62%), because most of its moisture content had been removed by drying. followed by green tea (22.3%). Fresh *Moringa* leaf had the least carbohydrate content (7.25%) because it was still in its fresh state when analysed and consequently contained more moisture.

Table 1: Proximate composition of *Moringa* leaf and tea samples (dry weight basis)

Samples	Protein (g)	Moisture (g)	Fat (g)	Crude fibre (g)	Ash (g)	CHO (g)
Fresh leaf	7.25 ± 0.08^{d}	70.48 ± 0.12^{a}	1.820 ± 0.08^{c}	1.09 ± 0.05^{d}	4.04 ± 0.07^{c}	15.31 ± 0.07^{d}
Leaf powder	26.62 ± 0.12^{a}	8.76 ± 0.20^{d}	2.380 ± 0.05^{b}	19.37 ± 0.18^{a}	9.36 ± 0.02^{b}	33.4900 ± 0.02^{c}
Green Tea	22.36 ± 0.00^{b}	10.37 ± 0.10^{c}	2.74 ± 0.04^{a}	18.64 ± 0.44^{b}	9.45 ± 0.21^{ab}	44.9000 ± 0.16^{a}
Black Tea	17.72 ± 0.05^{c}	12.62 ± 0.07^{b}	1.910 ± 0.02^{c}	17.82 ± 0.09^{c}	9.75 ± 0.02^{a}	40.1700 ± 0.18^{b}

Values represents Mean±SD (n = 3). Mean values within each column followed by different superscript letter significantly ($p<0.05$) differ

Vitamin composition of *Moringa* tea samples, fresh and powdered leaves: The vitamin composition of *Moringa* black tea, green tea, fresh and powdered leaves is shown in Table 2. Vitamins are organic compounds present in trace amounts in our diets (Heong *et al*., 2011). Black *Moringa* leaf tea had a significantly higher ($p<0.05$) amount of vitamin A than other samples, while fresh *Moringa* leaf sample had the least vitamin A content (7.5 β-carotene eq mg^{-1}). This could be attributed to the high percentage of moisture present in the leaves. In terms of vitamin B1 (thiamine), black tea had high vitamin B_1 content (2.85 mg) when compared to other samples. Green *Moringa* tea had the lowest vitamin B_1 content (0.11 mg). This could be attributed to the steaming process given to the leaves, during processing. In terms of vitamin B_2 (riboflavin) content, black *Moringa* tea leaf had the highest values (20.80 mg), while *Moringa* fresh leaf had the lowest riboflavin content (0.07 mg). There was no significant ($p<0.05$) difference between the vitamin B2 contents of *Moringa* black tea and powdered leaves. In terms of vitamin C (ascorbic acid) content, the fresh *Moringa* leaf sample was significantly ($p<0.05$) higher than other samples. *Moringa* green tea had the least ascorbic acid content (8.25 mg), due to the fact that vitamin C is heat labile and subsequently, was drastically reduced during the steaming process.

Mineral composition of *Moringa* leaf tea samples, fresh and powdered leaves: The mineral composition of *Moringa* black tea, green tea, fresh and powdered leaves is shown in Table 3. The result revealed that black tea had the highest concentration of all the minerals compared to other samples, which could be attributed to the high percentage of ash present. Black *Moringa* leaf tea also had the highest ash content (Table 1), which is in agreement with the observation of Mohammed and Sulaiman (2009) that high content of ash is an indication of a good source of minerals. The production processes of black tea that involves withering which reduces moisture content of fresh leaf to one third (Jabeen *et al*., 2015), helps to reduce loss of juice during maceration that aids enzymatic oxidation process called fermentation (Hsu *et al*., 2011) and subsequently enhanced mineral retention compared to green tea. There were significant ($p<0.05$) differences in the content of minerals between the samples. Thus, black tea had the highest calcium content (2057.50 mg) followed by green tea (2039 mg), due to concentration of minerals during drying, while fresh *Moringa* leaves had the least calcium content (465.50 mg). Relative to phosphorus and iron the same trend was observed, with *Moringa* black tea also having the highest content of these minerals, while *Moringa* fresh leaves had the least content. Steam blanching of *Moringa* leaves and subsequent maceration led to loss of fluid from the leaf matrix that contributed to reduction in the mineral content green tea. These vitamins and minerals are very important for a healthy diet and could therefore boost the immune system (Jimoh and Oladiji, 2005).

Table 2: Vitamin composition of *Moringa* leaf and tea samples (dry weight basis)

Samples	Vitamin A (β eq mg^{-1})	Vitamin B1 (mg)	Vitamin B2 (mg)	Vitamin C (mg)
Fresh leaf	7.35 ± 0.21^{d}	0.20 ± 0.02^{c}	0.07 ± 0.00^{c}	213.00 ± 4.24^{c}
Leaf powder	18.70 ± 0.14^{b}	2.68 ± 0.04^{b}	20.80 ± 0.12^{a}	16.55 ± 0.07^{c}
Green tea	8.12 ± 0.17^{c}	0.11 ± 0.01^{d}	9.60 ± 0.56^{b}	8.25 ± 0.07^{d}
Black tea	20.37 ± 0.03^{a}	2.85 ± 0.02^{a}	21.46 ± 0.04^{a}	76.40 ± 2.68^{b}

values represents Mean±SD (n = 3). Mean values within each column followed by different superscript letter significantly ($p< 0.05$) differ

Table 3: Mineral composition of *Moringa* leaves and tea samples (dry weight basis)

Samples	Calcium (mg)	Phosphorus (mg)	Iron (mg)
Fresh leaf	465.50 ± 7.77^{d}	74.80 ± 0.28^{d}	8.23 ± 0.04^{d}
Leaf powder	1982.00 ± 3.53^{c}	216.10 ± 1.27^{c}	27.55 ± 0.06^{c}
Green tea	2039.00 ± 0.00^{b}	220.00 ± 0.00^{b}	30.30 ± 0.56^{b}
Black tea	2057.50 ± 3.53^{a}	225.00 ± 1.41^{a}	32.15 ± 0.21^{a}

Values represents Mean±SD (n = 3). Mean values within each column followed by different superscript letter significantly ($p<0.05$) differ

Phytochemical composition of *Moringa* leaf tea samples, fresh and powdered leaves: The phytochemical composition of the *Moringa* black tea, green tea, powdered and fresh leaves is shown in Table 4. According to Fahey (2005), phytochemicals are chemicals produced by plants and also refer to only those chemicals which may have an impact on health, or on flavour, texture, smell or colour of the plants but are not required by humans as essential nutrients. From the result, significant ($p<0.05$) differences existed among all the samples. The powdered *Moringa* leaf sample had the highest flavonoid content (16.50%), followed by green tea fresh *Moringa* leaf sample which had the least flavonoid content (6.00%). Green *Moringa* tea contains higher flavonoid content than black tea. Flavonoids, which are many in number, are strong anti-oxidants, also found to be effective antimicrobial substances. They have been reported to possess substantial anti-carcinogenic and anti-mutagenic activities due to their antioxidant and anti-inflammatory properties (Havsteen, 2002). They are also active in reducing high blood pressure (Kasolo *et al*., 2010). Saponin is the glucoside component referred to as "Natural detergent" because of their foamy nature. The leaves of *Moringa oleifera* are utilized as soap by some communities in Uganda because of the presence of saponins that form froth and act as soap (Kasolo *et al*., 2010). According to Davies (1991), saponins have anti-carcinogenic properties, immune modulation activities and regulation of cell proliferation as well as health benefits such as inhibition of the growth of cancer cells and cholesterol lowering activity. Powdered *Moringa* leaves had a highly significant ($p<0.05$) saponin content (5.50%), while green *Moringa* tea leaf had the lowest saponin content (2.25%). There was no significant ($p>0.05$) difference between saponin content of green *Moringa* tea and that of fresh leaf. For steroid, powdered *Moringa* leaf had the highest content of steroid (5.05%) that was significantly ($p<0.05$) different from other samples. Black *Moringa* tea had a steroid content of 4.00%, while fresh *Moringa* leaf sample had the least steroid content (1.05%). The terpenoid content powdered *Moringa* leaf had the highest terpenoid content, which could be attributed to shade drying, as it was not given any other treatment. The terpenoid contents of all the samples were generally low. However, there was no significant ($p>0.05$) difference between fresh *Moringa* leaf and black *Moringa* tea samples, in terms of their terpenoid contents. According to Kasolo *et al*. (2010), terpenoid and steroid present in *M. oleifera* leaves are active against bacteria such as staphylococcus aureus and capable of preventing cancer.

Effect of processing on some anti-nutritional composition of *Moringa oleifera* tea samples: The anti-nutritional composition of *Moringa* black tea, green tea, powdered and fresh leaves is shown in Table 5. When any type of tea leaf is steeped in hot water it brews a "Tart"

Table 4: Phytochemical composition of *Moringa* leaf and tea samples (dry weight basis)

Samples	Flavonoid (%)	Saponin (%)	Steroid (%)	Terpenoid (%)
Fresh leaf	11.00±0.00^{b}	3.50±0.00^{b}	3.00±0.01^{c}	1.05±0.00^{b}
Leaf powder	16.50±0.00^{a}	5.50±0.01^{a}	5.05±0.00^{a}	1.23±0.00^{a}
Green tea	6.50±0.01^{c}	2.25±0.00^{c}	4.00±0.00^{b}	0.70±0.65^{c}
Black tea	6.00±0.15^{d}	3.50±0.07^{b}	1.05±0.07^{d}	0.75±0.01^{c}

Values represents Mean±SD (n = 3). Mean values within each column followed by different superscript letter significantly ($p<0.05$) differ

Table 5: Anti-nutritional composition of *Moringa* leaf and tea samples (dry weight basis)

Samples	Tannin (%)	Phytate (%)	Cyanide (%)	Alkaloid (%)
Powdered *Moringa* leaf	1.320±0.00^{a}	3.120±0.05^{a}	2.00±0.07^{a}	2.20±0.04^{a}
Green *Moringa* tea	0.650±0.07^{b}	2.040±0.00^{c}	1.50±0.07^{c}	0.65±0.00^{c}
Black *Moringa* tea	1.240±0.02^{a}	1.050±0.02^{b}	0.80±0.00^{b}	0.95±0.07^{b}
Fresh *Moringa* leaf	0.227±0.01^{c}	0.950±0.02^{d}	0.55±0.02^{d}	1.00±0.00^{b}

Values represents Mean±SD (n =3). Mean values within each column followed by different superscript letter significantly ($p< 0.05$) differ

Table 6: Total viable count and mould count of *Moringa* leaf and tea samples

Sample	Total viable count (CFU g^{-1})	Mould count (CFU g^{-1})
Black *Moringa oleifera* leaf tea	1.34×10^{2}	-
Powdered *Moringa oleifera* leaf	1.63×10^{2}	5.0×10
Green *Moringa oleifera* leaf tea	8.0×10^{1}	-
Fresh *Moringa Oleifera* leaf	2.02×102	2.1×10

-: not present, TVC: Total viable count

(astringent) flavor that is characteristic of tannins, which is due to the presence of catechins and other flavonoids (Mohammed and Sulaiman, 2009). Powdered *Moringa* leaf and black *Moringa* tea samples had the highest tannin contents, which were not significantly ($p>0.05$) different from each other. Tannins are chemically distinct from other types of plant tannins such as tannic acid and tea extracts, which have been reported to contain no tannic acid inhibit the absorption of minerals, such as iron which may, if prolonged, lead to anaemia, if ingested in excessive quantities (Mohammed and Sulaiman, 2009). Osada *et al*. (1997) recommended drinking tea and coffee between meals, because foods rich in vitamin C are known to help in neutralizing tannin effects on iron absorption. Adding lemon juice to tea will reduce the negative effect of tannins in iron absorption as well (Mohammed and Sulaiman, 2009). However, adding milk to coffee and tea, has very little or no influence on the inhibitory effect of tannin (Dommgang *et al*., 1998). Powdered *Moringa* leaf sample had significantly ($p<0.05$) higher phytate content, when compared to other samples, while fresh *Moringa* leaf sample had the least phytate content (0.95%). The cyanide content of the samples ranged from 0.55-2.00% and was higher than the range 0.55-1.45% reported by Omah and Okafor (2015) for cookies made with 5-20% addition of cassava cortex. Powdered *Moringa* leaf sample had the highest cyanide content (2.00%) followed by green *Moringa* leaf tea (1.5%), while fresh *Moringa* leaf sample had the lowest cyanide content (0.55%). *Moringa oleifera* leaf sample also contain alkaloids which are nitrogen-containing naturally occurring compounds, known to posses antimicrobial properties, due to their ability to intercalate with DNA of microorganisms (Kasolo *et al*., 2010). The alkaloid content was high in powdered leaves (2.20%) and least in green tea leaves (0.65%), which can be attributed to the steaming treatment given to the leaves. No significant ($p>0.05$) difference was observed between *Moringa* black tea and fresh *Moringa* leaf samples.

Microbial profile of *Moringa* leaf products: The microbial profile of *Moringa* black tea, green tea, powdered and fresh leaves is shown in Table 6. Green *Moringa* leaf tea had the lowest total viable count (8.0×10^{1} CFU g^{-1}) which may be attributed to the steaming treatment given to the leaves. Fresh *Moringa* leaf sample had the highest TVC (2.02×10^{2} CFU g^{-1}). The high presence of microorganisms in the sample may be attributed to environmental contamination. The black and green *Moringa* teas did not have any mould growth in them, which may be because of the heat treatment given to them. While, the mould growth of powdered and fresh *Moringa* leaves were 5.0×10 and 2.1×10 CFU g^{-1}, respectively. The microbial levels detected in the teas were generally low and would still be reduced during tea brewing with hot water.

CONCLUSION

The results provide empirical basis for production of high quality herbal teas from leaves of plants other than that of *Camellia sinensis*. The moisture analysis conducted, clearly demonstrated that green *Moringa* tea leaves had the lowest moisture content, which will enhance the shelf stability of the products, if properly packaged. Green *Moringa* tea had high levels of protein and carbohydrate contents. The ash content of black *Moringa* tea leaf was highest when compared with other samples, thus indicating it as a good source of minerals. The black *Moringa* tea had the highest content of minerals when compared to other samples due to its high ash content. The *Moringa* black tea sample had high vitamin C content but that of fresh leaves was highest. The powdered *Moringa* leaves had the highest concentrations of phytochemicals, while *Moringa* teas had significant amounts of these phytochemicals. The microbial result revealed that there were no mould growths in black and green *Moringa* teas.

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