EFFECTS OF BLANCHING AND DEHYDRATION METHODS ON THE QUALITY OF MORINGA LEAF POWDER USED AS HERBAL GREEN TEA.

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DECLARATION

I hereby declare that this thesis is the result of my own work except references cited that have been duly acknowledged. It has never been submitted for the award of any degree.

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DEDICATION

This work is dedicated to my parents Mrs Christiana Saponmaah Tetteh and Mr. Moses Aryee Tetteh of blessed memory, and to my son Rophel Paditey Nii Tetteh Ashiakoley Asare.

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To God be the glory for how far he has brought me. He has been merciful and gracious to me throughout my life and I am forever grateful to Him.

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ABSTRACT

In order to determine the best processing and preservation method that will minimize nutrient loss of Moringa leaves used for the production of herbal tea, the effect of blanching and three different drying methods on the nutritional and physicochemical composition of *Moringa oleifera* and *Moringa stenopetala* were studied. Part of the harvested leaves (both species) was panellisted to steam blanching and part un-blanched, and three different drying methods (shade, solar and oven) applied. Parameters assessed were water insoluble ash (WIS), water soluble extractives (WSE), pH, stalks, β-carotene, light petroleum extractives (LPE), polyphenolics, proximate analysis, zinc and iron using standard methods. Sensory evaluation was also carried out to determine the best processing method resulting in best sensorial properties. Results revealed that among the three drying methods (solar, shade and oven), oven drying at 60 °C for 6hrs resulted in the best nutritional and physicochemical properties of the Moringa leaf powder. Blanching had variable effects on processed tea leaves with significant ($p \leq 0.05$) reductions in crude ash contents and a significant increase in β-carotene, fibre, WIS and pH values in both species. Sensory results showed that tea infusions of blanched and oven-dried leaf powder infusions received significantly higher sensory scores. Results also revealed that Moringa herbal green teas (mean scores ranging between 6.47 and 7.73) were preferred to the commercial green tea (mean score 5.87). It is therefore evident that different methods of processing could have an effect on the nutritional, physicochemical and sensorial properties of Moringa leaves and the overall acceptability by consumers.

KNUST

TABLE OF CONTENTS

Title Page

KNUST

KNUST

LIST OF FIGURES

Figure		Page

KNUST

KNUST

LIBRARY
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SCIENCE AND TECHNOLOGY
KUMASI-GHANA

LIST OF TABLES

KNUST

NYANSAPƆ WƆSANE NO BADWENMA

CHAPTER ONE

1.0 INTRODUCTION

Moringa (*Moringa* spp.) belongs to a monogeneric family, the *Moringaceae*. Cited as one of the world's most useful plants, it is a widely cultivated fast-growing tree and has become naturalized in many locations in the tropics (Fahey, 2005; Palada and Chang, 2003). Moringa leaves are edible and are of high nutritive value. It is consumed throughout West Africa as well as some Asian countries (Fuglie, 2001). It has been reported that ounce-for-ounce, Moringa leaves contain more vitamin A than carrots, more calcium than milk, more iron than spinach, more vitamin C than oranges, and more potassium than bananas, noting that the protein quality of Moringa leaves rivals that of milk and eggs. Moreover, total protein digestibility of these leaves is high (85 % to 90 %) and its amino-acid composition corroborates with the FAO reference protein for growing child. The leaves are also free of anti-nutritive factors such as phenols, tannins and saponins (Fuglie, 2001). Currently, the nutritional value of Moringa are well known that there seems to be little doubt of the substantial health benefit to be realized by consumption of Moringa leaf powder in situations where starvation is imminent. Nonetheless, the outcomes of well controlled and well documented clinical studies are still of great value (Fahey, 2005).

In developing countries Moringa leaves are rarely processed. A relatively small quantity of harvested Moringa leaves are however, sun- or shade-dried resulting in products with variable moisture contents thus affecting storage stability (*Moringa Oleifera* "Miracle Tree", 2006; Pere, 2007). Additionally, reports have proven that sun-dried vegetables have inferior colour, texture and acceptability compared with vegetables dried in the cabinet drier (Onayemi and Badifu, 1987). For Moringa leaves with very high moisture contents, dehydration results in considerable reduction in weight and bulk and consequent savings in storage and distribution costs. Also, unit operations that intentionally separate the component of foods alter the nutritional qualities of each fraction compared with the raw material. Fellows (1990) reported that blanching which is an important pre-processing heat-treatment of vegetable destined for freezing, canning or dehydration inevitably causes separation and loss of water soluble nutrients such as minerals, water soluble vitamins and sugars. According to Fellows (1990), blanching at 88°C stops all life processes, inactivates enzymes, fixes green colour and removes certain harsh flavours common in vegetables. Thus it is evident that different methods of processing could have an effect on the sensorial properties of Moringa leaves and the overall acceptability by consumers.

Recently, in Ghana, Moringa leaf products especially leaf powder are becoming increasingly popular because of its outstanding indigenous nutritive value. However, limited studies have been documented on the effects of processing and preservation on the nutritional, physicochemical and sensory characteristics of these products. One of such products is Moringa herbal tea. It has been noted that good practices in tea production and post harvest technology can be a good indication of how to handle Moringa leaves (Sauveur, 2006). The leaves of Moringa are fragile and high in moisture content, which is responsible for their rapid deterioration. Additionally, processing difficulties have lead to loss of nutrients in Moringa leaves and poor quality products. Thus in an attempt to extend post harvest useful life span and to optimize conditions in the production of Moringa herbal green tea, the objectives of this study is to determine the effect of blanching and three drying (preservation) methods that is;

solar-, oven- and shade- drying on the nutritional, physicochemical and sensorial properties of herbal green tea from two species of Moringa: *Moringa oleifera* and *Moringa stenopetala*.

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CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 PRE-TREATING VEGETABLES TO ENHANCE QUALITY AND SAFETY

Pre-treating fresh produce by blanching (scalded in boiling water or steam for a short time) is recommended to enhance the quality and safety of dried vegetables. Most fresh produce especially vegetables need to be blanched before drying, freezing, canning or packaged for storage. A few vegetables such as mushrooms, okra, and onions do not need to be blanched before drying (Keith, 1984; Osaki and Gavranich, 1999). The heat from blanching helps slow or stop the enzyme activity that can cause undesirable changes to reduce quality, which preservation methods such as drying cannot stop. Enzymes destroy the colour, flavour, texture and nutritive value during drying and storage, if vegetables are not blanched (Osaki and Gavranich, 1999). According to Fellows (1990), blanching at 88°C stops all life processes, inactivates enzymes, fixes green colour and removes certain harsh flavours common in leafy vegetables.

Additionally, studies have shown that pre-treating vegetables by blanching in boiling water or steam enhances the destruction of potentially harmful microorganisms on the surface of the vegetable during drying, including *Escherichia coli* O157:H7, *Salmonella* species and *Listeria monocytogenes*. Blanching also protects certain nutrients in the produce such as vitamins. For instance, Subadra *et al.* (1997) cited that blanching enhances the retention of β-carotene, strengthening the view of Fellows (1997) and DeMan (1990) that blanching reduces vegetable β-carotene predisposition to destruction. It is also known that β-carotene is not heat sensitive and thus is not destroyed by most methods of cooking except frying at high temperatures around 180ºC (Fuglie, 2005). Blanching also relaxes tissues of produce thus reduces the drying time, which is supported by Greve *et al.* (1994) and Waldron *et al.* (2003) who showed that cells in produce loose their wall integrity when blanched and thus bound water is lost faster during drying than when un-blanched. Another effect of blanching is that it makes some vegetables such as broccoli or spinach more compact, and reduces the time needed to refresh vegetables before cooking (Osaki and Gavranich, 1999; Kendall *et al*., 2004).

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Fellows (1990), however, reported that though blanching is an important pre-processing heat-treatment of vegetables, it inevitably causes separation and losses of water soluble nutrients such as minerals, water-soluble vitamins and sugars. Steam blanching takes more time, but fewer water-soluble nutrients are lost. To minimize the loss of nutrients, blanching is done only for the required length of time. However, it is necessary that food produce are not under-blanched; the enzymes will not be inactivated, and the quality of the dried foods will be inferior (Osaki and Gavranich, 1999).

Blanching is done by exposing fresh produce to boiling water or steam for a brief period of time. The vegetable must then be rapidly cooled in ice water or by use of evaporative cooling to prevent it from cooking. The quality of water used to blanch vegetables can have an effect on the texture of certain vegetables. Very hard water can cause the toughening of vegetables such as green beans (Osaki and Gavranich, 1999).

2.1.1 TYPES OF BLANCHING PROCESS

There are different types of blanching some of which are blanching in boiling water, steam blanching and microwave blanching. Blanching in boiling water requires a large kettle with a tight-fitting lid. For leafy greens, two gallons can be used per pound. Water is boiled and wire basket, blanching basket or mesh bag containing vegetable is fully immersed. Kettle is covered and boiled at top heat for the required length of time. Counting of time begin as soon as the water returns to a boil. The same blanching water may be used two or three times, keeping water at the required level. The water could be changed if it becomes cloudy. It is important to chill vegetables immediately after blanching. This can be done by plunging the basket of vegetables into pans of ice water for the same time used for blanching water. The water must be kept cold by changing frequently or by adding ice. Vegetables are then drained thoroughly, ensuring the removal of extra water, which will form too many ice crystals. Another chilling method is evaporative cooling. Vegetables are spread in a single layer in front of a fan. As the water evaporates, the vegetables are cooled. This chilling method does not add water to the vegetables. The result is often a less mushy product. With either method, the centre of a piece of food must be checked to be sure it is cool. Vegetables must never be packaged warm (Osaki and Gavranich, 1999).

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W J SANE NO BADWE

Blanching by steam is done by boiling water in a pan and placing the blanching basket over the pan such that only the steam generated from the boiling water is in contact with the vegetables, and the pan tightly covered with a lid. The blanching basket must cover the pan fully to prevent the steam from escaping into the atmosphere. If they are leafy vegetables ensure even and thin spreading of leaves in

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SCIENCE AND TECHNOLOGY
KUMASI-GHANA

the blanching basket. The basket is then removed from the steam after the time scheduled for blanching. Evaporative cooling is the best method of cooling for this form of blanching; this chilling process will not add water to the vegetables (Keith, 1984; Osaki and Gavranich, 1999). Vegetables are then ready to be canned, frozen or dehydrated (dried). However, Kendall *et al.* (2004) reported that water blanching is recommended over steam blanching or blanching in a microwave because water blanching achieves a more even heat penetration than the other two methods.

2.2 DRYING OF VEGETABLES

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Drying of agricultural products is the oldest and widely used preservation method. It involves reduction in as much water as possible from foods to arrest enzyme and microbial activities hence stopping deterioration. Moisture left in the dried foods varies between 2-30% depending on the type of food. In tropical countries, solar dryers can be used to dry fresh produce when average relative humidity is below 50% during drying period (Fruit and vegetable drying, 2008). Drying lowers weights and volume of the product hence lowers costs in transportation and storage. However, drying allows some lowering in nutritional value of the product, for example loss of vitamin C, and changes of colour and appearance that might not be desirable (Kendall *et al.*, 2004).

For a good-quality product, vegetables are prepared for drying as soon as possible after harvesting. They are blanched, cooled, and laid out to dry without delay. Foods should be dried rapidly, but not so fast that the outside becomes hard before the moisture inside has a chance to evaporate. Drying must not be interrupted. Once drying starts, the food must not be cooled down in order to start drying again later. Mould and other spoilage organisms can grow on partly dried foods.

2.2.1 TEMPERATURE REQUIREMENTS

During the first part of the drying process, the air temperature can be relatively high, that is, 150°F to 160°F (65°C to 70°C), so that moisture can evaporate quickly from the food. Because food looses heat during rapid evaporation, the air temperature can be high without increasing the temperature of the food. But as soon as surface moisture is lost (the outside begins to feel dry) and the rate of evaporation slows down, the food warms up. The air temperature must then be reduced to about 140°F (60°C). Toward the end of the drying process the food can scorch easily, so it must be watched carefully. Each vegetable has a critical temperature above which a scorched taste develops. The temperature should be high enough to evaporate moisture from the food, but not high enough to cook the food. Carefully follow directions for regulating temperatures (Keith, 1984).

2.2.2 HUMIDITY AND VENTILATION

Rapid dehydration is desirable. The higher the temperature and the lower the humidity, the more rapid the rate of dehydration will be. Humid air slows down evaporation. If drying takes place too fast, however, "case hardening" will occur. This means that the cells on the outside of the pieces of food give up moisture faster than the cells on the inside. The surface becomes hard, preventing the escape of moisture from the inside. Moisture in the food escapes by evaporating into the air. Trapped air soon takes on as much moisture as it can hold, and then drying can no longer take place. For this reason, there must be adequate ventilation around the oven or in the food dryer (Keith, 1984).

2.2.3 EFFECTS OF DRYING ON THE NUTRITIVE VALUE OF VEGETABLES

Vegetables that are practical to dry include peas, corn, peppers, zucchini, okra, onions, green beans and leafy vegetables. They are a good source of minerals and the B vitamins thiamine, riboflavin, and niacin. They also provide useful amounts of the fibre (bulk) the body needs. Drying, like all methods of preservation, can result in loss of some nutrients. Effects of drying on the nutritive value of vegetables include:

- Calorie content: does not change, but is concentrated into a smaller mass as moisture is removed.
- Fibre: no change.
- Thiamin, riboflavin, niacin: some losses during blanching but fairly good retention if the water used to rehydrate also is consumed.
- Minerals: some may be lost during rehydration if soaking water is not used. Iron is not destroyed by drying (Kendall *et al*., 2004).
- Vitamin A: fairly well retained under controlled heat methods.
- Vitamin C: mostly destroyed during blanching and drying of vegetables.

Pro-vitamin A and vitamin C are especially prone to oxidative destruction in the presence of heat, light, oxygen, enzymes, moisture and metal ions. Thus sun drying causes marked losses in these vitamins due to exposure of the drying vegetables to greater solar radiation particularly ultra violet (UV) rays, which catalyses β-carotene oxidation leading to loss of vitamin activity (Tannenbaum *et al*., 1985; McDowell,

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1989; Berry, 1993; Ndawula *et al.*, 2004). For best retention of nutrients in dried foods store in a cool, dark, dry place and use within a year.

2.2.4 SUCCESSFUL DRYING

The drying process is simply not as precise as canning and freezing because it involves so many different factors. A trial-and-error approach is often used to find suitable drying process for a particular type of food. Whatever method is used, however, it must remove enough moisture from the final product so that spoilage organisms cannot grow. Cleanliness and sanitation are essential factors to consider when drying.

Drying the food evenly to attain successful drying takes a little extra effort and attention. Stirring the pieces of food frequently and shifting the racks in the oven or dryer are essential because heat is not the same in all parts of the dryer. For the best results, spread thin layers of uniformly-sized pieces of food on the drying racks (DeLong, 1979). Table 2.1 shows steps for successful drying of vegetables.

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Table 2.1: Steps for drying some vegetables.

Vegetable	Preparation	Blanching Time* (mins.)	Drying Time (hrs.)	Dryness test
Asparagus	Wash thoroughly. Halve large tips.	4-5	6-10	Leathery to brittle
Broccoli	Wash. Trim, cut as for serving. Quarter stalks lengthwise.	4	12-15	Crisp, brittle
Cabbage	Wash. Remove outer leaves, quarter and core. Cut into strips 1/8" thick.	4	10-12	Crisp, brittle
Cauliflower	Wash. Trim, cut into small pieces.	4-5	12-15	Tough to brittle
Celery	Trim stalks. Wash stalks and leaves thoroughly. Slice stalks.	4	10-16	Very brittle
Horseradish	Wash, remove small rootlets and stubs. Peel or scrape roots. Grate.	None	6-10	Brittle, powdery
Parsley, other herbs	Wash thoroughly. Separate clusters. Discard long or tough stems.	4	4-6	Flaky
Spinach, greens like Kale, Chard, mustard	Trim and wash very thoroughly. Shake or pat dry to remove excess moisture.	4	6-10	Crisp

* Blanching times are for 3,000 to 5,000 feet. Times will be slightly shorter for lower altitudes and slightly longer for higher altitudes or for large quantities of vegetables.
** **WARNING:** The toxins of poisonous varieties of mushrooms are **not** destroyed by drying or by cooking. Only an expert can differentiate between poisonous and edible varieties.

Source: Kendall *et al*., 2004

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2.2.5 EQUIPMENT

One of the advantages of drying foods rather than canning or freezing them is that no special equipment is required. A kitchen oven, drying trays or racks, and storage containers are the only basic equipment needed. For sun drying only racks and storage containers may be needed. Although the following equipments are not absolutely necessary, it will help in making a more uniformly good product:

- a food scale to weigh food before and after drying
- an electric fan to circulate the air
- a thermometer to check the oven temperature
- a blancher for vegetables

Wood slats or stainless steel screen mesh are the best materials to use for the racks. Cake racks or a wooden frame covered with cheesecloth or other loosely-woven cloth can also be used for drying racks. The use of solid metal trays or cookie sheets to dry food prevents air from circulating all around the food to allow drying to take place from the bottom and the top at the same time, thus must not be used. Racks made of galvanized screen, aluminium, copper, fibreglass, or vinyl must not be used. Galvanized screen contains zinc and cadmium. These metals cause an acid reaction that forms harmful compounds and darkens the food. Copper materials destroy vitamin C. Fibreglass may leave dangerous splinters in the food, and vinyl melts at temperatures used for drying (Keith, 1984).

2.2.6 TYPES OF DRYING METHODS

2.2.6.1 DEHYDRATORS

Thermostatically controlled electric dehydrators are recommended for home food drying. They are relatively inexpensive, convenient for drying large or small batches of food, and easy to use. The best dehydrators have thermostatically controlled heat settings and fans that blow warm air over the foods. Some models have a heat source at the bottom and removable, perforated trays (for air circulation) stacked above the heat source. Dehydrators should be used indoors in a dry, well-ventilated room. Food

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on lower trays near the heat source will often dry more rapidly than food on higher trays and, therefore, trays should be rotated throughout drying (Kendall *et al*., 2004).

2.2.6.2 OVEN DRYING

Oven drying is the simplest way to dry food because you need almost no special equipment. It is also faster than sun drying or using a food dryer. However, oven drying can be used only on a small scale. An ordinary kitchen oven can hold only 4 to 6 pounds of food at one time. To dry foods oven is set on the lowest possible setting and preheat to 140°F (60°C). The broiler unit of an electric oven must not be used, because the food on the top tray will dry too quickly. The unit is removed, if it has no separate control. Some gas ovens have a pilot right, which may keep the oven warm enough to dry the food. It is important to keep the oven temperature at 140 to 160°F (60 to 70°C). Thus an oven thermometer can be inserted on the top tray about half way back where you can see it easily, to help check the temperature about every half hour (Keith, 1984; Kendall *et al*., 2004).

About 1 to 2 pounds of prepared food is arranged in a single layer on each tray and one tray put on each oven rack. Spacing of 1-1/2 inches is allow on the sides, front, and back of the trays so that air can circulate all around them in the oven. A lighter load dries faster than a full load. The oven door is opened slightly during drying. An electric fan placed in front of the oven door helps to keep the air circulating. Food scorches easily toward the end of drying time; therefore, heat turned off when drying is almost complete and the door widely opened for an additional hour or so. Vegetables take from 4 to 12 hours to dry. The length of time depends on the kind and amount of food being dried, the method used (oven or food dryer), and the drying temperature (Keith, 1984; Kendall *et al*., 2004).

KNUST

2.2.6.3 SUN DRYING

Sun drying is the old-fashioned way to dry food because it uses the heat from the sun and the natural movement of the air. But bright sun, low humidity, and temperatures around 100 °F are necessary. This process is slow and requires a good deal of care. The food must be protected from insects and covered at night (Keith, 1984). Sun drying is not as sanitary as other methods of drying. An improved indirect solar dryer used recently, a natural-draft dryer, is a rectangular shaped box dryer with two chamber for heating and drying respectively. The two chambers have clear glass tops or on the side. The dryer is also painted black for better heat absorption (Fruit and vegetable drying, 2008).

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Drying of leafy vegetables requires that leaves are selected and washed thoroughly in clean water. The leaves are chopped (finely chopped vegetables dry faster, but may loose more vitamins) and blanched for required time schedule. The leaves are cooled to avoid overcooking and spread on the trays of the dryer in thin layers. The drying chamber has movable trays that can be removed, loaded on to the chamber and shifted during drying. The shifting of trays ensures even drying. Over heating during drying is controlled by increasing ventilation by opening the rear windows of the dryer. The rear windows are closed when temperature drops more than 20°F. Dew and sudden temperature change put moisture back into the food and lengthen the drying time. Vegetables take 3 to 7 days to dry in the sun. The length of time depends on the type of food and the atmospheric conditions. Natural heat is slower and less dependable than controlled drying in an oven or food dryer. For better drying the dryer is rotated on its stand to face the direction of the sun. The advantage of this kind of dryer is that it hastens drying by trapping heat from the sun. It also

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protects the food from insects and birds (Fruit and vegetable drying, 2008; Keith, 1984).

2.2.6.4 SHADE DRYING

Some vegetables especially leafy vegetables and herbs are not sun dried because light destroys the natural aroma and certain nutrients such as ß-carotene and vitamin C, resulting in poor-quality product. Prepared leaves are placed on a tray in a warm, dry, airy place away from direct sunlight. For best results, a doth-covered rack or an open mesh screen is used. Leaves are turned or stirred occasionally to assure even drying (Keith, 1984).

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Air drying is not as satisfactory as oven drying, because the temperature cannot be controlled and is usually low. Also, the produce may be exposed to insanitary conditions from dirt in the air. Outdoor drying may invite unwanted guests such as dogs, cats, wild animals, and insects. If practical, produce may be covered loosely with cheesecloth to prevent contamination (Keith, 1984).

2.3 TYPES OF TEA

Teas are generally classified according to their colour, which is due to the processing procedure. Based on this, Kirk and Sawyer (1997) classified teas into three types namely, Black tea, Green Tea and Oolong tea Apart from the country of origin and the individual garden marks, teas are usually graded as Orange Pekoe, Broken Orange Pekoe, Broken Orange Pekoe Fannings, Pekoe, Broken Pekoe, Broken Pekoe Souchong, Fannings and Dust. The terms Pekoe and Orange refer to the young leaf. These teas contain a good portion of tips, which are the small golden pieces of leaf bud from the tip and shoot. Fannings have a smaller particle size and are often used in tea bags (Kirk and Sawyer, 1997)

2.3.1 TEA PRODUCTION

A similar process is engaged in the production of almost all tea types. The leaves are handpicked from the farms, transported to the production house where they are washed, and allowed to go through four principal stages i.e. withering, rolling, fermentation and firing (Kirk and Sawyer, 1997). After the leaves have been washed they are then subjected to exposure on rocks to soften the leaf, this is done so that at the next stage (rolling) the leaves will be softened enough to allow for rolling and also to activate the inherent polyphenol oxidases to start fermentation in the next two stages. In the preparation of green tea, the withering stage is done at a high temperature, so that the enzymes are destroyed.

The leaves are then rolled in a roller; this ruptures the cells of the leaves and releases the juice for the fermentation process. It allows the binding of the enzyme with its substrate (polyphenols) contained in the juice. At this stage the fermentation process begins, though to a lesser extent. For the green tea, when the rolling is done, fermentation does not occur at this stage, because the enzymes polyphenol oxidase present in the leaves, which causes browning by oxidizing the phenolics when the leaves are bruised, are inactivate. When the leaves are rolled it allows for quick drying (Kirk and Sawyer, l997).

Fermentation is done at 27°C, which is the optimum temperature for the enzymes to act, for about three (3) days (Kirk and Sawyer, 1977). At this point the enzyme,

KNUST

polyphenol oxidase, catalyses the conversion of the phenols specifically *o*-cresol to 4- methyl-*o*-benzoquinone, which is unstable and undergoes further non-enzyme-catalysed oxidation by O_2, and polymerization to give melanins. This is responsible for the desirable brown and black colours of teas (Whitaker, 1996). This stage is omitted in the preparation of green tea (Kirk and Sawyer, 1997).

The last stage, being the firing stage is done immediately after fermentation. At this stage, the fermented leaves for black or brown tea, partially fermented leaves for oolong tea and unfermented leaves for green tea are passed through hot dry air, for the drying of the leaves. Hot air is used because, it allows for the denaturing of the enzyme for fermentation and quick drying of the leaves (Kirk and Sawyer, 1997). The leaves are then milled, packaged into non-drip tea bags and then stored for consumption.

2.3.2 QUALITIES OF TEA

The main constituents of tea are moisture, tannin, nitrogenous matter (including caffeine), oil, wax, inorganic matter (especially potassium salts) and fibre (Kirk and Sawyer, 1997). Several types of carotene exist in tea leaves and β-carotene is the most prevalent (22mg %). Reports (www.greentealovers.com, 2007) indicate that carotene content is high in quality teas. The constituents of importance regards with the overall flavour of tea are caffeine, tannins and volatile oil. In good teas the ratio of caffeine to tannin is about 1:3. The flavour of tea is dependent on a number of volatile substances present such as terpenoids and sulphur containing compounds, fatty acids, alcohols esters and carbonyl compounds. Over 80 compounds have been identified using gas chromatography and there is little evidence of which ones have

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the greatest organoleptic significance. Volatile flavour components have been associated with the degradation of lipids during processing (Kirk and Sawyer, 1997).

Color is one of the determinant sensory qualities for green tea. Wang *et al.* (2004) reported that certain compounds contribute to the green nature of dry tea leaves as well as infusion. It was observed that chlorophylls were influential for the colour of the dry tea leaves and water-insoluble chlorophylls released from the fragile tea leaves during infusion increased both the green colour and turbidity of tea infusions. They also observed that among the flavonoids (catechins and flavonols) detected in green tea infusions, quercetin was the most important phenolic compound contributing to the green nature of tea infusion. It has been cited (www.teainfusion.com/types/greentea.html, 2006) that green tea rarely brews as green - rather, the name refers to the colour of its leaves, which are green. Green tea usually has a yellow appearance when brewed, whereas herbal infusions have pale yellow to dark golden colour. The tea may have a yellow-greenish appearance when water is first poured. It has been reported that processing and storage can have effects on the flavanols and sensory qualities of green tea extract. Wang *et al.* (2000) investigated this by subjecting fresh tea leaves to steam and roasted the green teas by commercial methods. Thereafter, infusion was extracted and processed at 121 °C /1 min and then stored at 50 °C to accelerate chemical reactions. Changes were observed in flavanol composition and sensory qualities of green tea extracts. The outcome was that among eight major flavanols (catechin, epicatechin, gallocatechin, epigallocatechin, epicatechin gallate, catechin gallate, epigallocatechin gallate, and gallocatechin gallate), as identified in the processed tea extract, epigallocatechin gallate and epigallocatechin appeared to play the key role in the changes of sensory qualities of processed green tea beverage. Hence steamed tea leaves produced desired quality of processed green tea beverage than the roasted products (Wang *et al.*, 2000).

Astringency is caused by four different classes of chemicals. Two of these, polyphenols and acids, are found in both Moringa and *Camellia sinensis* (Duke, 1983; www.greentealovers.com, 2007; www.leafpowder.wordpress.com, 2008). The astringency of polyphenols and tannins is understood to result from their combination with salivary proline-rich protein (PRP); the resulting complexes are insoluble and their formation removes from solution the PRPs, which ordinarily provide lubrication in the mouth. This results in the sensation of astringency. The manner in which these interact to create and influence astringency is only partially understood. Acids alone in water are also astringent and they have been shown to increase the astringent sensation of polyphenols (Siebert, 2005).

While astringency is a natural part of the overall flavour of many foods, it can be strong enough to be unpleasant for example, in persimmons, tamarinds, some red wines and in green tea where tannin is mostly catechin and is a key component in its taste providing the astringency (Siebert, 2005; www.greentealovers.com, 2006). The amount of catechin tends to increase as the season progresses. If leaf order is compared, younger leaves include more catechin than mature ones (www.greentealovers.com, 2006). Similar to catechin, young tea buds contain higher amounts of caffeine than mature buds. A cup of green tea contains about 15 to 30 mg of caffeine, which is an important quality in green tea, providing bitterness. Studies (www.greentealovers.com, 2006) have shown that caffeine is released as a gas from solid substances when heated, thus teas roasted for processing in high temperatures are low in caffeine content.

There are about 20 different types of amino acids in tea. More than 60% of these amino acids consist of theanine, which is unique to green tea, because the steaming process does not eliminate it. Theanine has a similar structure to glutamine providing an elegant taste and sweetness in green tea. L-theanine is a healthy amino acid that is only found in tea plants and certain mushrooms. There are more significant amounts of amino acids contained in early-crop tea and are abundant in tea buds. The content of amino acids is significantly lower in mature buds (www.greentealovers.com, 2006).

2.3.3 COMPOSITION OF A GREEN TEA BEVERAGE

A good quality tea seldom has moisture content in excess of 7%. Tea with moisture in excess of 11% is liable to go mouldy and consequently produce a musty infusion. Thus percentage moisture should range from 6.1%-9.2%. Kirk and Sawyer (1997) also mentioned that total ash should not exceed 7% and that values for green tea should range from 5.2%-7.2%. Water-soluble ash values ranges between 2.6% and 4.1%, and that of crude fibre values should range from 9%-15%. Accordingly, proportion of stalks should preferably be below 25% (Kirk and Sawyer, 1997).

2.4 BENEFITS OF GREEN TEA

2.4.1 COMPONENTS OF GREEN TEA – POLYPHENOLS AND CATECHINS

Polyphenols in green tea are responsible for the health benefits (www.greentea.com, 2006). More specifically, certain catechins found in tea are believed to be the most powerful. The catechins in green tea make up a large percentage of the total amount of polyphenols. Catechins, especially epigallocatechin gallate (EGCE) are believed to provide the most protection. The level of polyphenols and catechins in green tea can vary depending on growth conditions, quality of the leaf and brewing methods. The following approximates the amount in a cup of green tea; the percentages are measured in percent weight of extract solids of a green tea beverage: total polyphenols ranges from 37% to 56% of green tea solids, total catechins ranges from 30% to 42% of green tea solids and main catechin EGCG ranges from 10% to 13% of green tea solids (www.greentea.com, 2006).

Mitscher (1997) reported that green tea contains the strongest of any known form of antioxidants. It was noted that catechin in green tea called epigallocatechin gallate (EGCG), was 100 times more effective at neutralizing free radicals than vitamin C, and 25 times more powerful than vitamin E - both are well known antioxidants. EGCG also ranked above other antioxidants, such as Butylated Hydroxyanisole (BHA), Butylated Hydroxytoluene (BHT) and Resveratol (www.greenteaeffectsandhealth.com, 2006). Antioxidants are thought to prevent cellular damage that leads to certain diseases – especially cancer. Green tea contains, by far, the highest concentrations of active EGCG. The daily consumption of green tea needed for antioxidant effect has not been established, even though previous studies in China and Japan, where people customarily drink four (or more) cups per day has not been determined whether one cup per day is sufficient (Mitscher, 1997).

2.5 SIDE EFFECTS OF GREEN TEA

Side effects of tea may occur in people who are entero-sensitive. Heartburn, stomach irritation, loss of appetite, and diarrhea could result from drinking large amounts of green tea. The presence of caffeine could cause side effects such as: nervousness, insomnia, diabetes, hypertension and tachycardia. Caffeine has also been found to cause sleeplessness (www.farsinet.com, 2007). However, it has been reported that an amino acid called L-theanine helps our immune system by fighting off ailments and also counteracting the effects of caffeine. The L-theanine within the tea has been shown to suppress the jittery effects of caffeine. The amino acid actually relaxes the body without making one feel sleepy and drowsy (www.health.ninemsn.com, 2007).

Leung (1980) reported that green tea infusion, once recommended in China as a curative of cancer, contains some tannin, suspected of being carcinogenic. The tannic acid in tea also decreases absorption of iron from foods. It has been proven that iron supplements taken with milk or tea can interfere with iron absorption because of the calcium and phosphorus in milk and the tannic acid in tea (www.farsinet.com, 2007).

Moringa leaves, however, contain no anti-nutritive factors such as phenols, tannins and saponins and have not yet been associated with toxic compounds (Fuglie, 2001).

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Thus tea produced form Moringa leaves in terms of anti-nutritive factors will have no adverse effects on its consumers.

2.6 TWININGS EARL GREY GREEN TEA

Twinings is one of the best quality leaf teas that can be found. Twinings green tea has been described as a revelation for people looking for a healthy yet great-tasting drink. It is a natural source of antioxidants that may help protect the body from damage caused by free radicals, and is naturally low in calories when served without milk or sugar. These characteristics make green tea an ideal accompaniment for people wanting a healthy lifestyle today (www.twinings.com, 2006).

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In the manufacture of Twinings green tea plucking the leaves is a procedure of considerable skill. Tea pluckers learn to recognise the exact moment at which the flush should be removed, thus ensuring that the tenderest leaves are plucked to produce the finest teas (www.twinnings.com, 2006). The omission of oxidation process in the tea production, allow the tea to remain green in colour and retain its very delicate flavour. The non-oxidation of the freshly picked leaves is assured either by pan drying or steaming the leaves to kill active enzymes in the leaf before rolling. This prevents the air from interacting with any of the enzymes in the leaf, so no oxidation takes place. This manufacturing process is similar to what was described by Kirk and Sawyer (1997). There are two main strains of tea plant (otherwise known as tea bush) that are used in Twinings tea production, each with their own particular characteristics. These are *Camellia sinensis* and *Camellia assamica.*

2.7 COMPOSITION OF *CAMELLIA SINENSIS*

Duke (1983) reported that fresh leaves from Assam contain 22.2% polyphenols, 17.2% protein, 5.6% ash, 27.0% crude fibre, 2.0% ether extract. Per 100 g, the leaf is reported to contain 293 calories, 8.0 g H_2O, 24.5 g protein, 2.8 g fat, 58.8 g total carbohydrate, 8.7 g fibre, 5.9 g ash, 327 mg Ca, 24.3 mg Fe, 2700 μg beta-carotene equivalent. Another report tallies 300 calories, 8.0 g H_2O, 28.3 g protein, 4.8 g fat, 53.6 g total carbohydrate, 9.6 g fibre, 5.6 g ash, 245 mg Ca, 8400 μg beta-carotene equivalent. Yet another (Duke and Atchley, 1984) gives 299 calories, 8.1 g H_2O, 24.1 g protein, 3.5 g fat, 59.0 g total carbohydrate, 9.7 g fibre, 5.3 g ash, 320 mg Ca, 31.6 mg Fe, and 8400 μg beta-carotene equivalent.

2.8 MORINGA

The *Moringaceae* dumort is a mono-generic genus plant family with 14 species of Moringa trees. *Moringa oleifera*, is a drought tolerant tree, and is the best-known member of this family. It is native to sub-Himalayan regions of northern India and is distributed all over the world in tropics and sub tropics. The *Moringa oleifera Lamarck* was named by Swedish biologist Carl Linaeus in the 1700s. *Moringa stenopetala*, which produces larger seed and leaves than *M. oleifera*, inhabits Ethiopia and northern Kenya. *Moringa stenopetala* seeds have better water purifying properties than *Moringa oleifera* (www.avrdc.org/LC/indigenous/Moringa, 2006). *M. peregrina* is native in Egypt, Sudan, and the Arabian Peninsula and as far north as the Dead Sea. *M. ovalifolia* is found in Angola and Namibia (www.Moringanews.org/documents/Nutrition, 2006).

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The other species of this genus are *Moringa arborea, M. borziana, M. concanensis, M. drouhardii, M. hildebrandtii, M. longituba, M. pygmaea, M. rivae, M. ruspoliana*. Of these species, *Moringa oleifera* L is synonymous with *Moringa pterygosperma Gaertn*. (Maroyi, 2006). Mostly, the Moringa species are located in Africa, Arabia, Southeast Asia, the Pacific and Caribbean Islands, South America and now in all other tropical and sub-tropical parts of the world where it easily thrives.

2.8.1 ORIGIN AND TAXONOMY OF *MORINGA OLEIFERA*

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Moringa oleifera Lam (syns. *M. pterygosperma* Gaertn., *M. Moringa* (L.) Millsp., *M. nux-ben* Perr., *Hyperanthera Moringa* Willd., and *Guilandina Moringa* Lam.), commonly referred to as the `drumstick tree' (describing the shape of its pods) or `horseradish tree' (describing the taste of its roots) grows throughout most of the tropics, and is native to the sub-Himalayan tracts of north-west India, Pakistan, Bangladesh and Afghanistan (Morton, 1991; Makkar and Becker, 1997). The Indians knew that the seeds contain edible oil and they used them for medicinal purposes. It is probable that the common people also knew of its value as fodder or vegetable. This tree can be found growing naturally at elevations of up to 1,000m above sea level and is now cultivated throughout the Middle East and in almost the whole tropical belt (Ramachandran *et al*. 1980; Odee, 1998).

Moringa was introduced in Eastern Africa from India at the beginning of 20^{th} century. In Nicaragua, the Marango (local name for *Moringa oleifera*) was introduced in the 1920s as an ornamental plant and for use as a live fence. The tree grows best and is most commonly found in the Pacific part of Nicaragua but can be found in forest inventories in every part of the country. As a non-cultivated plant it is known for its resistance to drought and diseases. The plant possesses many valuable properties which make it of great scientific interest. These include the high protein content of the leaves, petioles and stems, the high protein and oil contents of the seeds, the large number of unique polypeptides in seeds that can bind to many moieties, the presence of growth factors in the leaves, and the high sugar and starch content of the entire plant. Equally important is the fact that few parts of the tree contain toxins that might decrease its potential as a source of food for animals or humans.

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2.8.2 ORIGIN AND TAXONOMY OF *MORINGA STENOPETALA*

Northeast tropical Africa is a centre of endemism and diversity to the species *M. stenopetala*. *M. stenopetala* is a tree 6-10m tall; trunk: more or less 60cm in diameter at breast height; crown: strongly branched sometimes with several branches; thick at base; bark: white to pale grey or silvery, smooth; wood: soft; Leaves: up to 55cm long; Inflorescence: pubescent; flowered panicles: dense and about 60cm long (Mark, 1998).

The Genus follows the distribution pathway from Rajasthan to south West Africa (Africa, Madagascar and parts of Asia, including Arabia and India). The habitat where the species occur in Ethiopia includes: rocky areas along rivers, dry scrub land, Acacia-Commiphora woodland, water courses with some evergreens, Open Acacia-Commiphora bush land on grey alluvial soil and in cultivation around villages. *M. stenopetala* is cultivated in terraced fields, gardens and small towns. The species is found to grow in Keffa, Gamo Gofa, Bale, Sidamo, Borana and Debub

Omo zones, and in Konso and Dherashe especially Weredas (Mark, 1998). *M. stenopetala* is often referred to as the African Moringa Tree because it is native only to southern Ethiopia and northern Kenya. Though it grows in many other parts of the tropics, it is not as widely known as its close relative, *Moringa oleifera* but often considered, generally, more desirable than *M. oleifera* (Mark, 1998).

It is reported that the edible parts are exceptionally nutritious (Rams, 1994). The leaves are one of the best leafy vegetables ever found. All parts of the tree except the wood are edible, providing a highly nutritious food for both humans and animals. The flowers are a good nectar source for honey; can be eaten or used to make a tea and the seeds are rich oil sources for cooking and lubricant uses (Mark, 1998). Many parts of the plant have been used in medicinal preparations. The wood is very soft; useful for paper but makes low-grade firewood and poor charcoal. Attracting attention in recent decades is the use of the dried, crushed seeds as a coagulant (Jahn, 1984). Even very muddy water can be cleared when crushed seeds are added. Solid matter and some bacteria will coagulate and then sink to the bottom of a container. The cleaned water can then be poured off and boiled. Hundred (100) milligrams (about 1 to 1 ½ seeds) of crushed seed can be used to clean 1 litre of muddy water (Gupta and Chaudhuri, 1992).

2.9 HEALTH PROMOTING PHYTOCHEMICALS IN *MORINGA* LEAVES

2.9.1 NATURAL ANTIOXIDANTS

Vegetables as a group are useful sources of a number of nutrients including vitamin C, vitamin K, folate, thiamin, carotenes, several minerals and trace elements and dietary fibre. They are universally recognized to have a great nutritional value and form an essential part of a balanced human diet. There is a group of vitamins, minerals, and enzymes called antioxidants that help protect our body from the formation of free radicals. Free radicals are atoms or groups of atoms that can cause damage to our cells, impairing our immune system and leading to various chronic and degenerative diseases. Research implicates free radicals in development of a number of degenerative diseases, such as cancer and cardiovascular disease, cognitive impairment and Alzheimer's disease, immune dysfunction cataracts and macular degeneration. While the body has its defences against free radicals, they still have the potential to damage key components such as DNA, proteins and lipids (fats). Antioxidants are capable of stabilizing free radicals before they can cause harm. However, free radicals are also acknowledged to have beneficial roles (Bortz, 2001) in the body. Thus, free radicals and antioxidants must exist in balance. It is suggested that certain conditions, such as chronic diseases and aging, can tip the balance in favour of free radicals that cause ill effects.

Siddhuraju and Becker (1998) studied the antioxidant properties of various solvent extracts of total phenolic constituents from three different agro-climatic origins of drumstick tree (*Moringa oleifera* Lam.) leaves. Water, aqueous methanol and aqueous ethanol extracts of freeze-dried leaves of *Moringa oleifera* Lam. from different agro-climatic regions were examined for radical scavenging capacities and antioxidant activities. All leaf extracts were capable of scavenging peroxyl and superoxyl radicals. The major bioactive compounds of phenolics were found to be flavonoid groups such as quercetin and kaempferol. Both methanol (80%) and ethanol (70%) were found to be the best solvents for the extraction of antioxidant

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compounds from *Moringa* leaves. In all, based on the results obtained, Moringa leaves are found to be a potential source of natural antioxidants due to their marked antioxidant activity.

2.10 OCCURRENCE AND GENERAL PROPERTIES OF NATURAL ANTIOXIDANTS

Anti-oxidants naturally occur in many foods like tomatoes, corn, carrots, mangoes, sweet potatoes, broccoli, soybeans, cantaloupe, oranges, spinach, nuts, lettuce, celery, liver, fish oil, seeds, grains and tea (black and green). In general they neutralize free radicals in the body, maintain healthy vision and may reduce risk of cancer (Colon, Prostate, Skin) Cognitive Impairment, Immune Dysfunction and Cardiovascular Diseases. Table 2.2 shows some common dietary antioxidants, their source and health benefits.

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Table 2.2 Some Common Dietary Phytochemical (Antioxidants), Their Sources, and Established Human Health Effects.

Compound	Sources	Established Effect on Human Health
Flavonoids (Quercetin & Kaempferol)	Moringa, Onions, Snap Beans, Lettuce, The Majority of Common Vegetables	Direct Antioxidants, Reduce the Risks of Heart Disease, Anticancer, Effects on Circulatory System
Chlorogenic Acid	Moringa, Blackberry, Apple, Peach, Coffee, Quince	Direct Antioxidants, Anticancer Effects, Modulate Cholesterol Levels
Glucosinolates (Hydrolysis Products:Isothiocyanates Regulate Antioxidant Mechanisms in Cells)	Moringa, Cabbage, Broccoli, Radish, Cauliflower, Kale, Mustard	Indirect Antioxidants, Potent Anticancer Activity of Isothiocyanates, Potential Effects on Immune System

Sources: Bahorun, *et al.* 1996; Periera da Silva *et al.* 2000; Estruch, 2000; Santos-Buelga and Scalbert, 2000; Bortz, 2001; Czinner *et al.* 2001; Lodovici, *et al.* 2001; Stupans *et al.* 2002; Sun *et al.* 2002;

2.11 MEDICINAL PROPERTIES OF MORINGA LEAVES

Generally, the flowers, leaves and roots are widely used as remedies for several ailments. The bark of the Moringa root should be scraped off because of its toxicity and the flesh of the root should be eaten sparingly (Oliver-Bever, 1986). Studies have shown that the leaf juice has a stabilizing effect on blood pressure. The leaf juice controls glucose levels in diabetic patients. Fresh leaves and leaf powder are recommended for tuberculosis patients because of the availability of vitamin A that boosts the immune system. If leaf juice is used as diuretic, it increases urine flow and cures gonorrhoea. Leaf juice mixed with honey treats diarrhoea, dysentery and colitis (colon inflammation). Fresh leaves are good for pregnant and lactating mothers; they improve milk production and are prescribed for anaemia. Moringa leaves and seeds contain 4-(.alpha.-L-rhamnopyranosyloxy)-benzylgucosinolate and three monoacetyl isomers of this glucosinate, which treat diarrhoea, regulate blood sugar, normalize blood cholesterol and are reputed to be aphrodisiac. Moringa leaf juice is used as a diuretic and as a skin antiseptic. Its flowers and leaves are both anti-helminitic and commonly used internally and externally as a poultice against parasites (www.leafpowder.wordpress.com, 2008).

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2.12 HEALTH AND NUTRITIVE BENEFITS OF MORINGA LEAVES

The leaves also contribute great values of calcium, magnesium, phosphorus, potassium, sulphur, manganese, zinc, selenium, vitamin E, vitamin B2 (riboflavin), vitamin B3 (niacin) and choline. Moringa contains all essential amino acids along with many others, namely, aspartic acid, glutamic acid, serine, glycine, threonine, alanine, valine, leucine, isoleucine, histidine, lysine, arginine, phenylalanine, tryptophan, cystine, serine, proline, tyrosine and methionine. Amino acids are the building blocks of proteins and many amino acids have antioxidant and anti-inflammatory effects. The combination of multiple antioxidants and/or anti-inflammatory agents appears to have a synergistic effect in the body, with increased potency and effectiveness. Some amino acids are only found in the Moringa seeds, while other amino acids are found exclusively in the leaves of the Moringa plant. The efficacious combination of the leaves and seeds of the Moringa plant to provide the most beneficial blend of synergistic amino acids, is not found in any prior art (www.leafpowder.wordpress.com, 2008).

It is interesting to note that the leaves contain generous amounts of the omega-3 and 6 oils and only traces of the omega-9 oil, while the seeds contain generous amounts of the omega-9 oil and just trace elements of the omega-3 and 6 oils. The efficacious combination of the leaves and seeds further enhances the efficacy of the essential fatty acids (www.leafpowder.wordpress.com, 2008). Table 2.3 contains information about the some nutrients of the edible leaves from this plant compared with common foods. Moringa seem to have most of the food nutrients required by the body to replenish its defensive mechanisms. A list (Table 2.4) of some of the proven characteristics of Moringa, a plant which has no known impurities or adverse reactions when consumed, is shown.

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Table 2.3 Edible Portion of Common Foods Compared per 100g of Moringa.

Nutrient	Moringa	Other Foods
Vitamin A	6780 mcg	Carrots: 1890 mcg
Vitamin C	220 mg	Oranges: 30 mg
Calcium	440 mg	Cow's milk: 120 mg
Potassium	259 mg	Bananas: 88 mg
Protein	6.7 gm	Cow's milk: 3.2 gm

Source: (www.zijaMoringa.net, 2004)

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Table 2.4 Nutritional Analysis of *MORINGA* fresh (raw) leaves, and dried leaf powder per 100 grams of edible portion.

	Leaves	Leaf Powder
Moisture (%)	75.0	7.5
Calories	92.0	205.0
Protein (g)	6.7	27.1
Fat (g)	1.7	2.3
Carbohydrate (g)	13.4	38.2
Fibre (g)	0.9	19.2
Minerals (g)	2.3	0.0
Ca (mg)	440.0	2,003.0
Cu (mg)	1.1	0.6
Fe (mg)	7.0	28.2
Oxalic acid (mg)	101.0	0.0

Source: Fuglie, 2001

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2.13 MORINGA PRODUCTS

Moringa trees have many benefits. Trees provide nutrients to the soil. Leaves, tender young capsules, immature seeds, fruits and roots are edible. The young leaves are collected, cooked and eaten like other vegetables. The young roots can be collected and used as a sort of spice, but care should be taken when using the root as a food, because the root bark contains poisonous alkaloids (French, 2006).

In Ghana, Moringa leaf powder is very much on the increase, however, products are of bad quality or adulterated (Sauveur, 2008). This is attributed to the fact that factors including time of harvest, harvest to drying (post harvest handling), washing the leaves or not, drying technology, % of humidity after drying and storage method have not been standardized. As Moringa leaf powder is new on the market, promoters sometimes tend to keep some kind of confidentiality around what they are doing, and react like competitors (Sauveur, 2006). This is not assisting the progress of technical knowledge and common problems with certification have not been overcome.

However, many promoters of Moringa prepare the leaf powder simply by leaving the harvested leaves to dry in the shade on a clean cloth (in a room or under a tree to reduce loss of vitamins). Stems and spines of dry leaves are removed and pounded or rubbed over a wire screen to a fine powder and conveniently added to soups, sauces and other foods without changing their taste or can be stored in an airtight container for latter use (www.Moringatrees.org, 2006; French, 2006).

Rich in nutritive value, shade (shadow) dried Moringa leaf powder is used in pharmaceutical and food industries. 100% Moringa leaves is used to make Moringa capsule. In preparing leaf sauces, dried leaf powder may be used in place of fresh leaves (www.Murungaexports.diytrade.com, 2008). It has been reported that in the Philippines, moringa leaves are occasionally ground into a mash, boiled and made into moringa puree then spoon-fed to infants. The leaves have also been incorporated into biscuits, porridges and other food products. Moringa tea is usually prepared by brewing dried leaf powder in hot water for some time and consumed (www.churchworldservice.org/Moringa, 2000).

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CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 SOURCE AND SAMPLING OF RAW MATERIALS

The Moringa tops of the two species (*Moringa oliefera* and *Moringa stenopetala*) were obtained from the Horticultural Department of Kwame Nkrumah University of Science and Technology, Kumasi. They were harvested for use as tea at about 10 cm from the tip of the vine, which included some of the leaves along the vines of the plant (Appendix D).

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3.2 PREPARATION OF HERBAL GREEN TEA LEAF POWDER

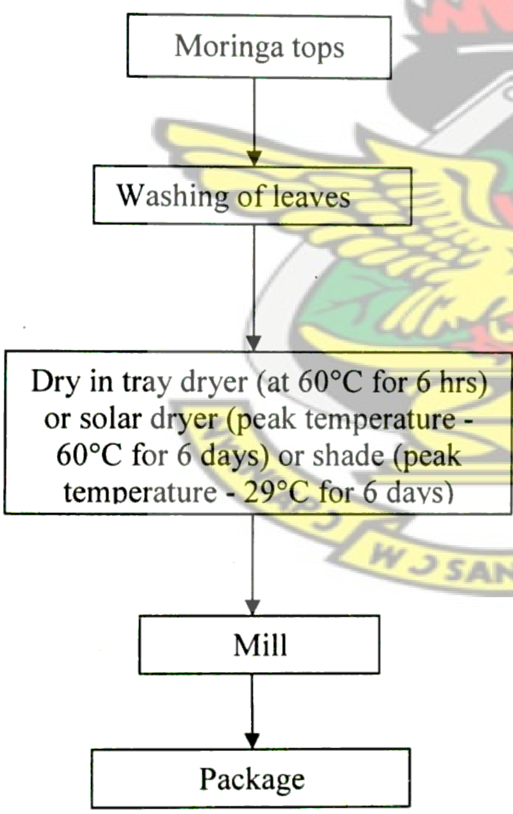

Figure 3.1 Preparation of green tea (Un-blanched)

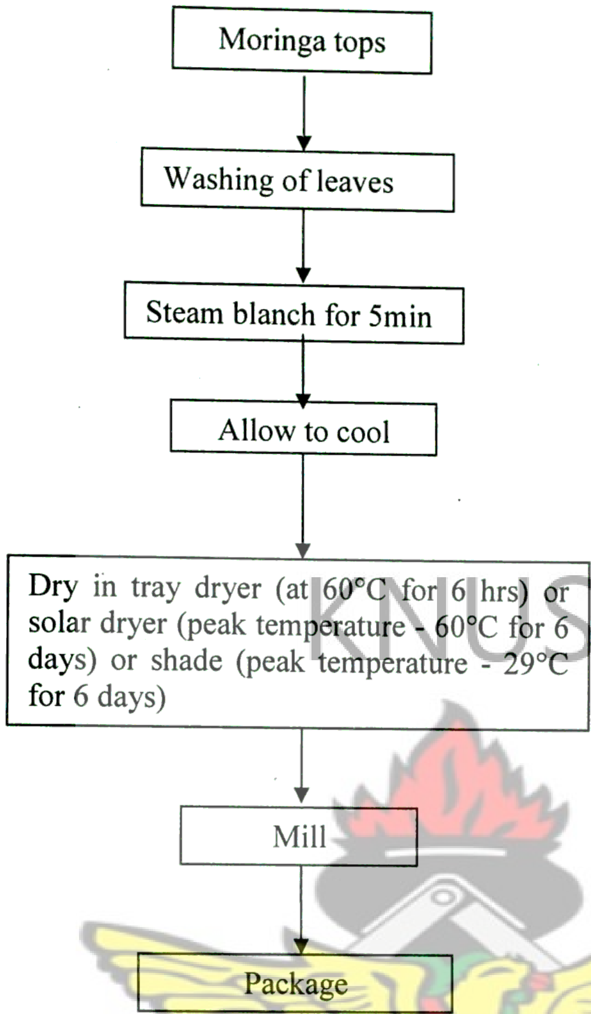

Figure 3.2 Preparation of Green Tea (blanched)

The flow chart for green tea preparation (Figures 3.1 and 3.2) shows the preparation of un-blanched and blanched green teas respectively (Plates shown in appendix C). Packaging was done using polypropylene bags and labelled as blanched and un-blanched. Some Moringa tops were left as fresh samples (un-blanched and without drying) and were also packaged into polypropylene bags and labelled as fresh samples. Samples for sensory analysis were packaged in non-drip bags (Appendix D) for analysis. All the samples were stored in a deep freezer (-18 °C) prior to analysis. In all, fourteen samples were obtained for all treatments (Appendix C). The Twinings

Earl Grey green tea was used as a control green tea, making the samples fifteen in number.

3.3 CHEMICAL ANALYSIS

Chemical analysis carried out on the green tea samples were based on Pearson's Composition and Analysis of Foods (Kirk and Sawyer, 1997) and the Official Methods of Analysis, (AOAC, 1990).

3.3.1 DETERMINATION OF MOISTURE

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Two grams of sample placed into a previously dry (weighed) glass crucible was dried in a thermostatically controlled oven at 105°C for 6 hours. The dried samples were removed and placed in a desiccator to cool, re-weighed, placed in the oven, heated, cooled, re-weighed repeatedly until a constant weight was obtained. The moisture content was then determined by differences expressed as a percentage of the initial fresh sample weight (AOAC, 1990).

3.3.2 DETERMINATION OF TOTAL ASH

Two grams of the sample from each variety of tea samples in duplicates placed in Gouch porcelain crucible (previously washed, dried, ignited and weighed) with its contents were placed in a Muffle furnace (Gallenkamp, England), set to 600°C for two hours. The crucibles and their contents were removed and cooled in a desiccator after which they were weighed. The ash content was then calculated by difference and expressed as a percentage of the initial sample weight.

3.3.3 DETERMINATION OF MINERAL MATTER

Mineral composition was determined by acid digestion. Ash obtained after incineration at 600 °C were dissolved in 5ml of 5M HCl solution and transferred into a 50ml volumetric flask. The resulting solution was made up to the mark with distilled water. The mineral contents were then measured using the Atomic Absorption Spectrophotometer (AAS) (UNICAM 960 series) (AOAC, 1990).

3.3.4 DETERMINATION OF WATER-INSOLUBLE ASH

The ash from the total ash determination was transferred into a 100mL beaker boiled with 25mL distilled water for five (5) minutes and the liquid filtered through an ashless filter paper and thoroughly washed with hot water. The filter paper was then ignited in the original dish for thirty (30) minutes, cooled and the water insoluble ash weighed. The water insoluble ash was determined by difference (Kirk and Sawyer, 1997).

3.3.5 DETERMINATION OF STALKS

Five grams (5 g) of the different samples were weighed and boiled for 15minutes in a 1000ml flat bottomed flask with 500ml distilled water. The contents of the flask were transferred into a large plastic basin and the stalks were hand picked out of the basin with forceps. The leaves were dried in the drying oven at 100 °C for five hours and left overnight till a constant weight was obtained and weighed. The stalks content was then determined by difference and expressed as a percentage of the initial sample weight (Kirk and Sawyer, 1997)

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3.3.6 DETERMINATION OF TOTAL PHENOLS

The extraction and determination of total phenols followed the method of Makkar *et al*. (1993) with some modifications. Four hundred milligrams (400mg) of plant samples (dried and finely ground) was weighed into centrifuge tubes. A solution of 20ml of 70% acetone (with pH adjusted to 3 with acetic acid) was added and allowed to stand at room temperature for 20min with intermittent gentle vortexing. The tubes were panellist to centrifugation for 10min at approximately 3000rpm at 4°C. The supernatant was collected (containing polyphenols) and kept on ice.

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An aliquot of 0.1ml of the polyphenol-containing extract was taken into test tubes. The volume was made up to 2ml with distilled water, 1ml of the Folin-Ciocalteu reagent (1N) added and then 5ml of 20% sodium carbonate solution was added. The tubes were vortexed and the absorbance at 725nm was read after 40min. The amount of total phenols was determined as tannic acid equivalent from a calibration curve prepared using standard tannic acid solution (0.1mg/ml). Total phenols content was expressed on a dry matter basis (x %).

3.3.7 CRUDE FIBRE DETERMINATION

Two grams of the sample was transferred into a 750ml Erlenmeyer flask and ½ g of asbestos was added. A volume of 200ml of hot and boiling 1.25% H_2SO_4 solution was added and heated to boil under reflux until the sample was thoroughly wetted for 30 minutes on a hot plate. The sample was then filtered through linen cloth in a funnel and washed thoroughly with boiling water until the washings were no longer acidic (did not change blue litmus paper red). The sample and asbestos were washed back into the flask with 200ml boiling 1.25% NaOH solution. The flask with its contents was refluxed for another 30 minutes. The sample with asbestos were again filtered and washed with boiling water until the washings were no longer alkaline (did not turn red litmus paper blue). They were then washed with 15ml alcohol and the residue left was transferred into a Gouch porcelain crucible. The crucible and its contents was dried for 1hour at 105°C in a drying oven and cooled in a desiccator, and weighed. The crucible and its content were then ignited in a muffle furnace for 30 minutes at 600°C, cooled in a desiccator and reweighed. The loss of weight was reported as percentage crude fibre, (AOAC, 1990).

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3.3.8 DETERMINATION OF CRUDE PROTEIN

The Kjeldahl method was used for the determination of the total nitrogen. Two grams (2 g) of sample was digested with 25 ml of concentrated sulphuric acid (H_2SO_4) in Kjeldahl digestion flask in the presence of a catalyst (Selenium tablet (½ tablets)) and anti bumping agents, in a fume chamber, until the solution was clear. The clear digested solution was transferred into a 100ml volumetric flask and made to the mark with distilled water after cooling at room temperature. Distillation was carried out using the steam distillation apparatus.

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A solution of 25ml of 2% Boric acid was poured into a 250 ml conical flask and 2 drops of mixed indicator added, and placed under the condenser outlet with the tip of the condenser completely immersed in the solution (Boric acid), 10 ml of the digested sample solution and about 20ml of 40% NaOH solution were transferred into the decomposition flask and well closed. Ammonia (NH_3) liberated during the distillation was collected by the Boric acid solution turning it bluish green. The distillation was continued until about 5 minutes after the solution in the conical flask has changed to bluish green. The distillate was titrated with 0.1N HCl solution and the end point or titre, recorded. The titre values obtained were used to calculate the total Nitrogen. This was then converted into percentage crude protein by multiplying this percentage by an appropriate conversion factor 100/X, where X is the percentage nitrogen in the food protein. A blank was carried out using distilled water (AOAC, 1990).

3.3.9 WATER EXTRACTIVES DETERMINATION

Two grams (2 g) of the sample was refluxed with 100 ml distilled water for one hour (1 hr). The sample was then filtered into a 250ml volumetric flask using filter paper in a funnel. The residue and the filter paper were returned to the boiling flask, and boiled with further 100ml water. The contents of the boiling flask were again filtered into the volumetric flask, and the residue washed thoroughly with hot water. The filtrate was made to 250ml mark, mixed and 50ml of it was pipetted into a clean and weighed moisture crucible, and dried in a 100°C oven. The crucible and its contents were then cooled in a desiccator and reweighed. The results were calculated as a percentage of the sample on a moisture free basis (Kirk and Sawyer, 1997).

3.3.10 pH

Fifty milliliters (50mls) of the solution from the water soluble extractive determination was taken and the pH measured and recorded using the Sper scientific basic pH meter (model 840087, Taiwan). This was done in duplicates (AOAC, 1990).

3.3.11 LIGHT PETROLEUM EXTRACT DETERMINATION.

Two grams (2 g) of the moisture free sample was put in a paper thimble and plugged with cotton wool. The thimble was placed in Soxhlet extraction apparatus and extracted with light petroleum ether (b.p 40-60 °C) at low heat for 5 hours in a continuous extraction manner. The extract was collected in a flask and dried at 100°C, cooled and weighed. The difference in weight of the empty flask and the flask and its dry contents was recorded as light petroleum extract (LPE) (Kirk and Sawyer, 1997).

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3.3.12 CARBOHYDRATE DETERMINATION

Carbohydrate contents were calculated by difference of total contents from 100, and caloric value estimation was done by summing the multiplied values for crude protein, fat and carbohydrate (excluding crude fibre) by their respective Atwater factors; 17, 37, and 17 (FAO, 2006).

3.3.13 β-CAROTENE DETERMINATION

0.05 g of the sample was weighed and ground smoothly with celite using mortar and pestle. 50 ml acetone was added while grinding to extract carotene. The extracts were filtered using the hand aspirator and the filtrate added to 20 ml of petroleum ether in a separating funnel. Water was gently added at the side of the funnel with each addition being allowed to separate from the removal residual acetone, and the extract dried over anhydrous sodium sulphate. A volume of 100 ml of the concentration was evaporated to dryness with nitrogen gas and re-dissolved (reconstituted) in varying volumes of the mobile phase depending on anticipated concentration. The absorbance was then determined by spectrophotometer at 450nm and HPLC

(Detector- shimadzu SPD-6AV; recorder – shimadzu C- R6A; Injector- Model7125; Pump- shimadzu LC-6A; column-Zorbox ODS columns) was used to measure β-carotene concentrations in the extracts (Appendix G) (Rodriguez-Amaya and Kimura, 2004).

3.4 SENSORY EVALUATION

Sensory evaluation was conducted on the tea samples that were processed and on the Twinings Earl Grey green tea (as the control sample) to find the degree of acceptability. A descriptive analysis of the tea samples was also carried out. The tea samples were prepared by boiling water (100°C) and infusing a teabag (2g) in a mug containing 150mls of hot water.

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The sensory panellists were trained particularly for herbal green tea. A lecture was given on what attributes to consider when tasting green teas. Also, the exact colour and flavour for green teas were told to the panellists. During the training programme, they were served with unripe bananas to have a sensorial knowledge about the astringency attribute. They were later served with four different concentrations of a commercial green tea (with all the attributes of green tea) to identify the lowest to the highest concentrated green tea in terms of colour, flavour and astringency. Additionally, they were served with two of the Moringa tea infusions and a control (Twinings Earl grey green tea infusion) to assess in terms of colour, flavour, after-taste, mouth feel, astringency and overall acceptability.

Fifteen (15) trained panellists were used in the actual sensory evaluation to assess the colour, flavour, after-taste, mouth feel, astringency and the overall acceptability for all the twelve (12) processed Moringa leaf powders and the control. Each panellist was given the tea in a random order to assess; they did not specifically follow the serving orders. They were served in single cabins in a sensory evaluation laboratory at Food Research Institute. The panellists were required to cleanse their palates with a bite of low-salt cream crackers, a sip of room-temperature water and a 30 seconds time lag before evaluating every sample.They evaluated the tea samples using a hedonic scale of 1 – 9 with 9 representing like extremely and 1 dislike extremely.

The sensory evaluation questionnaire form is shown in appendix E. The data generated were pooled together and analyzed using Microsoft Excel and SPSS.11 software. The means were calculated and significant differences among the teas were also determined. The mean ranking of the scores given by the panellists were also determined using Krusal-Wallis test.

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CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 MOISTURE CONTENT

Figure 4.1 shows that drying reduced moisture content markedly with oven-dried samples having the lowest moisture contents of 2.90 % and 3.38 % for blanched and un-blanched respectively for *M. oleifera* leaves, and 2.24 % and 2.66 % respectively for blanched and un-blanched *M. stenopetala* leaves. Results were higher in shade-dried leaves with blanched and un-blanched leaves having moisture values of 12.94 % and 17.67 % respectively for *M. oleifera*, and 18.48 % and 19.92 % for blanched and un-blanched respectively for *M. stenopetala* leaves. This observation could be as a consequence of the high and constant temperature in the oven tray dryer (60 ºC) than that of the shade (peak temperature-29 ºC). Statistically, effects of the drying methods were significant ($p < 0.05$).

It was also observed that the moisture contents of all the blanched samples were lower than those of the un-blanched samples in both species under all the drying methods. This result is consistent with the findings of Greve *et al.* (1994) and Waldron *et al.* (2003) who showed that cells loose their wall integrity when blanched with steam and thus bound water is lost faster than in un-blanched samples. However, the moisture contents for blanched and un-blanched leaves were statistically not different ($p > 0.05$).

M. stenopetala fresh leaves had a slightly higher moisture content of 76.99 % than the fresh leaves of *M. oleifera*, which had moisture content of 76.36 % (Figure 4.1).

Additionally, after panellisting the leaves to the various processes, *M. oleifera* had higher moisture contents than *M. stenopetala*. These results are expected, since there are differences in species. Regardless of these observations, there was no significant difference ($p < 0.05$) between the moisture contents of the two species after processing.

Twinning Earl Grey green tea (control) had mean moisture content of 9.82 %, which is rather on the high side. According to Kirk and Sawyer (1997), good quality tea seldom has moisture content in excess of 7 %. Tea with moisture in excess of 11 % is liable to go mouldy and consequently produce a musty infusion. Thus percentage moisture should range from 6.1 % to 9.2 %.

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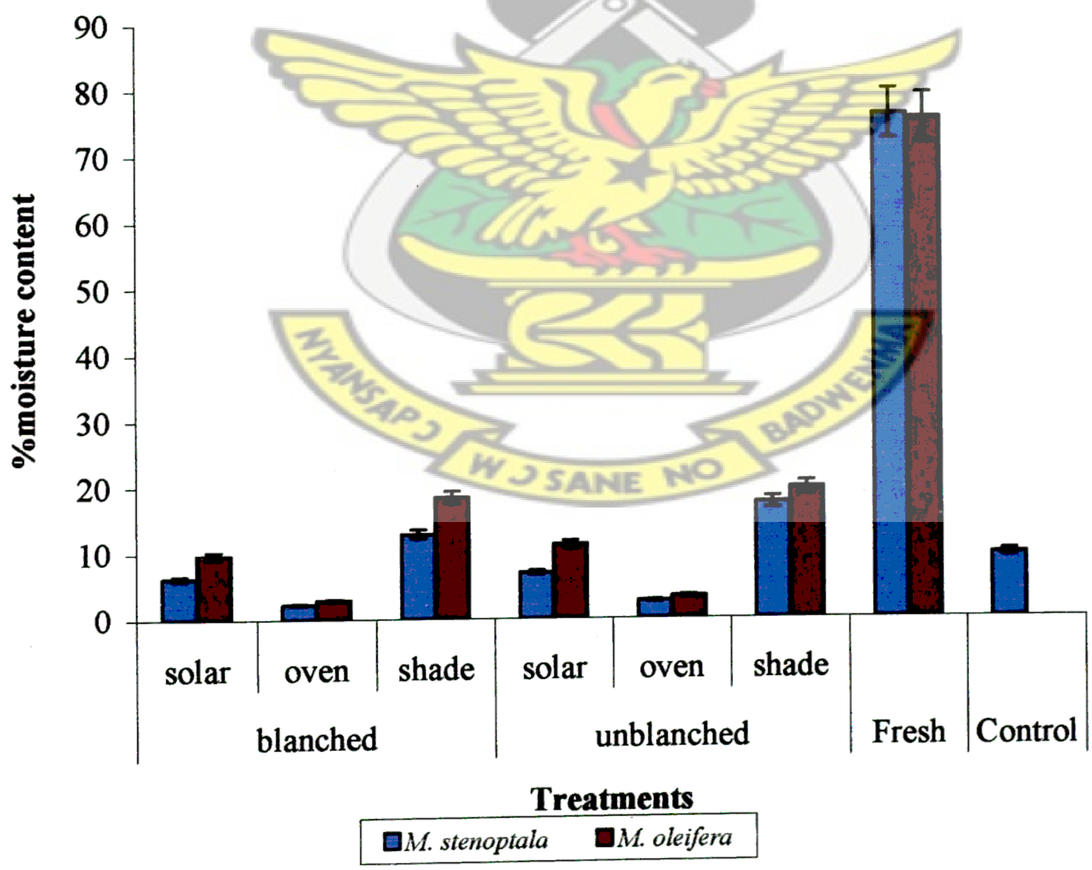

Figure 4.1 Effects of blanching and drying methods on moisture contents of tea samples

4.2 CRUDE ASH CONTENT

The results showed that crude ash contents in oven-dried leaves was significantly higher ($p < 0.05$) than in those leaves dried in solar and shade with the highest being 9.95 % (figure 4.2) for oven-dried un-blanched *M. stenopetala* leaves. The lowest ash content was in shade-dried blanched leaves for *M. stenopetala* with a value of 5.01 % (Figure 4.2). This could be attributed to the reduction in moisture contents during drying that resulted in corresponding increases in dry matter contents due to concentration of soluble solids.

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Generally, blanched dried leaves had lower ash content than un-blanched dried leaves in all the drying methods. This observation supports reports by Fellows (1990) that blanching which is an important pre-processing heat-treatment of vegetable destined for dehydration inevitably causes separation and losses of water soluble nutrients such as minerals. Crude ash contents differed significantly between blanched and un-blanched leaves at 5 % level. Values were generally particularly high in *M. oleifera* than in *M. stenopetala* (Figure 4.2 and Appendix F2) and were significantly different ($p < 0.05$). This variation may also be due to varietal differences.

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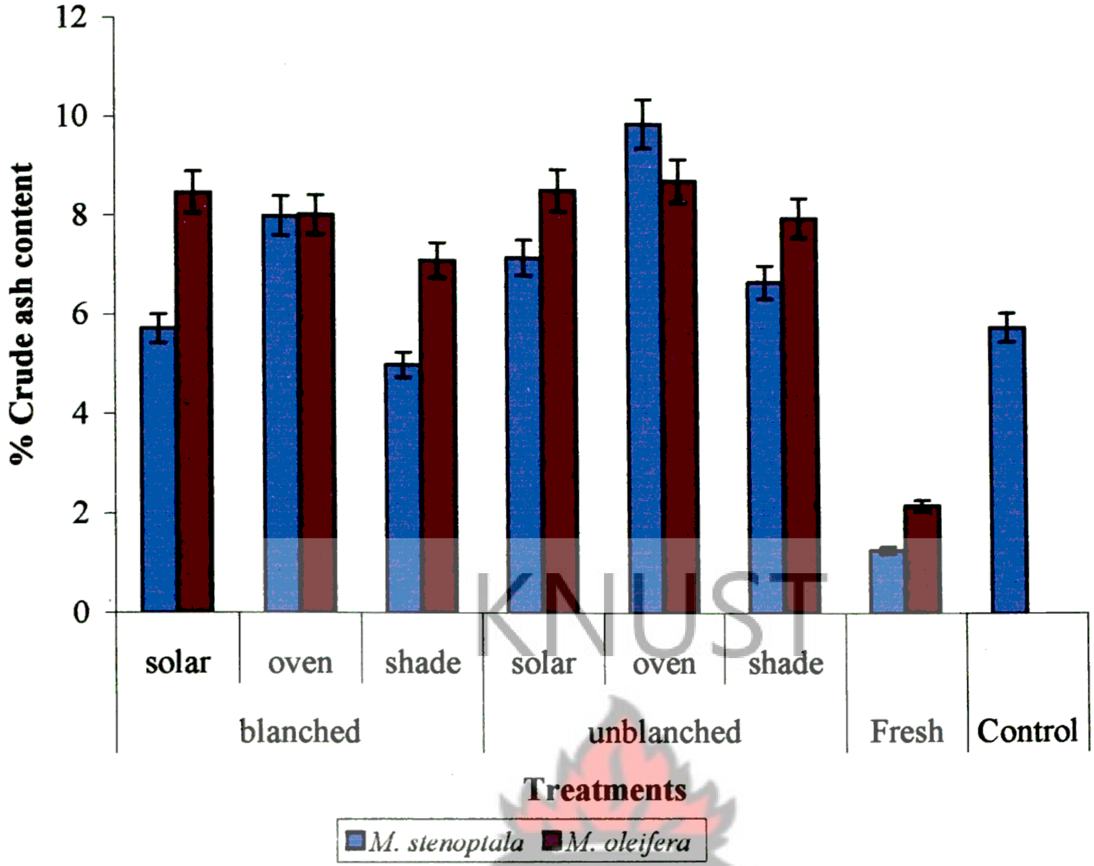

Figure 4.2 Effects of blanching and drying methods on crude ash contents of tea samples

4.2.1 MINERAL CONTENT

4.2.1.1 ZINC (Zn) CONTENT

Results in Figure 4.3 show that oven-dried leaves had higher Zn contents than solar- and shade-dried leaves. A multiple comparison (Appendix F3) among drying methods revealed that there are significant differences ($p < 0.05$) when Zn contents of solar- and oven-dried leaves (with means of 3.44 mg/100g and 5.99 mg/100g respectively), and shade- and oven-dried leaves (with means of 3.46 mg/100g and 5.99 mg/100g respectively) were compared. The higher values observed in the oven-dried leaves could be due to concentration effect leading to concentration of soluble solids.

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A general trend observed was that blanched leaves had lower Zn contents than their corresponding un-blanched leaves, which could be attributed to leaching of minerals during blanching. However, statistical analysis showed no significant difference between blanched and un-blanched leaves ($p > 0.05$), indicating that blanching did not affect Zn content. Zn is an essential micronutrient for human growth, development, and maintenance of immune function, which enhances both the prevention of and recovery from infectious diseases (Black, 2003; Walker, 2005). Meat products are the best source of Zn (Walker, 2005), and consequently, Zn deficiencies may exist in populations that consume diets with insufficient amounts of animal-source foods. From this present study, Zn contents (ranging from 2.32 mg/100g to 9.68 mg/100g) in the treated moringa leaves for tea are sufficient and the intake of herbal tea from moringa leaves could ideally enhance improvement of diet deficient of Zn.

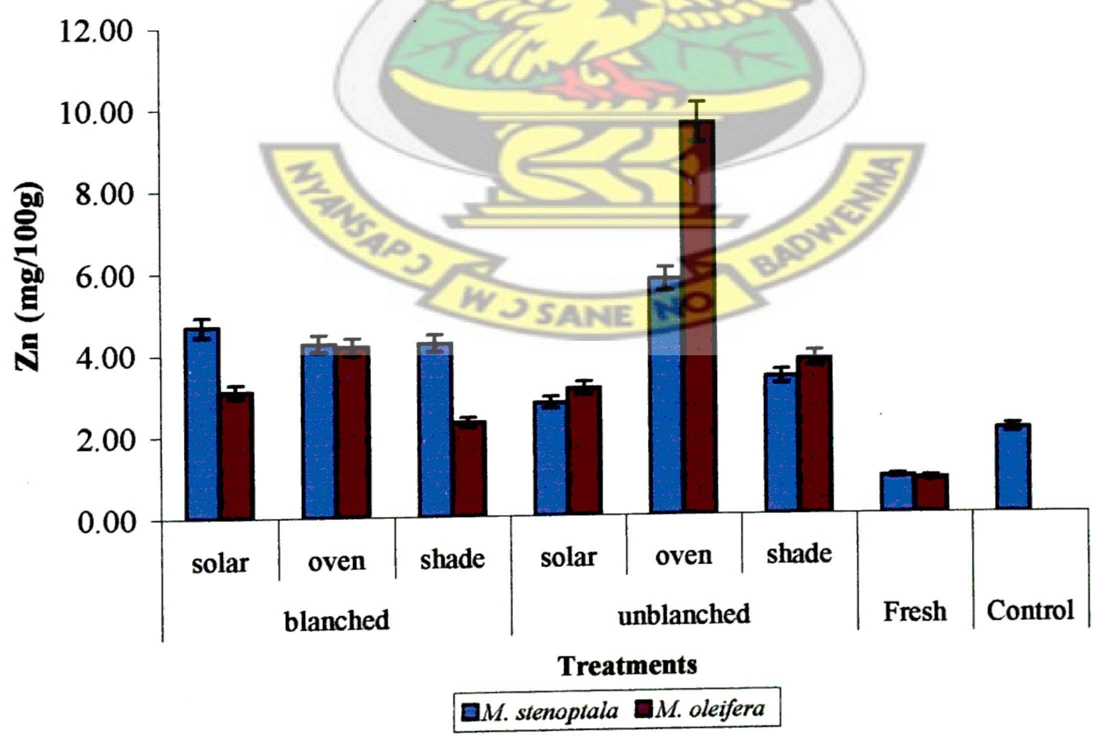

Figure 4.3 Effects of blanching and drying methods on zinc (Zn) contents of tea samples

4.2.1.2 IRON (Fe) CONTENT

Figure 4.4 shows that oven-dried leaves had high Fe contents than solar- and shade-dried leaves with *M. oleifera* un-blanched leaves dried in oven having the highest value of 16.94mg/100g. *M. stenopetala* un-blanched leaves which were solar-dried had the lowest Fe content (8.90mg/100mg). A multiple comparison among drying methods (Appendix F3) showed that there were significant differences ($p < 0.05$) in Fe contents when oven-dried leaves were compared with solar- and shade-dried leaves. However, Fe contents of solar and shade-dried leaves did not show any statistical difference in their values ($p > 0.05$). Though Fe is not affected during the drying process (Kendall *et al.*, 2004), the low moisture contents observed in oven-dried leaves with the consequence of high dry matter contents could account for the high levels of Fe in oven dried leaves than solar- and shade-dried leaves.

In addition, it was observed that Fe values for blanched leaves were slightly lower than those of the un-blanched leaves in most cases. However, there was no statistical difference ($p > 0.05$) in Fe contents for blanched and un-blanched leaves, likewise the two species, *M. oleifera* and *M. stenopetala* (Figure 4.4). Loss of Fe in blanched leaves is supported by findings of Wapnir (1990) which states that the extent of possible losses of minerals such as Fe is related to the solubility of the salts present in the product. Also, blanching using boiling water temperature at normal atmospheric pressure accelerates Fe losses (Wapnir, 1990). Similarly, Oladunmoye *et al.* (2005) observed significant ($P \leq 0.05$) reductions in Fe content of blanched matured cassava leaves. Moringa leaf powder for tea with such high values of iron (ranging from 8.90mg/100mg to 16.94mg/100g) falls within the Recommended

Daily Allowance for children (10mg/100g to 13mg/100g), men (7mg/100g), women and breast feeding mothers (12mg/100g to 16mg/100g) (Fuglie, 2001).

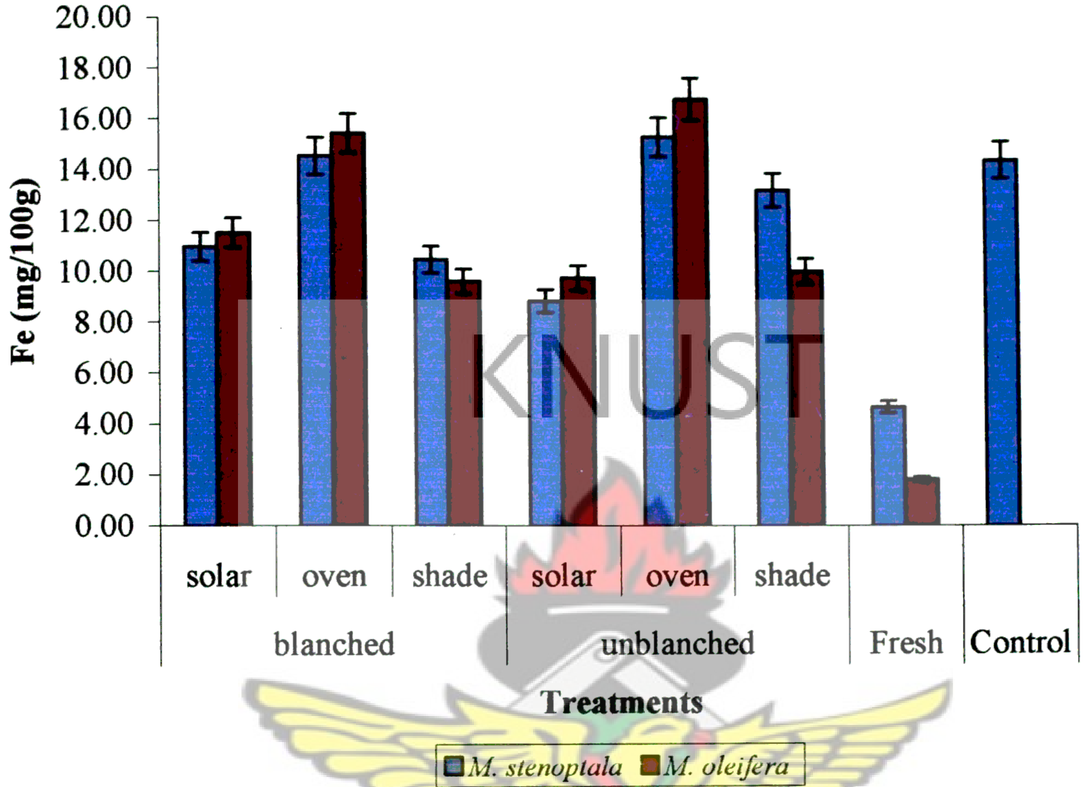

Figure 4.4 Effects of blanching and drying methods on iron (Fe) contents of tea samples

4.3 CRUDE PROTEIN CONTENT

Results in figure 4.5 shows that crude protein contents increased significantly ($p < 0.05$) when the leaves were panellisted to dehydration. Values were relatively higher in oven-dried leaves with *M. stenopetala* blanched leaves having the highest value of 29.37 %. The values were particularly lower in shade-dried samples with un-blanched *M. oleifera* leaves having the lowest value of 24.81 % (Figure 4.5). This could be attributed to concentration effect leading to concentration of soluble solids.

Additionally, crude protein contents for blanched leaves were slightly higher than their corresponding un-blanched leaves. This observation is supported by the report of Greve *et al*. (1994) and Waldron *et al*. (2003) which showed that loss of the cell wall integrity of blanched samples leads to a high mean moisture loss when they are panellisted to drying than when un-blanched. Thus, crude protein contents were more concentrated in blanched leaves than those of their corresponding un-blanched samples when dried. However, statistically, there was no significant difference ($p < 0.05$) in crude protein contents between blanched and un-blanched samples, suggesting that blanching did not significantly affect crude protein content.

There was also no significant difference ($p < 0.05$) in the crude protein content between the two species (*M. stenopetala* and *M. oleifera*). Their values are in agreement with the protein content (27.1 %) Fuglie (2001) reported for *M. oleifera*. The author also stated that the protein quality of Moringa rivals that of meat and eggs and protein digestibility is high (85 % to 90 %), with its amino-acid composition corroborating with the FAO reference protein for a growing child.

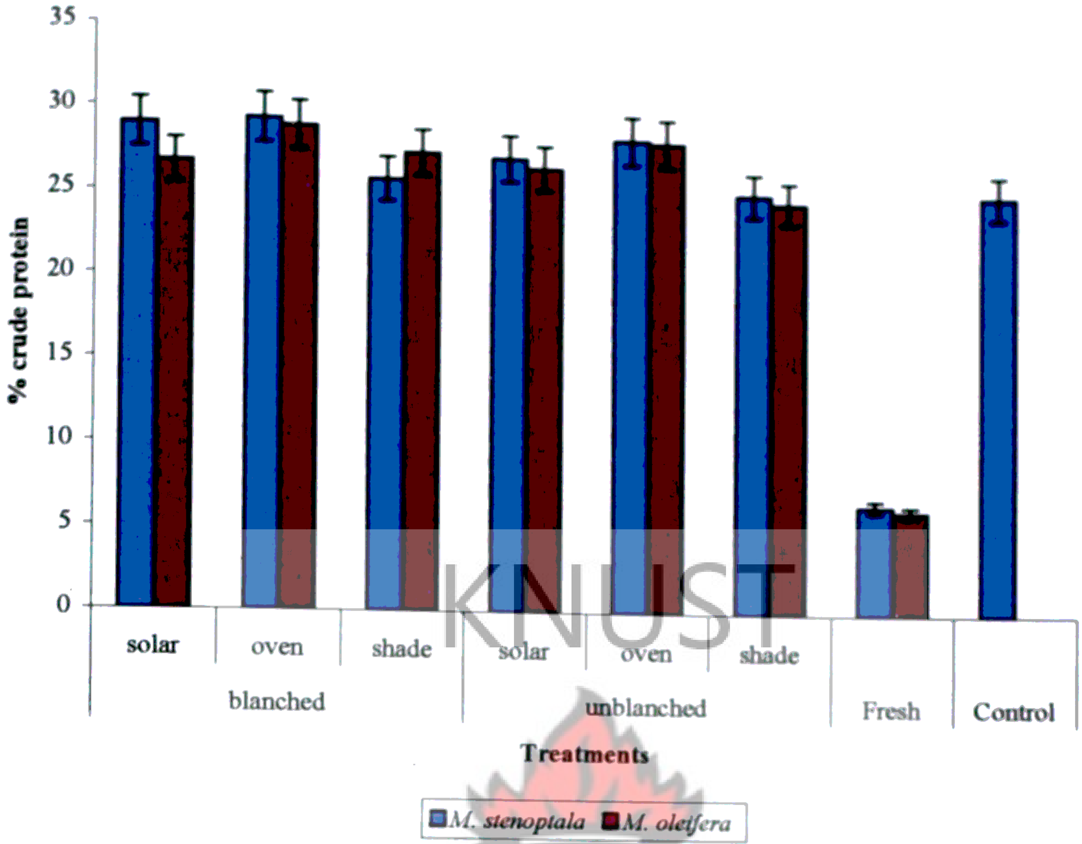

Figure 4.5 Effects of blanching and drying methods on crude protein contents of tea samples

4.4 LIGHT PETROLEUM EXTRACTS (LPE)

Light petroleum extracts (LPE) (figure 4.6) showed that LPE contents were particularly high in oven-dried leaves than solar- and shade-dried leaves. The highest value was 5.73 % for oven-dried *M. oleifera* blanched leaves and the lowest value was 2.61 % for shade-dried *M. stenopetala* un-blanched leaves. A multiple comparison analysis (Appendix F3) among the methods of dehydration suggests that there was significant difference ($p < 0.05$) in LPE contents between shade- and solar-dried leaves and shade- and oven-dried leaves. However, there was no significant difference in LPE content between solar- and oven-dried leaves. Leaves dried in solar and oven driers yielded higher values than shade-dried samples. This may be due to the extent of reduction in moisture contents in solar and oven-dried leaves

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resulting in corresponding increases in dry matter contents due to concentration of soluble solids.

The blanched dried Moringa leaves had higher β-carotene contents than their corresponding un-blanched dried leaves in both species. This could be explained by the findings of Francis (1996) which revealed that LPE such as β-carotene and chlorophylls are not water soluble. It is also known that β-carotene is heat stable and thus is not destroyed by most methods of cooking except frying at high temperatures around 180°C (Fuglie, 2005). Subadra *et al*. (1997) cited that blanching also enhances the retention of β-carotene, strengthening the observation of Fellows (1997) and DeMan (1990) that blanching reduces vegetable β-carotene predisposition to destruction. Additionally, pre-treatment of leaves with steam (blanching) for a short time (5 minutes) generally results in smaller losses of nutrients (Tannanbaum *et al*., 1996), thus losses of these pigments during blanching were minimal. Also, blanching facilitated moisture loss during drying and thus blanched dried leaves were concentrated in solid matter than un-blanched dried leaves, giving blanched leaves higher LPE values than the un-blanched. However, there was no significant difference ($p > 0.05$) between blanched and un-blanched LPE values. An observed trend from the data was that *M. oleifera* had relatively higher LPE contents than *M. stenopetala* though the differences were not significant ($p > 0.05$).

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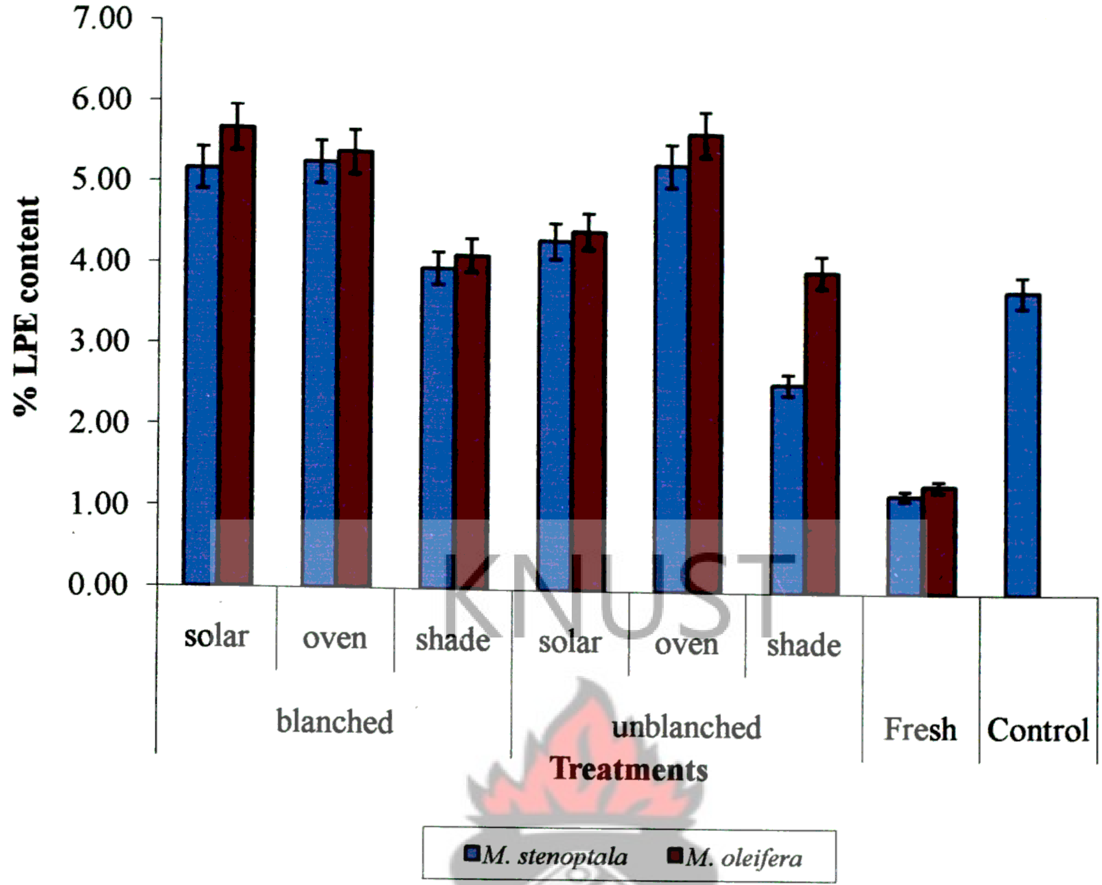

Figure 4.6 Effects of blanching and drying methods on Light petroleum extracts (LPE) of tea samples.

4.5 CRUDE FIBRE CONTENT

Changes in crude fibre content of the leaves panellisted to different processes were not consistent. Fibre in all processed leaves ranged from 8.39 % to 12.26 % (Figure 4.7). The lowest fibre content was in oven-dried leaves with un-blanched *M. oleifera* leaves which were oven dried having 8.39 %. There were significant differences ($p < 0.05$) in the fibre contents when values of solar-dried leaves were compared with values of oven- and shade-dried samples. Solar-dried leaves had higher values than those of oven and shade. However, between oven- and shade-dried leaves there was no significant difference ($p > 0.05$). Blanching did not have effect on fibre content, since the contents for the blanched and un-blanched did not significantly differ at 5 % probability level, likewise the specie type. The content of fibre found in these processed moringa leaves is indicative that they are substantial and will provide bulk for peristaltic action, which will enhance movement of food through the alimentary canal with the potential to prevent colon cancer (BeMiller and Whistler, 1999). Waldron *et al.* (2003) reported that fibre serves as a filter system to prevent unwanted materials from leaching into the tea and that it contains most of the minerals that seep into the tea during infusion. The values (8.39 % to 12.26 %) are in agreement with the range for fibre content stated by Kirk and Sawyer (1997), which is from 9 % to 15 %. Thus the observed values in this study are of significant interest in terms of crude ash content for green tea.

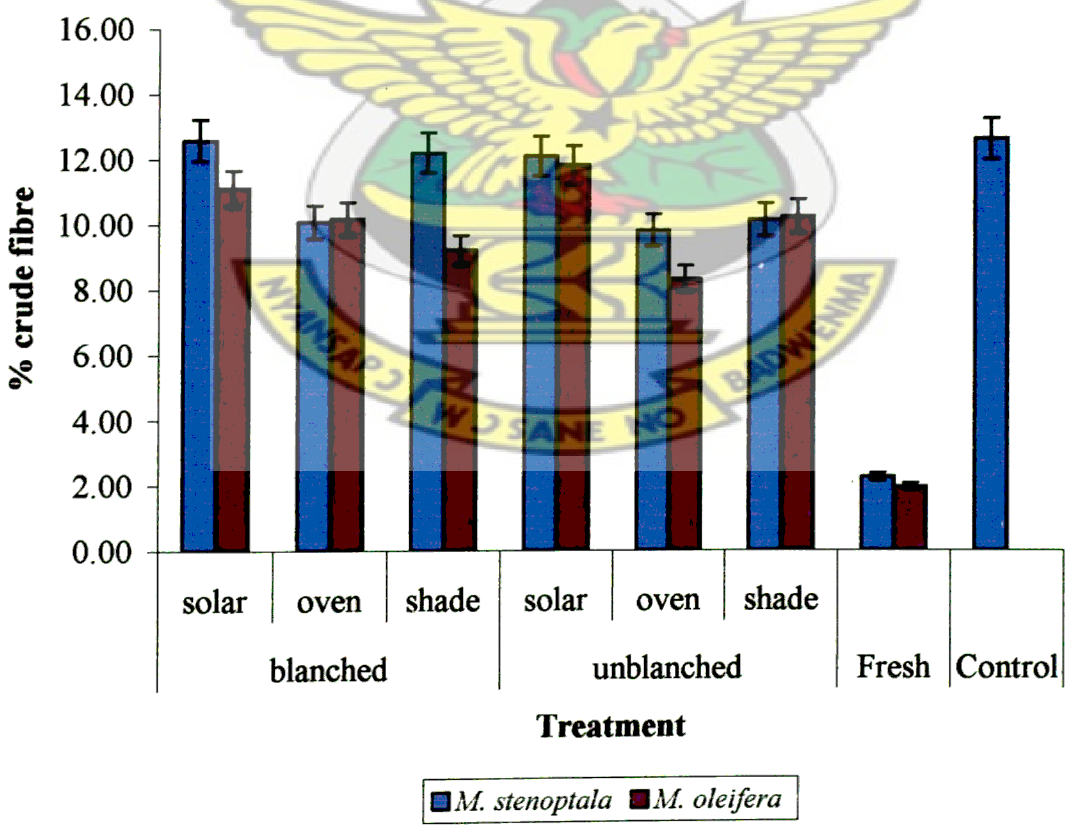

Figure 4.7 Effects of blanching and drying methods on crude fibre contents of tea samples

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4.6 CARBOHYDRATE CONTENTS

Carbohydrate content ranged from 32.84 % to 45.40 % (Figure 4.8). The results showed that oven-dried leaves had relatively high carbohydrate values than solar- and shade-dried leaves. This result is expected since among the drying methods oven-dried leaves had the least moisture values (Figure 4.1) after drying, which could result in high dry matter content than in solar- and shade-dried leaves. There were significant differences among the drying methods ($p < 0.05$); when shade-dried leaves were compared with solar- and oven-dried leaves. However, carbohydrate contents of solar- and oven-dried leaves did not differ significantly ($p > 0.05$).

There were no significant differences in carbohydrate contents between blanched and un-blanched dried leaves. Also, the two species (*M. oleifera* and *M. stenopetala*) did not show any significant difference ($p > 0.05$) in their values. The values obtained after processing and drying these species of Moringa leaves suggest that Moringa leaves gives an appreciable amount of dietary carbohydrates which are known to permit protein to be used for other important purposes such as replenishing of tissue protein (Fenneman and Tannanbaum, 1996). The energy source from these carbohydrates under normal condition promote fat utilization which will intend reduce adipose stores and obesity. This disposition could be supported with the results of the caloric value of the processed Moringa leaves having low caloric values, which also ranged from 1128.90 J/g to 1459.74 J/g (Appendix B). Also, a multiple comparison among the dry methods revealed that statistically, caloric values for solar-dried leaves are not significantly different from those of shade-dried leaves, but significantly different from those of oven-dried leaves. There was no significant difference ($p < 0.05$) in caloric value between blanched and un-blanched leaves.

However, values differed significantly between *M. oleifera* and *M. stenopetala*, which is attributed to differences in species.

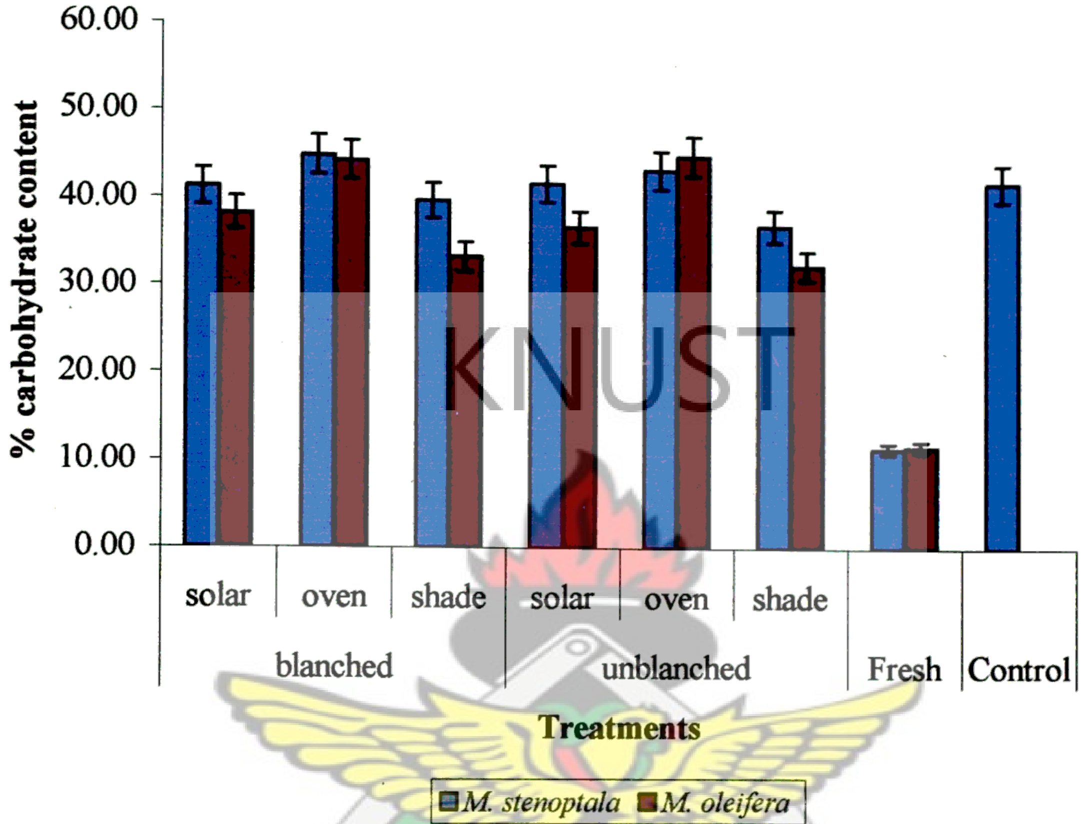

Figure 4.8 Effects of blanching and drying methods on carbohydrate contents of tea samples.

4.7 WATER SOLUBLE EXTRACTIVES (WSE)

Water soluble extractives (WSE) ranged from 4.37 % to 7.06 % (Figure 4.9) for processed Moringa leaves. WSE values did not follow any trend (Figure 4.9). There were no significant differences ($p > 0.05$) in WSE among all processed Moringa leaves suggesting that blanching and different drying technologies applied did not affect WSE. WSE indicates percentage of extractive that can be dissolved during the brewing of the tea. When its percentage is high, and the water-soluble substances

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present are low, then most of it will be obtained in the tea after infusion (Kirk and Sawyer, 1997).

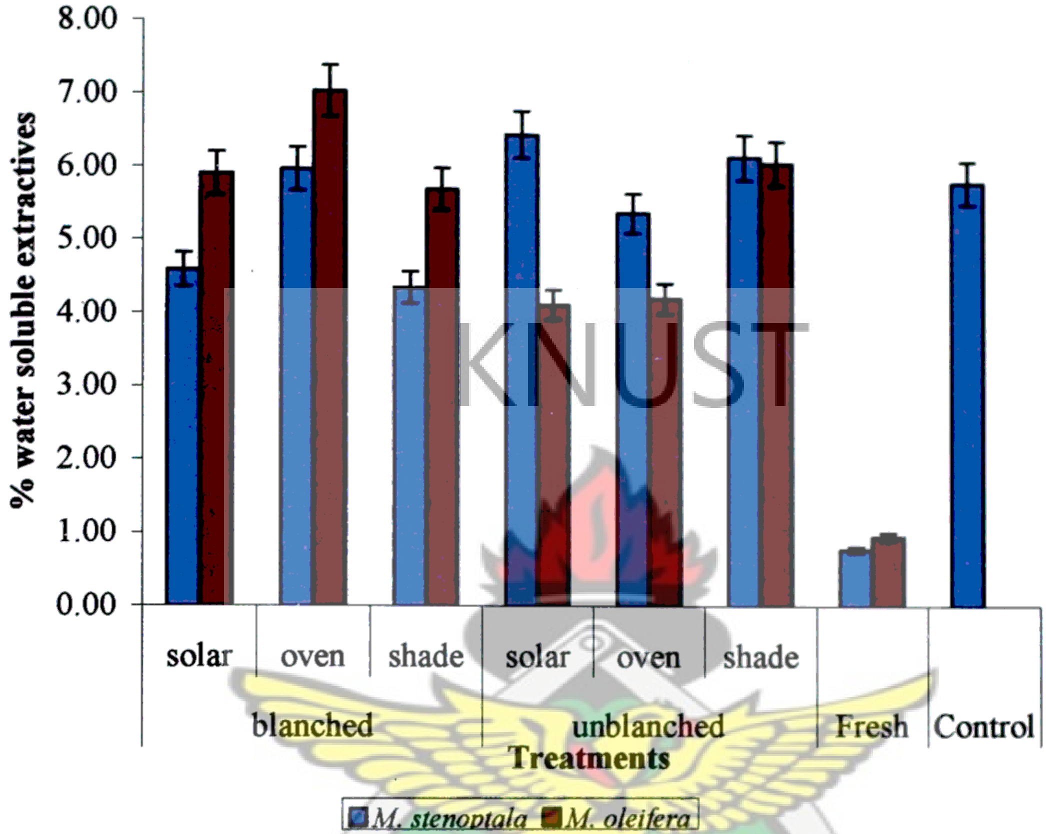

Figure 4.9 Effects of blanching and drying methods on Water soluble extractives contents of tea samples.

4.8 WATER-INSOLUBLE ASH (WIS)

Water-insoluble ash contents (WIS) ranged between 2.84 % to 4.70 % (figure 4.10) with oven-dried leaves for *M. oleifera* having the highest value (4.70 %). Values were generally high in un-blanched treated leaves than blanched treated leaves. It can be inferred from the observation made in the results of crude ash that blanched samples had lower values of water insoluble ash because of blanching effect; that is leaching of minerals during steam blanching. Regardless, there were no significant differences ($p > 0.05$) in WIS contents between blanched and un-blanched leaves.

Also, the three drying methods used did not bring about significant differences among the values observed ($p > 0.05$). However, there was significant difference at a probability level of 5% between species with *M. stenopetala* having lower values than *M. oleifera*. This could be attributed to differences in the two species.

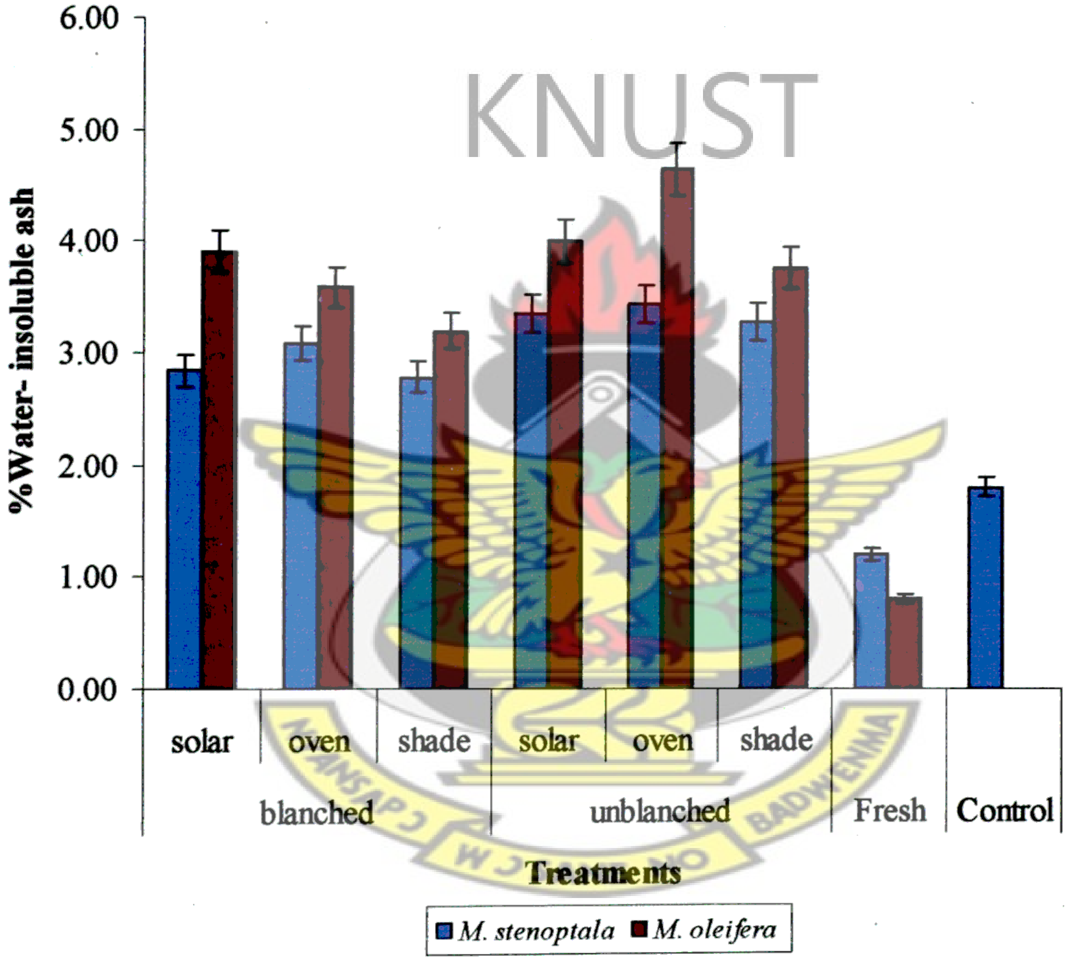

Figure 4.10 Effects of blanching and drying methods on water-insoluble ash contents of tea samples.

4.9 STALKS

Stalk contents for all treated leaves ranged from 2.89 % to 9.12 % (Figure 4.11). In a multiple comparison (Appendix F3) among the three drying methods, there was no significant difference in stalk contents between shade-dried leaves and solar-dried leaves. However, there was significant difference in stalks content between solar-dried and oven-dried leaves, where solar-dried leaves had mean value of 7.25% and oven-dried leaves had 5.14% (Appendix F2). There was no significant difference in stalks content between blanched and un-blanched leaves ($p > 0.05$). Values for *M. stenopetala* were relatively higher than those of *M. oleifera*, and this could be attributed to the large leaves of *M. stenopetala* (www.avrdc.org/LC/indigenous/Moringa, 2006) and thus have longer and thicker leaf stalks than those of *M. oleifera*. Stalk contents differed significantly ($p < 0.05$) between species.

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Stalks content was less marked in Twinnings earl grey green tea with a value of 0.71%. This is probably due to differences in leaf structure of *Camellia sinensis* used for the control and the two Moringa species used in this study, and the time of harvest. The stalks content of the Moringa leaves used in this study are desirable, since Kirk and Sawyer (1997) reported that the proportion of stalks should preferably be below 25 %. Percentage stalks exceeding this value means that the tea has lesser leaves than is expected.

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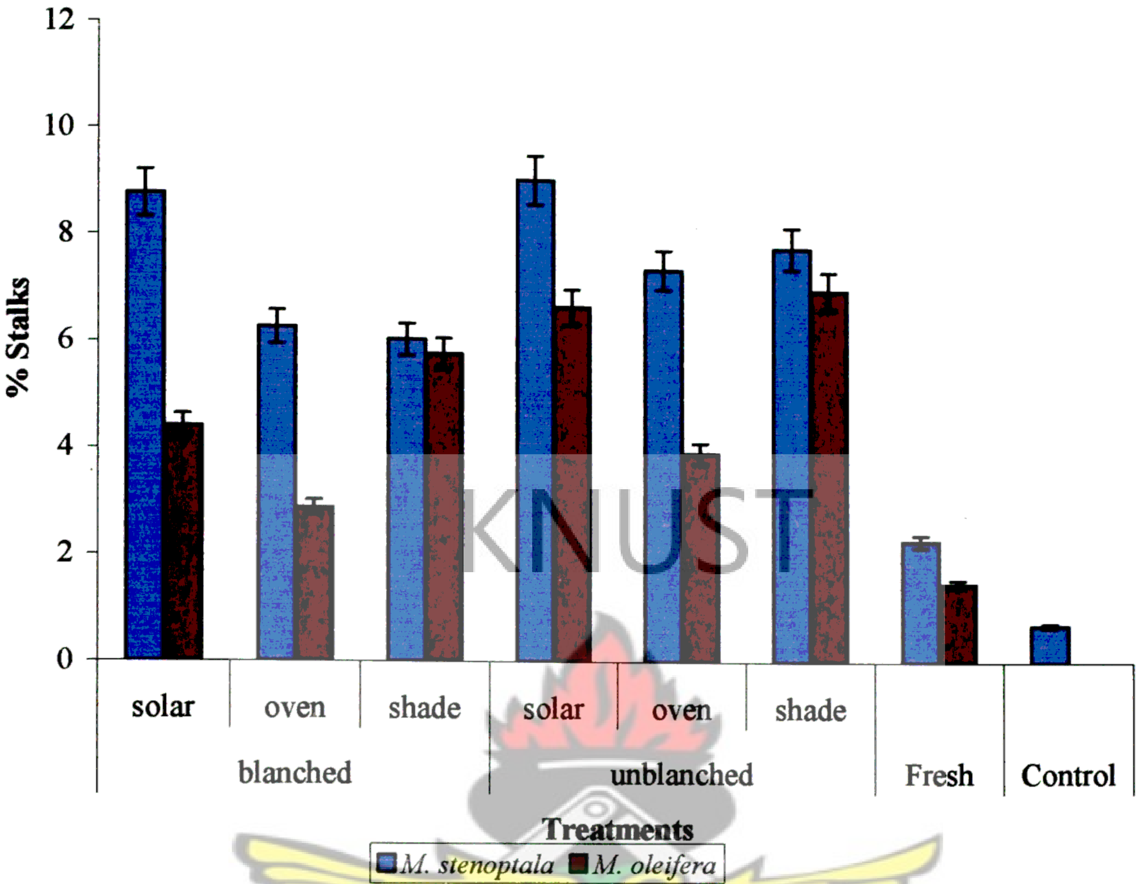

Figure 4.11 Effects of blanching and drying methods on stalks contents of tea samples.

4.10 pH

pH values ranged between 5.31 for oven-dried un-blanched for *M. oleifera* and 6.21 for solar-dried un-blanched for *M. stenopetala*, which means that the leaves are slightly acidic. Infusions from Moringa leaves had this pH range probably because of the high contents of heavy metals present in the leaves (Fuglie, 2001). They are also known to contain oxalic acids, which is an organic acid and phenolics such as chlorogenic acids (Amaglog, 2004). However, there was no significant difference ($p > 0.05$) in pH values between blanched and un-blanched leaves. pH values for the two species were significantly different ($p < 0.05$) with infusions of *M. stenopetala* leaves having relatively higher values than those of *M. oleifera* leaves. This could be attributed to differences in species. Green tea usually has a pH of 5.9, especially Japanese green tea (www.thenibble.com, 2008). Thus the observed pH range for the Moringa leaf infusions and that of the control (5.53) (Figure 4.12) are desirable.

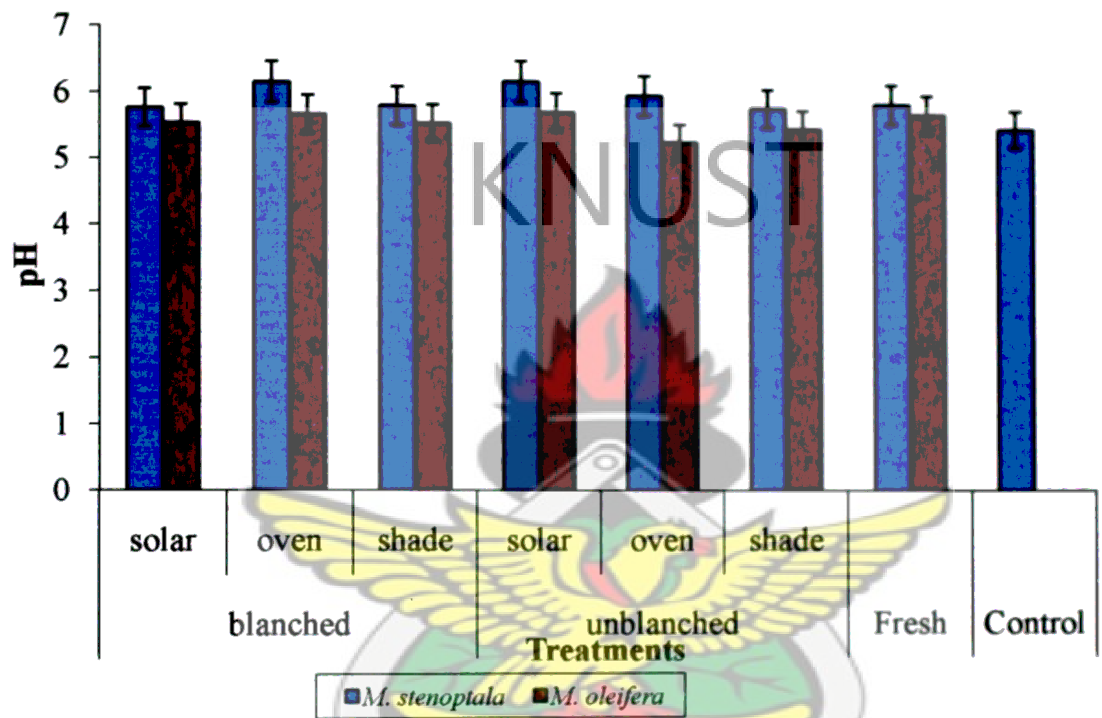

Figure 4.12 Effects of blanching and drying methods on pH of tea samples.

4.11 TOTAL POLYPHENOLS (TP) CONTENT

The results shown in figure 4.13 reveals that oven-dried leaves had the highest total polyphenols (TP) value of 2.08 % for *M. stenopetala* blanched leaves. The lowest value (1.40 %) was observed in shade-dried *M. stenopetala* leaves which were un-blanched. The results, also, showed that there were significant differences in TP contents ($p < 0.05$) when shade-dried leaves were compared with oven- and solar - dried leaves. Values were, however, not statistically different when solar- and oven-dried leaves were compared (Appendix F3). It can be inferred from the moisture contents results that since shade-dried leaves had higher moisture contents and the least were observed among oven-dried leaves, it is expected that shade-dried leaves will have lower concentrations of dry matter and the vice versa in oven-dried leaves. This reasoning could support these observations in TP contents. There was no significant difference ($p > 0.05$) in TP contents between blanched and un-blanched leaves suggesting that blanching did not have a significant effect on TP contents. TP contents for *M. oleifera* and *M. stenopetala* did not differ at the 5 % probability level.

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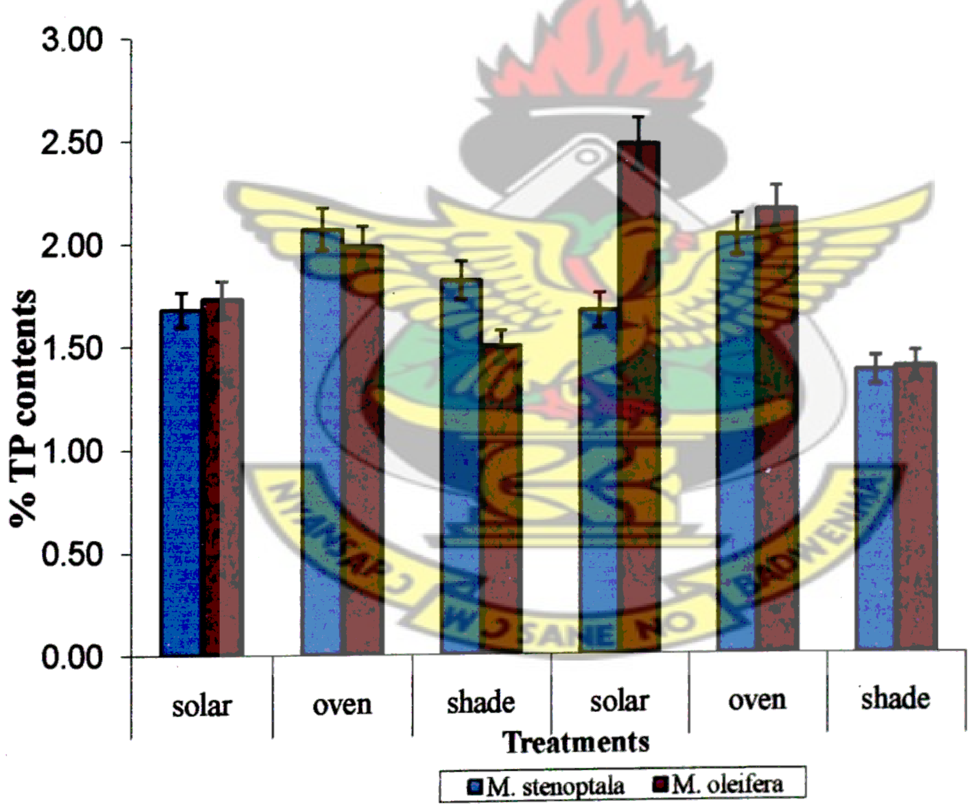

Figure 4.13 Effects of blanching and drying methods on total polyphenols contents of tea samples.

4.12 β–CAROTENE CONTENT

As indicated in Figure 4.14, β-carotene contents were particularly high in oven-dried leaves with the highest value being 21.62 mg/100g for blanched *M. oleifera* leaves. Solar-dried leaves had lowest values with blanched *M. stenopetala* leaves having the least value of 4.37 mg/100g. This observation strengthens the finding of Francis (1996) who reported that β-carotene is light sensitive, and thus significant losses can occur if leaves are exposed to sunlight during the drying process than in shade or oven. β-carotene contents were significantly different ($p < 0.05$) among the three drying methods, which suggest that the drying methods used had significant effect on β-carotene.

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β-carotene contents in blanched leaves were significantly ($p < 0.05$) higher than those of their corresponding un-blanched leaves. By inference, blanched leaves had lower moisture values than un-blanched leaves causing an increase in solid matter content (Greve *et al,* 1994; Waldron *et al*, 2003). More so, blanching does not destroy β-carotene, since β-carotene is heat stable and therefore is not destroyed by most methods of cooking (Francis, 1996). These are possible reasons why β-carotene content in blanched leaves are higher than un-blanched leaves. Additionally, *M. oleifera* leaves had more concentrations of β-carotene than *M. stenopetala* leaves (figure 4.14) which could be due to differences in species, and values differed significantly ($p < 0.05$).

The results showed that Moringa leaves have very high levels of ß-carotene with values ranging from 4.89 mg/100g to 23.42 mg/100g, whereas the Twinnings Earl Grey green tea had 4.37 mg/100g ß-carotene content (Figure 4.14). This observation is of significant interest since reports (www.greentealovers.com, 2006) indicate that β-carotene content is high in quality green teas. Also, this observation is desirable since Moringa leaves when treated have ß-carotene contents (per 100g of edible portions) which exceed the Recommended Daily Allowance for children (1.5 mg/100g) and for women and lactating mothers (5.7 mg/100g) (Fuglie, 2001). ß-carotene particularly has strong antioxidant effects *in vitro*, eliminating free radicals. It has been demonstrated to quench singlet oxygen ($^1O_2$), scavenge peroxyl radicals and inhibit lipid peroxidation. Antioxidants effects help prevent aging and cancer. It also promotes better vision (www.greentealovers.com, 2006).

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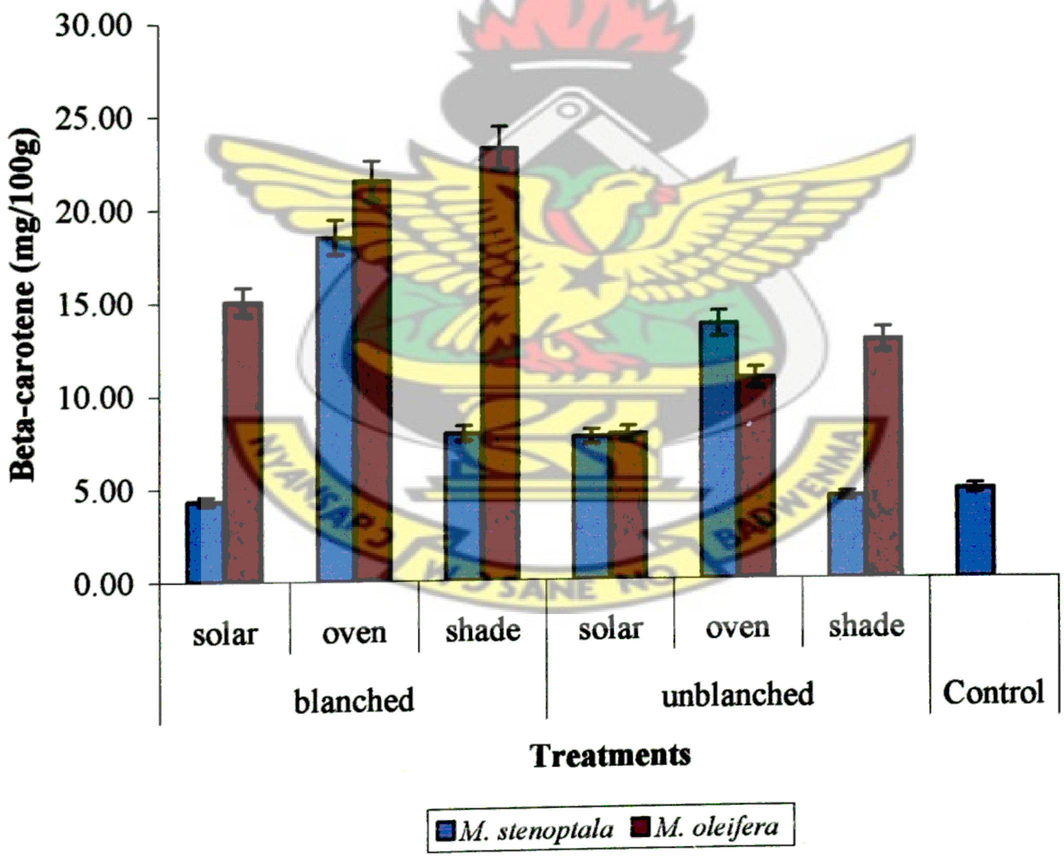

Figure 4.14 Effects of blanching and drying methods on β-carotene contents of tea samples.

4. 13 SENSORY ANALYSIS

4.13.1 COLOUR

Discriminatory test results in Figure 4.15 for tea infusions shows that tea infusions for solar-dried leaves for *M. stenopetala* which were blanched and the control had higher mean scores than all the tea samples. Also, blanched-dried leaves infusions revealed higher colour scores than those of the un-blanched, although not significant at 5 % probability level (appendix F5). However, all the tea infusions of processed Moringa leaves and the control rated high with no significant differences ($p > 0.05$) among their mean scores.

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A descriptive test results shown in Appendix F6 on tea samples revealed that 75.9 % of the sensory panellists described the colour of the Moringa tea infusions as golden yellow, whereas 6.7% of the panellists described the control (Twinnings earl grey green tea) infusion to have a brownish colour (dark golden yellow). These colours are desirable since green tea rarely brews as green - rather, the name refers to the colour of its leaves, which are green. Green tea usually has a yellow appearance when brewed, whereas herbal infusions have pale yellow to dark golden colour (www.teainfusion.com/types/greentea.html, 2006). Any other colour especially, brown, would mean that fermentation processes have occurred during drying resulting in enzymatic browning by polyphenol oxidase present in the leaves. This leads to the formation of furfurals which are brown pigment undesirable in green tea production (Kirk and Sawyer, 1997).

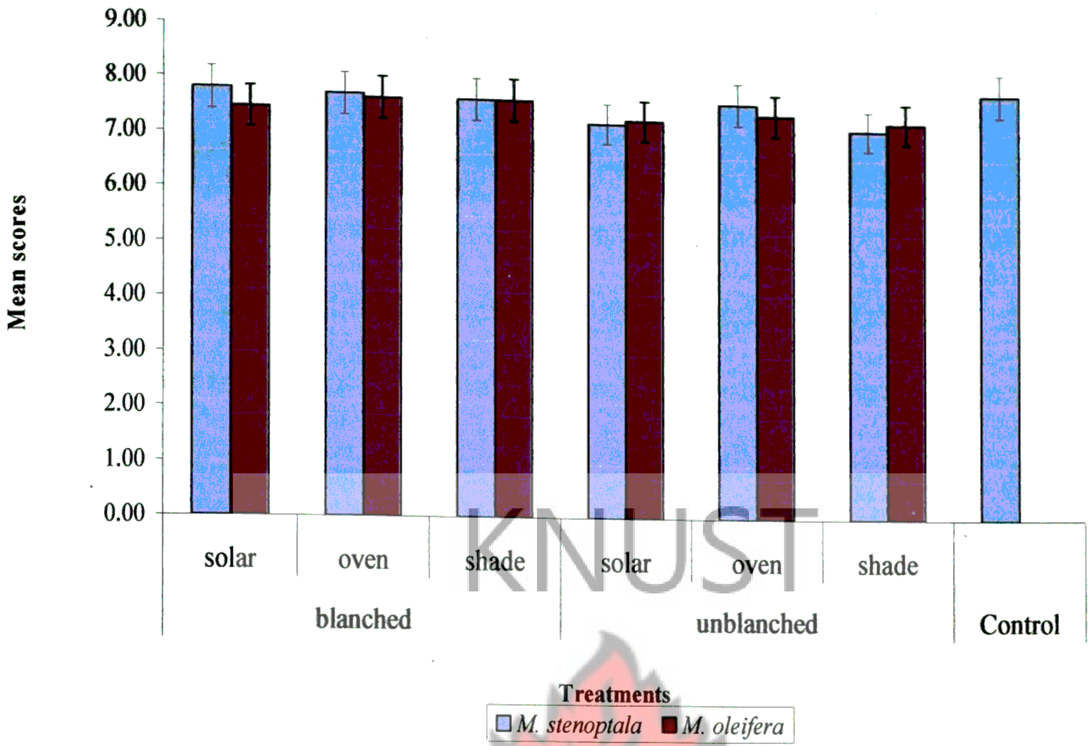

Figure 4.15 Effects of blanching and drying methods on colour acceptability of tea samples.

4.13.2 FLAVOUR

Flavour is the perception one gets after tasting food, which includes both the taste and aroma of the food (Stone and Sidel, 2004). The preference on the aroma score for all the tea samples were not significantly different ($p > 0.05$) with mean scores ranging between 6.33 and 7.47 for moringa tea leaves and 7.80 (Figure 4.15) for the Twinnings earl grey green tea (control). This suggests that the different processing techniques did not influence the aroma of the tea infusions for Moringa leaves and that they compared very well with the commercial green tea (control).

Majority (64.1%) of the panellists described the tea infusions including that of the control as having herbal flavour, but 32.3% described the flavour as being pleasant (Appendix F6). This could be attributed to the fact that, generally, green tea has a

(Appendix F6). This could be attributed to the fact that, generally, green tea has a fresh, light taste reminiscent of grass - "true taste of herbs" (www.teainfusion.com/types/greentea.html, 2006). Green tea retains most of the major compounds (for example essential oils) occurring in the leaves, which are either soluble in boiling water or will release into the water in time, due to the interactions occurring during the water extraction process. Therefore, green tea infusion allows the natural interactions between the various components in the herbs to occur (www.traditionalmedicinal.com, 2006) resulting in the herbal taste. The herbal taste observed in this study for the tea samples is desirable.

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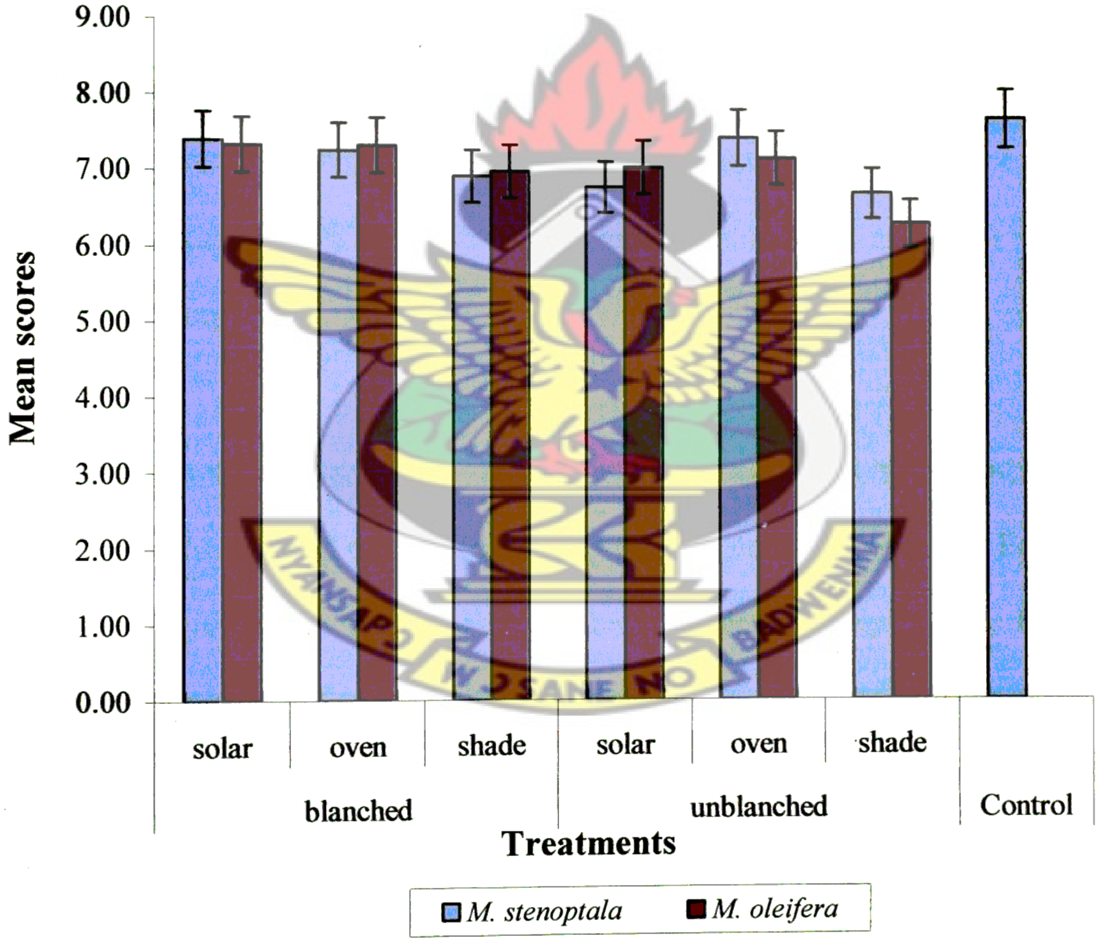

Figure 4.16 Effects of blanching and drying methods on aroma acceptability of tea samples

4.13.3 ASTRINGENCY

Infusion from solar-dried un-blanched leaves for *M. stenopetala* had a significantly lower ($p < 0.05$) mean score of 6.80 (Figure 4.17). However, there were no significant differences among the other Moringa tea samples. Generally, astringency of blanched leaves tea samples were preferred to the un-blanched ones, though not significantly different.

Descriptive test results (Appendix F6) indicate that, 5.1% out of 7.7% of panellists described astringency of the control to be very high, and that of the Moringa tea leaves to be on the lower side or not perceived. This could be attributed to the high content of polyphenols (mostly tannins) in the control than the Moringa tea leaves. Also, by inference younger leaves are used in the production of the control (www.twinnings.com, 2007), which include more catechin than mature ones, when leaf order is compared.

The discriminatory sensory test on the tea samples revealed that astringency for the Moringa tea infusions had higher mean scores than the control (Twinnings Earl Grey green tea) (Figure 4.17). Mean scores for the Moringa tea samples were between 6.80 and 7.73 (which were close to the like extremely point on the hedonic scale), and that of the control was 5.40 (Figure 4.17). This observation is consistent with findings of Siebert (2005) who reported that astringency being a natural part of the overall flavour of many foods can be strong enough to be unpleasant for example, in green tea where tannin is mostly catechin and is a key component in its taste providing the astringency (Siebert, 2005; www.greentealovers.com, 2007). This could explain the low mean score observed for the control. Mean scores were significantly different ($p > 0.05$) between the Moringa tea infusions and that of the control.

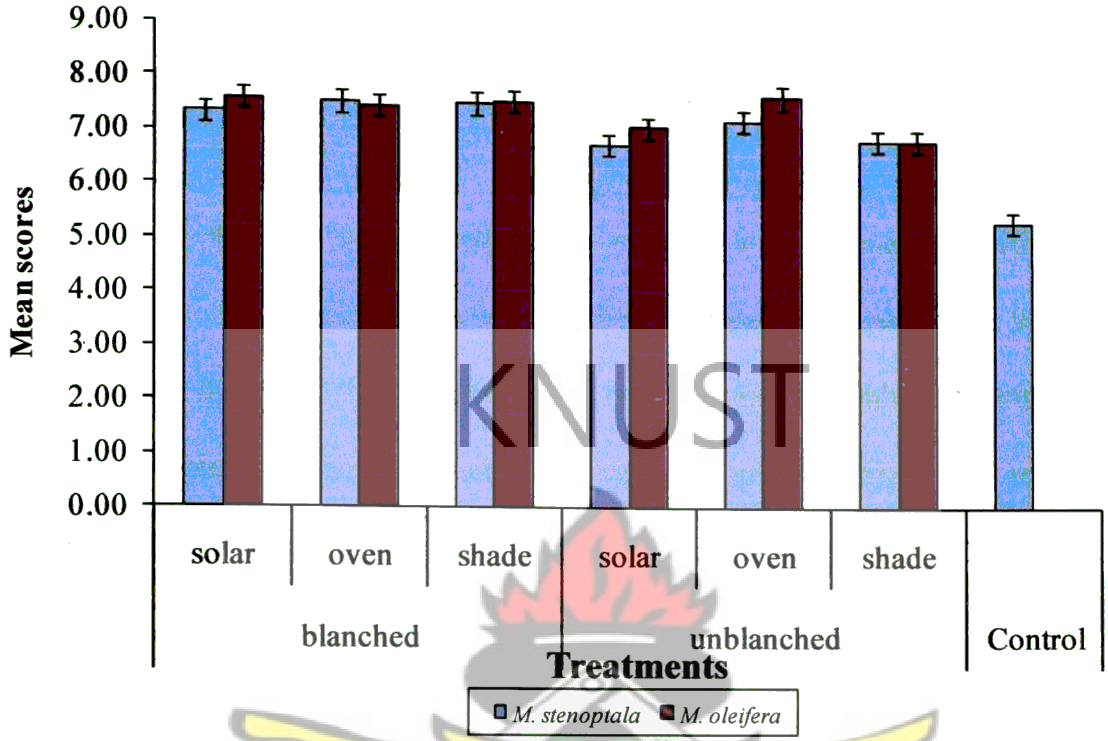

Figure 4.17 Effects of blanching and drying methods on astringency acceptability of tea samples.

4.13.4 AFTER-TASTE

The results of after-taste preference test in Figure 4.18 show that the mean scores for Moringa tea infusions ranged from 6.27 to 7.60, and were significantly different ($p < 0.05$) from the control which had a mean score of 5.33 (Figure 4.18). Thus the after-taste of Moringa tea samples was preferred to that of the Twinnings Earl Grey green tea (commercial green tea). Among the Moringa teas, panellists did not like the infusions from un-blanched solar-dried leaves for both *M. stenopetala* and *M. oleifera*, with mean scores of 6.27 and 6.67 respectively and un-blanched shade-dried leaves for *M. stenopetala* with mean score of 6.53 (Figure 4.18 and Appendix

F5), however, these values were still within the acceptable range on the hedonic scale. Mean scores for these samples were lower than the other moringa tea infusions ($p < 0.05$) probably because the processing methods used gave an undesirable after-taste. However, mean scores for the other Moringa tea samples were not significantly different ($p > 0.05$) (Appendix F5).

Of the panellists, 90.3 % described the tea infusions as being pleasant with 2.1 % out of the 90.3 % describing the control as being pleasant. The remaining 9.7 % of the panellists described the tea infusions as being unpleasant with 5.6 % out of the 9.7 % describing the control as being unpleasant (Appendix F6). This is probably because of the high astringent taste (as shown by a low mean score of 5.40; Figure 4.17) due to the presence of high tannins in the control.

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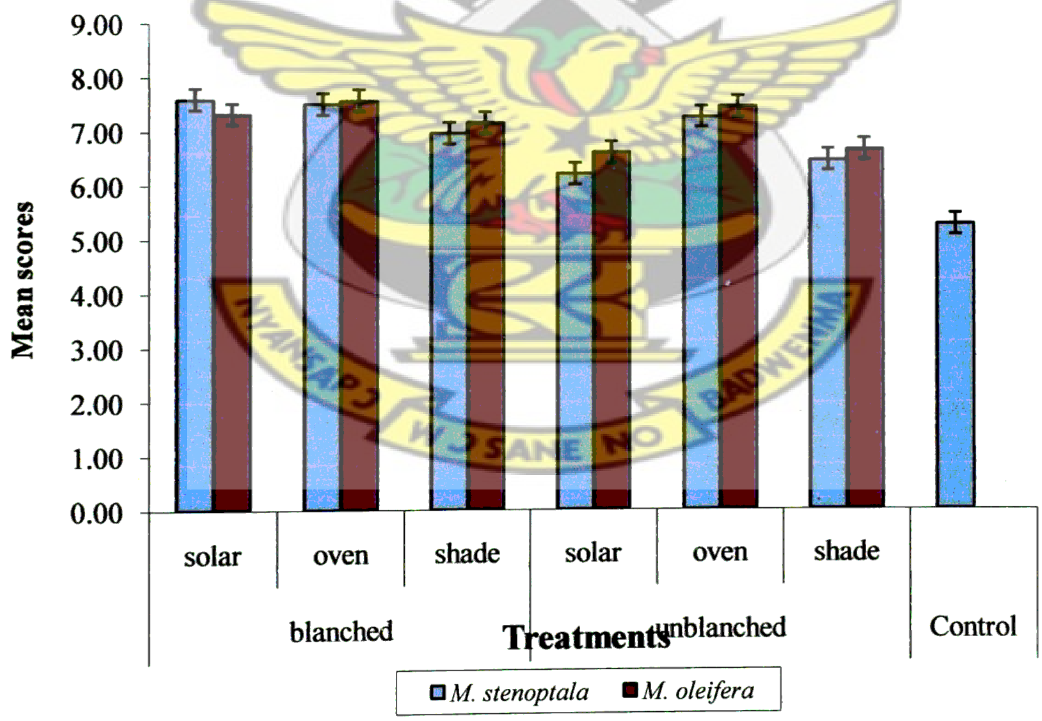

Figure 4.18 Effects of blanching and drying methods on After-taste acceptability of tea samples

4.13.5 MOUTH FEEL

The results (Figure 4.19) showed that the Moringa tea infusions record significantly ($p < 0.05$) higher mouth feel score (mean score ranging from 6.87 to 7.87) than that of the control (mean score of 5.53). Mouth feel gives an indication of what the consumer feels when the tea is tasted. It could be sweet, bitter, astringent or tasteless. Caffeine is known to give teas a bitter taste, certain amino acids, for example thiamine, gives teas a sweet taste (www.greentealover.com, 2006), polyphenols and acids give teas an astringent taste and a tea free from all these will be tasteless (Seibert, 2005). Thus the high astringent taste of the control could have accounted for the low mean score ranking of the control by the panellists. Also, the blanched leaves tea infusions had higher mean scores than those of the un-blanched (Figure 4.19 and Appendix F5).

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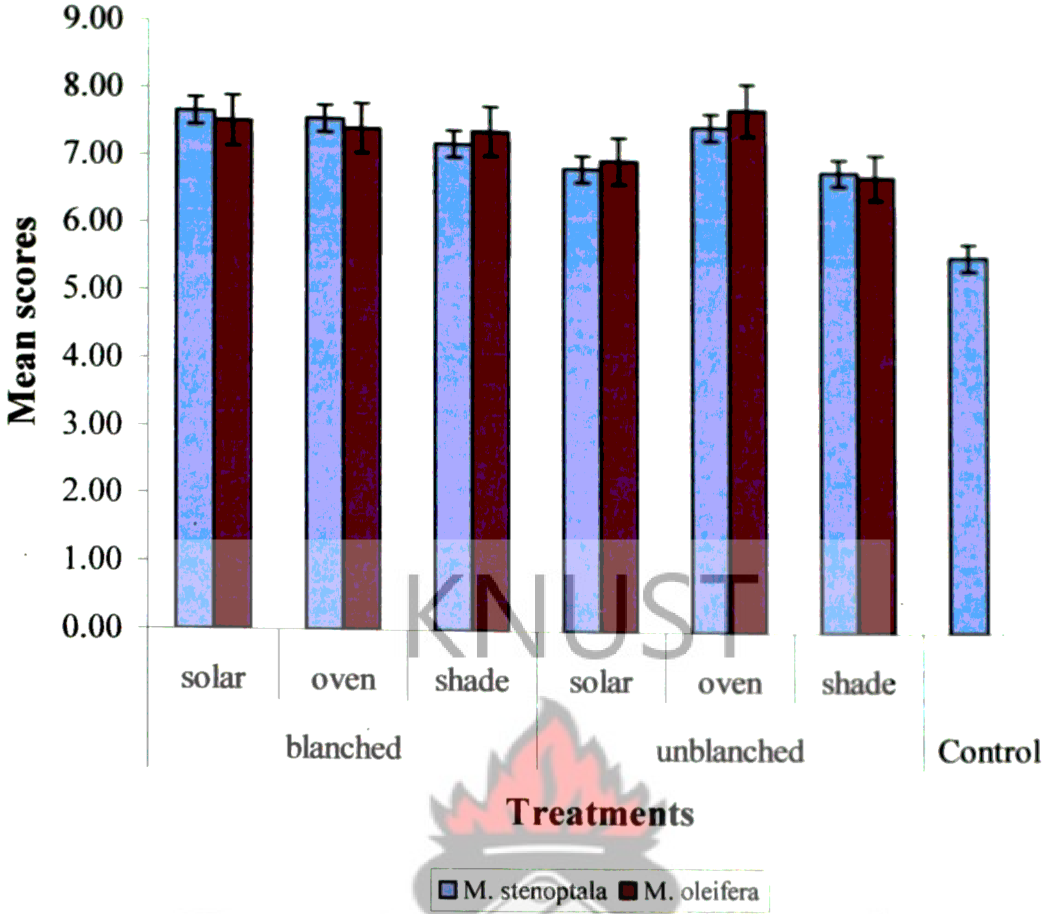

Figure 4.19 Effects of blanching and drying methods on mouth feel acceptability of tea samples

4.13.6 OVERALL ACCEPTABILITY

Solar-dried blanched leaves for *M. stenopetala* had a significantly higher ($p < 0.05$) overall acceptability score of 7.73 while the least preferred among all the processed leaves was solar-dried un-blanched *M. stenopetala* with a mean score of 6.47 (Figure 4.20). As expected, blanched leaves tea samples were rated relatively higher than those of the un-blanched (Appendix F). The mean scores for Moringa tea infusions ranged from 6.47 to 7.73, whereas the mean score for the control was 5.87 (Figure 4.20). Overall acceptability is a sensory parameter, which indicates the overall preference of a product. Its score is based on all the sensory attributes such as colour, aroma, mouth feel, after-taste and astringency perceived by the panellist. The results revealed that the choice of the Moringa leaves over the control was based on the mouth feel, after-taste and astringency attributes rather than colour and aroma attributes. This is because the mean scores for colour and aroma acceptability were not significantly different for all the tea samples (including the control).

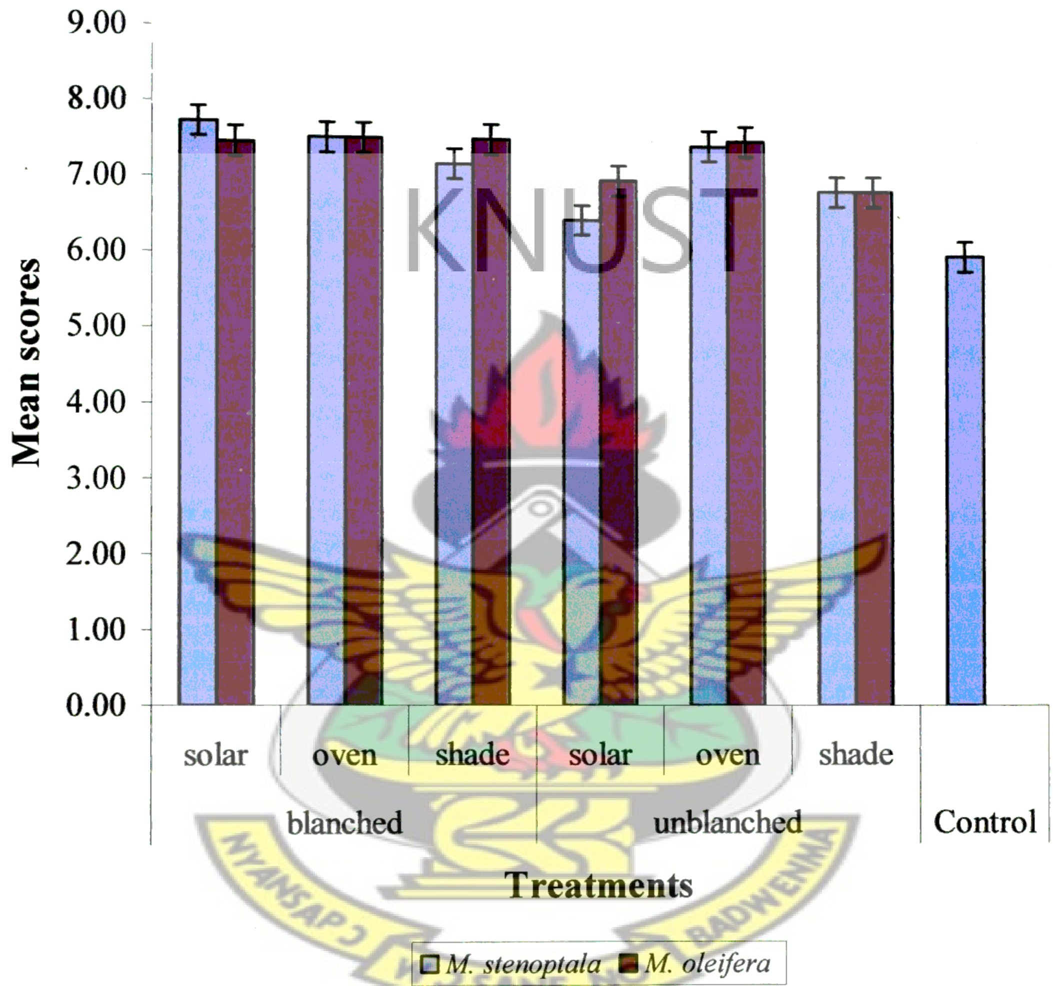

Figure 4.20 Effects of blanching and drying methods on overall acceptability of tea samples

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The two species of Moringa used for the herbal tea in this study had relatively high levels of crude protein, crude fibre, LPE, β-carotene as well as sufficient Zn and Fe when processed. There were no significant differences in all the parameters carried out on both species except in crude ash and β-carotene contents, where contents in *M. oleifera* leaf powder were significantly higher than those of *M. stenopetala*. This indicates that there exist differences in species. Among the three drying methods (solar, shade and oven), oven drying at 60 °C for 6hrs had the best nutritional and physicochemical properties of the processed leaf powder for Moringa herbal tea. Blanching had variable effects on the dry matter contents of processed leaves. It caused significant reductions in crude ash and WIS contents in both species. However, blanching facilitated moisture loss during drying, thus there was significant increase in contents of β-carotene, fibre and pH values.

These latter trends was consolidated by the sensorial results showing much difference between blanched and un-blanched tea samples with tea infusions of blanched leaves receiving significantly higher sensory scores than those of un-blanched. Also, infusions of oven-dried leaf powders had the best sensorial results. Furthermore, results showed that Moringa herbal green teas were preferred to the commercial green tea in terms of astringency, after-taste and mouth feel. It is therefore evident that different methods of processing could have an effect on the nutritional, physicochemical and sensorial properties of Moringa leaves and the overall acceptability by consumers.

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5.2 RECOMMENDATIONS

1. Further research regarding the shelf life for Moringa tea samples must be done.
2. Processors and consumers need to be educated about the best processing method which will give Moringa herbal tea the best nutritional and sensorial properties.
3. Awareness needs to be raised among processors and consumers that processing methods used in the production of Moringa products can greatly alter nutritional contents (especially vitamins).
4. Consciousness must be raised among consumers about Moringa products which may be adulterated, as well as erroneous information on Moringa products on the market.

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APPENDICES

APPENDIX A: FORMULAE USED IN THE ANALYSES

1. $$\% \text{ moisture} = \frac{\text{loss in weight of sample} * 100}{\text{original weight of the sample}}$$

2. $$\% \text{ Ash} = \frac{\text{weight of ash} * 100}{\text{dry weight of the sample used}}$$

3. $$\% \text{ LPE} = \frac{\text{weight of LPE extract} * 100}{\text{dry weight of sample used}}$$

4. $$\% \text{ crude fibre} = \frac{\text{weight of fibre obtained} * 100}{\text{dry weight of sample}}$$

5. $$\% \text{ nitrogen} = \frac{100 * (V_A - V_B) * N_A * 0.01401}{\text{Weight of sample} * 100}$$

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Where;

V_A = Volume in mL of standard acid used in the titration of the sample

V_B = Volume in mL of standard acid used in the titration of the blank

N_A = Normality of the acid used

% crude protein = % total nitrogen * 6.25

6. $$\beta\text{-carotene content } \mu g/\mu l = \frac{\text{Absorbance} \times 10{,}000}{2592 \times \text{sample weight}}$$

7. $$\text{Iron (mg/100g)} = \frac{50 \times \text{Concentration}}{\text{Sample weight} \times 10}$$

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8. $$\text{Calcium (mg/100g)} = \frac{50 \times \text{Concentration} \times 100}{\text{Sample weight} \times 10}$$

APPENDIX B: TABLES OF RESULTS

Table .1 **Nutrtional analysis of treated *Moringa oleifera* leaves**

	%Moisture	% protein	% ash	% LPE	% Fibre	Cabohydrate (by ifference)	Caloric value (J/g)
Treatment							
Blanched							
Solar-dried	9.75 ±0.03	26.67 ± 0.15	8.46 ± 0.06	5.68 ± 0.10	11.13 ± 0.02	38.25 ± 0.26	1314.78 ± 0.05
Shade-dried	18.48 ± 0.06	27.47 ± 0.05	7.13 ± 0.03	4.15 ± 0.07	9.26 ± 0.04	33.51 ± 0.08	1190.23 ± 2.16
Oven-dried	2.9 ± 0.02	28.97 ± 0.00	8.03 ± 0.06	5.41 ± 0.03	10.22 ± 0.01	44.47 ± 0.02	1448.48 ± 0.99
Un-blanched							
Solar-dried	11.32 ± 0.11	26.74 ± 0.05	8.57 ± 0.08	4.48 ± 0.08	11.92 ± 0.04	37.04 ± 0.47	1248.93± 2.26
Shade-dried	19.92 ± 0.02	24.81 ± 0.00	8.04 ± 0.04	4.02 ± 0.02	10.36 ± 0.07	32.84 ± 0.07	1128.90± 0.39
Oven-dried	3.38 ± 0.08	28.31 ± 0.10	8.79 ± 0.06	5.73 ± 0.06	8.39 ± 0.04	45.40 ± 0.26	1465.02 ± 0.57
Fresh	76.36 ± 0.22	6.24 ± 0.05	2.19 ± 0.03	1.98 ± 0.03	1.35 ± 0.00	11.88 ± 0.11	358.11 ± 2.72

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Table .2 Nutritional analysis of treated *Moringa stenopetala* leaves

	%Moisture	% protein	% ash	% LPE	% Fibre	Cabohydrate (by difference)	Caloric value (J/g)
Treatment							
Blanched							
Solar-dried	6.24 ± 0.02	29.01 ±0.05	5.71± 0.13	5.17 ± 0.02	12.6 ± 0.07	41.28 ± 0.14	1385.91 ± 4.11
Shade-dried	12.94 ± 0.07	25.87 ±0.10	5.01± 0.05	3.98 ± 0.06	12.26 ± 0.01	39.94 ± 0.13	1266.15± 3.40
Oven-dried	2.24 ± 0.05	29.37 ±0.05	8.00± 0.09	5.27 ± 0.04	10.11 ± 0.05	45.02 ± 0.00	1459.74 ± 0.75
Un-blanched							
Solar-dried	7.00 ± 0.02	27.22 ± 0.05	7.2 ± 0.05	4.35 ± 0.08	12.19 ± 0.09	42.04 ± 0.16	1338.43 ± 1.99
Shade-dried	17.67 ± 0.07	25.28 ± 0.05	6.73 ± 0.04	2.61 ± 0.07	10.26 ± 0.07	37.42 ± 0.01	1162.62 ± 2.06
Oven-dried	2.66 ± 0.02	28.46 ± 0.10	9.95 ± 0.02	5.33 ± 0.04	9.92 ± 0.05	43.76 ± 0.03	1423.60± 0.60
Fresh	76.99 ± 0.10	6.57 ± 0.00	1.29 ± 0.04	2.28 ± 0.00	1.23 ± 0.00	11.64 ± 0.14	354.82 ± 2.20
Control	9.82 ± 0.28	25.28 ± 0.05	5.82 ± 0.05	3.79 ± 0.12	12.79 ± 0.72	42.50± 0.32	1292.55 ± 10.81

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Table 3 Physicochemical Analysis of treated *Moringa oleifera* leaves

	%WSE	Ph	%WIS	%Stalks
Treatment				
Blanched				
Solar-dried	5.91 ± 0.03	5.53 ± 0.01	3.91 ± 0.03	4.41 ± 0.11
Shade-dried	5.73 ± 0.01	5.56 ± 0.03	3.21 ± 0.04	5.81 ± 0.02
Oven-dried	7.06 ± 0.01	5.68 ± 0.02	3.60 ± 0.02	2.89 ± 0.07
Un-blanched				
Solar-dried	4.15 ± 0.02	5.75 ± 0.04	4.04 ± 0.01	6.72 ± 0.11
Shade-dried	6.14 ± 0.01	5.50 ± 0.01	3.82 ± 0.04	7.08 ± 0.05
Oven-dried	4.25 ± 0.01	5.31 ± 0.03	4.70 ± 0.02	3.96 ± 0.05
Fresh	0.97 ± 0.03	5.75 ± 0.06	0.81 ± 0.04	1.50 ± 0.01

Table 4 **Physicochemical Analysis on treated *Moringa stenopetala* leaves**

	%WSE	pH	%WIS	%Stalks
Treatment				
Blanched				
Solar-dried	4.59 ± 0.02	5.76 ± 0.04	2.84 ± 0.06	8.77 ± 0.12
Shade-dried	4.37 ± 0.01	5.82 ± 0.01	2.80 ± 0.03	6.07 ± 0.03
Oven-dried	5.98 ± 0.02	6.16 ± 0.04	3.10 ± 0.01	6.28 ± 0.03
Un-blanched				
Solar-dried	6.50 ± 0.02	6.21± 0.04	3.38 ± 0.02	9.12 ± 0.04
Shade-dried	6.22 ± 0.02	5.83 ± 0.03	3.32 ± 0.04	7.88 ± 0.09
Oven-dried	5.43 ± 0.01	6.01 ± 0.06	3.48 ± 0.02	7.45 ± 0.03
Fresh	0.79 ± 0.00	5.90 ± 0.01	1.21 ± 0.02	2.31 ± 0.11
Control	5.88 ± 0.02	5.53 ± 0.01	1.83 ± 0.03	0.7 ± 0.02

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Table 5 **Minerals, β-carotene and Polyphenol Analysis on treated *M. oleifera* leaves**

	%Zn	%Fe	%Polyphenol	β-carotene(mg/100g)
Treatment				
Blanched				
Solar dried	3.11 ± 0.01	11.52 ± 0.61	1.74 ± 0.04	15.10 ± 0.01
Shade dried	2.32 ± 0.02	9.66 ± 0.00	1.51± 0.00	23.42± 0.02
Oven dried	4.19 ± 0.01	15.48 ± 0.01	2.00 ± 0.03	21.62 ± 0.02
Un-blanched				
Solar dried	3.14 ± 0.02	9.82 ± 0.08	2.51 ± 0.05	7.94 ± 0.08
Shade dried	3.84± 0.00	10.11 ± 0.00	1.42 ± 0.01	13.05 ± 0.01
Oven dried	9.68 ± 0.00	16.94 ± 0.02	2.19 ± 0.02	10.99 ± 0.02
Fresh	0.87 ± 0.00	1.84 ± 0.10		

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Table 6 **Minerals, β-carotene and polyphenol analysis on treated *M. stenopetala* leaves**

Treatment	%Zn	%Fe	%Polyphenol	β-carotene(mg/100g)
Blanched				
Solar dried	4.69 ± 0.01	10.97 ± 0.01	1.68 ± 0.00	4.37± 0.01
Shade dried	4.27 ± 0.01	10.52 ± 0.01	1.83 ± 0.00	8.00 ± 0.01
Oven dried	4.27 ± 0.01	14.58 ± 0.01	2.08 ± 0.03	18.59 ± 0.01
Un-blanched				
Solar dried	2.79 ± 0.00	8.90 ± 0.14	1.69 ± 0.00	7.79 ± 0.01
Shade dried	3.40 ± 0.01	13.34 ± 0.01	1.40 ± 0.04	4.51 ± 0.01
Oven dried	5.81 ± 0.01	15.42 ± 0.02	2.06 ± 0.01	13.91 ± 0.01
Fresh	0.93 ± 0.00	4.72 ± 0.10		
Control	2.09 ± 0.01	14.54 ± 0.02	12.79 ± 0.05	4.89 ± 0.01

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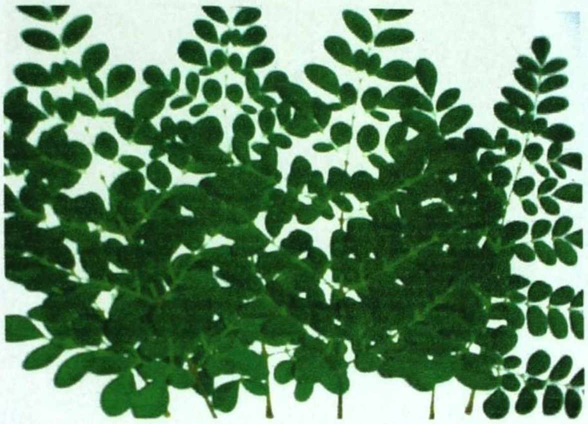
APPENDIX C: PLATES OF FRESH AND PROCESSED LEAVES



Un-blanched *Moringa oleifera* leaves

Blanched *M.oleifera* leaves

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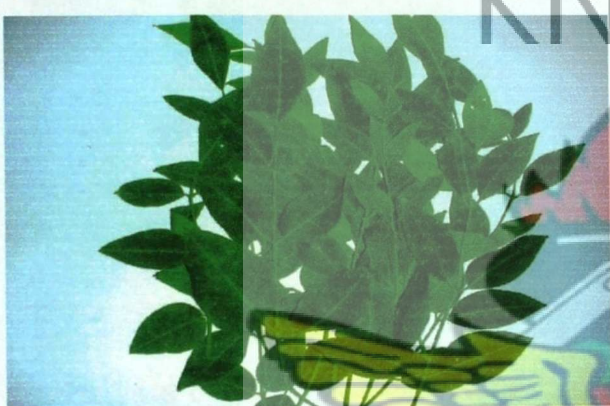


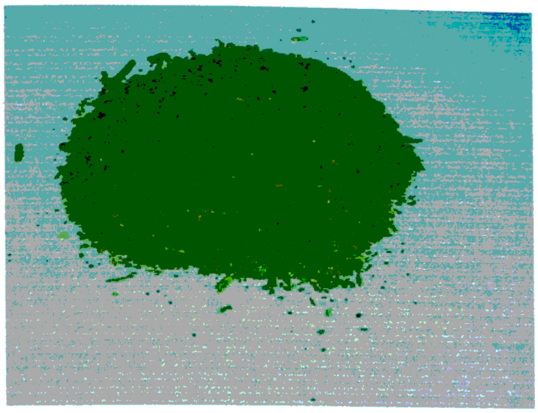
Un-blanched *M. stenopetala* leaves

Blanched *M. stenopetala* leaves

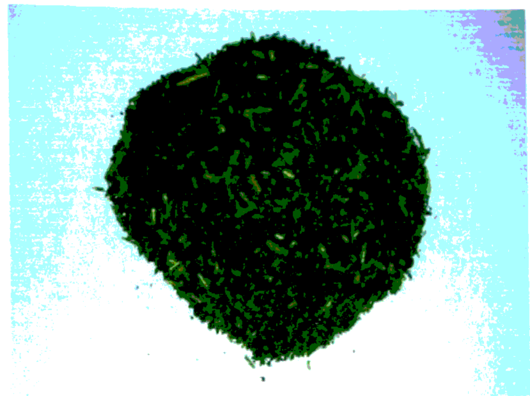
Solar-dried leaves

Un-blanched *M. oleifera*

blanched *M. oleifera*



Un-blanched *M. stenopetala*



Blanched *M. stenopetala*

Shade-dried leaves

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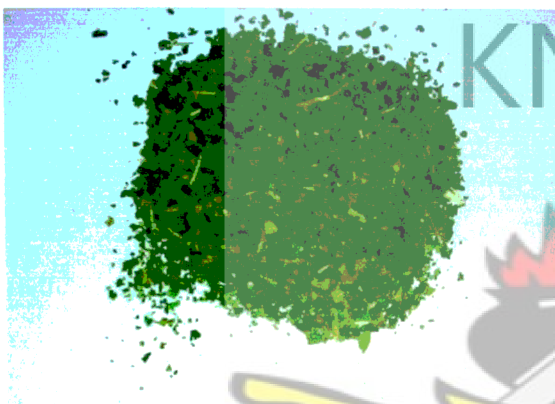
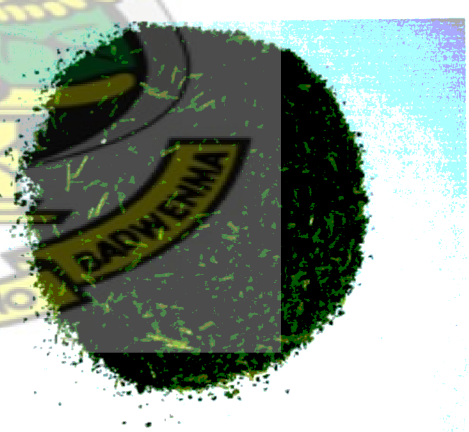


Un-blanched *M. stenopetala*

Blanched *M. stenopetala*

Un-blanched *M. oleifera*



Blanched *M. oleifera*

Oven-dried leaves

Un-blanched *M. stenopetala*

Blanched *M. Stenopetala*

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Un-blanched *M. oleifera*

Blanched *M. oleifera*

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APPENDIX D: PLATE OF THE MORINGA TEA PACKAGE

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APPENDIX E: SENSORY EVALUATION QUESTIONNAIRE DESIGN

Name: Date:

Product: Sample code:

You have been given samples of green tea. Examine and evaluate them in terms of the listed attributes and the scale below. Wash down the previous sample before attempting the next.

		Colour	Aroma	After-taste	Mouth feel	Astringency	Overall Acceptability
9	Like extremely						
8	Like very much						
7	Like moderately						
6	Like slightly						
5	Neither like nor dislike						
4	Dislike slightly						
3	Dislike moderately						
2	Dislike very much						
1	Dislike extremely						

Please underline and comment on the appropriate description of the sample
Flavour (Taste and aroma): Stale , Pleasant, herbal
Colour: Golden yellow, brownish, dark brown
Astringency: slightly, very, not at all
After-taste: Pleasant, unpleasant

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APPENDIX F 1: STATISTICAL TABLES

Table1. Anova for treatments

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
% stalks	Between Groups	36.015	1	36.015	18.389	.000
	Within Groups	43.086	22	1.958		
	Total	79.101	23			
%WSE	Between Groups	.004	1	.004	.004	.948
	Within Groups	20.571	22	.935		
	Total	20.575	23			
%Ash	Between Groups	6.880	1	6.880	4.418	.047
	Within Groups	34.257	22	1.557		
	Total	41.137	23			
%WIS	Between Groups	3.147	1	3.147	21.299	.000
	Within Groups	3.250	22	.148		
	Total	6.396	23			
%Protein	Between Groups	.767	1	.767	.339	.566
	Within Groups	49.744	22	2.261		
	Total	50.510	23			
%Moisture	Between Groups	48.167	1	48.167	1.192	.287
	Within Groups	889.186	22	40.418		
	Total	937.352	23			
%LPE	Between Groups	1.265	1	1.265	1.610	.218
	Within Groups	17.288	22	.786		
	Total	18.553	23			
%Fibre	Between Groups	6.161	1	6.161	4.308	.050
	Within Groups	31.465	22	1.430		
	Total	37.626	23			
%Carbohydrate	Between Groups	.155	1	.155	.020	.890
	Within Groups	173.337	22	7.879		
	Total	173.492	23			
%Caloric value	Between Groups	396.825	1	396.825	.783	.386
	Within Groups	11144.075	22	506.549		
	Total	11540.901	23			
PH	Between Groups	.984	1	.984	36.203	.000
	Within Groups	.598	22	.027		
	Total	1.582	23			
Fe	Between Groups	.006	1	.006	.001	.977
	Within Groups	166.002	22	7.546		
	Total	166.009	23			
Zn	Between Groups	.182	1	.182	.049	.828
	Within Groups	82.425	22	3.747		
	Total	82.607	23			
Polyphenols	Between Groups	.065	1	.065	.588	.451
	Within Groups	2.436	22	.111		
	Total	2.501	23			
Beta Carotene	Between Groups	204.575	1	204.575	6.598	.018
	Within Groups	682.157	22	31.007		
	Total	886.733	23			

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Table2. **Anova for Drying Method**

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
% stalks	Between Groups	19.115	2	9.558	3.346	.055
	Within Groups	59.986	21	2.856		
	Total	79.101	23			
%WSE	Between Groups	.724	2	.362	.383	.687
	Within Groups	19.852	21	.945		
	Total	20.575	23			
%Ash	Between Groups	15.676	2	7.838	6.464	.006
	Within Groups	25.462	21	1.212		
	Total	41.137	23			
%WIS	Between Groups	.760	2	.380	1.416	.265
	Within Groups	5.636	21	.268		
	Total	6.396	23			
%Protein	Between Groups	33.693	2	16.847	21.037	.000
	Within Groups	16.817	21	.801		
	Total	50.510	23			
%Moisture	Between Groups	847.464	2	423.732	98.994	.000
	Within Groups	89.888	21	4.280		
	Total	937.352	23			
%LPE	Between Groups	12.822	2	6.411	23.494	.000
	Within Groups	5.731	21	.273		
	Total	18.553	23			
%Fibre	Between Groups	21.499	2	10.750	13.998	.000
	Within Groups	16.126	21	.768		
	Total	37.626	23			
%Carbohydrate	Between Groups	154.343	2	77.172	84.631	.000
	Within Groups	19.149	21	.912		
	Total	173.492	23			
%Caloric value	Between Groups	3354.894	2	1677.447	4.303	.027
	Within Groups	8186.007	21	389.810		
	Total	11540.901	23			
PH	Between Groups	.077	2	.038	.535	.594
	Within Groups	1.506	21	.072		
	Total	1.582	23			
Fe	Between Groups	134.970	2	67.485	45.659	.000
	Within Groups	31.039	21	1.478		
	Total	166.009	23			
Zn	Between Groups	34.496	2	17.248	7.528	.003
	Within Groups	48.112	21	2.291		
	Total	82.607	23			
Polyphenols	Between Groups	1.238	2	.619	10.282	.001
	Within Groups	1.264	21	.060		
	Total	2.501	23			
Beta Carotene	Between Groups	222.776	2	111.388	3.523	.048
	Within Groups	663.956	21	31.617		
	Total	886.733	23			

Table 3. Anova for species

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
% stalks	Between Groups	10.587	1	10.587	3.399	.079
	Within Groups	68.514	22	3.114		
	Total	79.101	23			
%WSE	Between Groups	.149	1	.149	.160	.693
	Within Groups	20.427	22	.928		
	Total	20.575	23			
%Ash	Between Groups	8.039	1	8.039	5.343	.031
	Within Groups	33.099	22	1.504		
	Total	41.137	23			
%WIS	Between Groups	.810	1	.810	3.191	.088
	Within Groups	5.586	22	.254		
	Total	6.396	23			
%Protein	Between Groups	7.605	1	7.605	3.900	.061
	Within Groups	42.905	22	1.950		
	Total	50.510	23			
%Moisture	Between Groups	14.727	1	14.727	.351	.560
	Within Groups	922.626	22	41.938		
	Total	937.352	23			
%LPE	Between Groups	1.617	1	1.617	2.101	.161
	Within Groups	16.935	22	.770		
	Total	18.553	23			
%Fibre	Between Groups	1.042	1	1.042	.626	.437
	Within Groups	36.584	22	1.663		
	Total	37.626	23			
%Carbohydrate	Between Groups	4.923	1	4.923	.643	.431
	Within Groups	168.569	22	7.662		
	Total	173.492	23			
%Caloric value	Between Groups	3175.150	1	3175.150	8.350	.009
	Within Groups	8365.750	22	380.261		
	Total	11540.901	23			
PH	Between Groups	.003	1	.003	.039	.845
	Within Groups	1.579	22	.072		
	Total	1.582	23			
Fe	Between Groups	.543	1	.543	.072	.791
	Within Groups	165.466	22	7.521		
	Total	166.009	23			
Zn	Between Groups	5.636	1	5.636	1.611	.218
	Within Groups	76.971	22	3.499		
	Total	82.607	23			
Polyphenols	Between Groups	.030	1	.030	.268	.610
	Within Groups	2.471	22	.112		
	Total	2.501	23			
Beta Carotene	Between Groups	179.909	1	179.909	5.600	.027
	Within Groups	706.824	22	32.128		
	Total	886.733	23			

APPENDIX F2: GROUP STATISTICS

Table 4. Group Statistics for solar and oven drying

Group Statistics

	Drying Method	N	Mean	Std. Deviation	Std. Error Mean
% stalks	Solar	8	7.2525	2.01169	.71124
	Oven	8	5.1463	1.93513	.68417
%WSE	Solar	8	5.2863	1.01816	.35997
	Oven	8	5.6838	1.08294	.38288
%Ash	Solar	8	7.4863	1.23882	.43799
	Oven	8	8.6925	.84812	.29986
%WIS	Solar	8	3.5425	.50514	.17859
	Oven	8	3.7213	.63251	.22363
%Protein	Solar	8	27.4088	1.01306	.35817
	Oven	8	28.7588	.46948	.16599
%Moisture	Solar	8	8.5800	2.19377	.77561
	Oven	8	2.7925	.44206	.15629
%LPE	Solar	8	4.9188	.57419	.20301
	Oven	8	5.4338	.19287	.06819
%Fibre	Solar	8	11.9575	.57740	.20414
	Oven	8	9.6600	.78976	.27922
%Carbohydrate	Solar	8	48.2288	.61816	.21855
	Oven	8	47.4537	.90691	.32064
%Caloric value	Solar	8	1467.8387	21.18345	7.48948
	Oven	8	1496.7037	20.28540	7.17197
PH	Solar	8	5.8113	.26352	.09317
	Oven	8	5.7875	.34972	.12365
Fe	Solar	8	10.3013	1.11613	.39461
	Oven	8	15.6075	.90945	.32154
Zn	Solar	8	3.4350	.78827	.27870
	Oven	8	5.9900	2.37686	.84035
Polyphenols	Solar	8	1.9063	.37405	.13225
	Oven	8	2.0825	.07536	.02664
Beta Carotene	Solar	8	8.8150	4.17395	1.47571
	Oven	8	16.2700	4.38852	1.55158

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Table 6. **Group statistic for solar and shade drying methods**

Group Statistics

	Drying Method	N	Mean	Std. Deviation	Std. Error Mean
% stalks	Solar	8	7.2525	2.01169	.71124
	Shade	8	6.7063	.88191	.31180
%WSE	Solar	8	5.2863	1.01816	.35997
	Shade	8	5.6163	.79153	.27985
%Ash	Solar	8	7.4863	1.23882	.43799
	Shade	8	6.7300	1.17618	.41584
%WIS	Solar	8	3.5425	.50514	.17859
	Shade	8	3.2875	.38722	.13690
%Protein	Solar	8	27.4088	1.01306	.35817
	Shade	8	25.8588	1.07505	.38009
%Moisture	Solar	8	8.5800	2.19377	.77561
	Shade	8	17.2525	2.79877	.98952
%LPE	Solar	8	4.9188	.57419	.20301
	Shade	8	3.6912	.67213	.23763
%Fibre	Solar	8	11.9575	.57740	.20414
	Shade	8	10.5400	1.16046	.41028
%Carbohydrate	Solar	8	48.2288	.61816	.21855
	Shade	8	53.1787	1.23732	.43746
%Caloric value	Solar	8	1467.8387	21.18345	7.48948
	Shade	8	1480.2338	17.58390	6.21685
PH	Solar	8	5.8113	.26352	.09317
	Shade	8	5.6812	.15273	.05400
Fe	Solar	8	10.3013	1.11613	.39461
	Shade	8	10.9075	1.53663	.54328
Zn	Solar	8	3.4350	.78827	.27870
	Shade	8	3.4588	.77604	.27437
Polyphenols	Solar	8	1.9063	.37405	.13225
	Shade	8	1.5375	.18691	.06608
Beta Carotene	Solar	8	8.8150	4.17395	1.47571
	Shade	8	12.2462	7.62692	2.69652

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Table 7. Group statistic for the Species

Group Statistics

	Species	N	Mean	Std. Deviation	Std. Error Mean
% stalks	Stenopetala	12	7.5933	1.19576	.34519
	Oliefera	12	5.1433	1.57705	.45525
%WSE	Stenopetala	12	5.5158	.83782	.24186
	Oliefera	12	5.5417	1.08083	.31201
%Ash	Stenopetala	12	7.1008	1.67244	.48279
	Oliefera	12	8.1717	.56323	.16259
%WIS	Stenopetala	12	3.1550	.27358	.07898
	Oliefera	12	3.8792	.46969	.13559
%Protein	Stenopetala	12	27.1633	1.39167	.40174
	Oliefera	12	27.5208	1.60792	.46417
%Moisture	Stenopetala	12	8.1250	5.77859	1.66813
	Oliefera	12	10.9583	6.88789	1.98836
%LPE	Stenopetala	12	4.4517	1.00749	.29084
	Oliefera	12	4.9108	.74604	.21536
%Fibre	Stenopetala	12	11.2258	1.18607	.34239
	Oliefera	12	10.2125	1.20568	.34805
%Carbohydrate	Stenopetala	12	49.7008	3.33340	.96227
	Oliefera	12	49.5400	2.15554	.62225
%Caloric value	Stenopetala	12	1477.5258	15.98216	4.61365
	Oliefera	12	1485.6583	27.52577	7.94601
PH	Stenopetala	12	5.9625	.18221	.05260
	Oliefera	12	5.5575	.14549	.04200
Fe	Stenopetala	12	12.2883	2.43407	.70265
	Oliefera	12	12.2558	3.02761	.87400
Zn	Stenopetala	12	4.2075	.99753	.28796
	Oliefera	12	4.3817	2.54914	.73587
Polyphenols	Stenopetala	12	1.7900	.24746	.07144
	Oliefera	12	1.8942	.40028	.11555
Beta Carotene	Stenopetala	12	9.5242	5.36258	1.54804
	Oliefera	12	15.3633	5.76690	1.66476

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Table 8. Group statistic for treatments

Group Statistics

	Treatment	N	Mean	Std. Deviation	Std. Error Mean
% stalks	Blanched	12	5.7042	1.88094	.54298
	Unblanched	12	7.0325	1.64032	.47352
%WSE	Blanched	12	5.6075	.94731	.27347
	Unblanched	12	5.4500	.97957	.28278
%Ash	Blanched	12	7.0575	1.33711	.38599
	Unblanched	12	8.2150	1.10503	.31900
%WIS	Blanched	12	3.3333	.36051	.10407
	Unblanched	12	3.7008	.61471	.17745
%Protein	Blanched	12	27.9050	1.36109	.39291
	Unblanched	12	26.7792	1.43106	.41311
%Moisture	Blanched	12	8.7583	5.97101	1.72368
	Unblanched	12	10.3250	6.94422	2.00462
%LPE	Blanched	12	4.9408	.67038	.19352
	Unblanched	12	4.4217	1.04412	.30141
%Fibre	Blanched	12	10.9275	1.24979	.36078
	Unblanched	12	10.5108	1.32809	.38339
%Carbohydrate	Blanched	12	49.1675	2.44021	.70443
	Unblanched	12	50.0733	3.06102	.88364
%Caloric value	Blanched	12	1493.0942	8.41123	2.42811
	Unblanched	12	1470.0900	26.26355	7.58163
PH	Blanched	12	5.7492	.21773	.06285
	Unblanched	12	5.7708	.31012	.08952
Fe	Blanched	12	12.1217	2.24999	.64952
	Unblanched	12	12.4225	3.15909	.91195
Zn	Blanched	12	3.8100	.85928	.24805
	Unblanched	12	4.7792	2.50181	.72221
Polyphenols	Blanched	12	1.8067	.19961	.05762
	Unblanched	12	1.8775	.42989	.12410
Beta Carotene	Blanched	12	15.1817	7.25400	2.09405
	Unblanched	12	9.7058	3.41118	.98472

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Dependent Variable		(I) Drying Method	(J) Drying Method	95% Confidence Interval Lower Bound	Upper Bound
% stalks	LSD	Solar	Shade	-1.2111	2.3036
			Oven	.3489	3.8636
		Shade	Solar	-2.3036	1.2111
			Oven	-.1974	3.3174
		Oven	Solar	-3.8636	-.3489
			Shade	-3.3174	.1974
%WSE	LSD	Solar	Shade	-1.3410	.6810
			Oven	-1.4085	.6135
		Shade	Solar	-.6810	1.3410
			Oven	-1.0785	.9435
		Oven	Solar	-.6135	1.4085
			Shade	-.9435	1.0785
%Ash	LSD	Solar	Shade	-.3887	1.9012
			Oven	-2.3512	-.0613
		Shade	Solar	-1.9012	.3887
			Oven	-3.1075	-.8175
		Oven	Solar	.0613	2.3512
			Shade	.8175	3.1075
%WIS	LSD	Solar	Shade	-.2837	.7937
			Oven	-.7174	.3599
		Shade	Solar	-.7937	.2837
			Oven	-.9724	.1049
		Oven	Solar	-.3599	.7174
			Shade	-.1049	.9724
%Protein	LSD	Solar	Shade	.6195	2.4805
			Oven	-2.2805	-.4195
		Shade	Solar	-2.4805	-.6195
			Oven	-3.8305	-1.9695
		Oven	Solar	.4195	2.2805
			Shade	1.9695	3.8305
%Moisture	LSD	Solar	Shade	-10.8238	-6.5212
			Oven	3.6362	7.9388
		Shade	Solar	6.5212	10.8238
			Oven	12.3087	16.6113
		Oven	Solar	-7.9388	-3.6362
			Shade	-16.6113	-12.3087
%LPE	LSD	Solar	Shade	.6843	1.7707
			Oven	-1.0582	.0282
		Shade	Solar	-1.7707	-.6843
			Oven	-2.2857	-1.1993
		Oven	Solar	-.0282	1.0582
			Shade	1.1993	2.2857
%Fibre	LSD	Solar	Shade	.5063	2.3287
			Oven	1.3863	3.2087
		Shade	Solar	-2.3287	-.5063
			Oven	-.0312	1.7912
		Oven	Solar	-3.2087	-1.3863
			Shade	-1.7912	.0312

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Multiple Comparisons

Dependent Variable		(I) Drying Method	(J) Drying Method	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
%Carbohydrate	LSD	Solar	Shade	-5.9429	-3.9571
			Oven	-.2179	1.7679
		Shade	Solar	3.9571	5.9429
			Oven	4.7321	6.7179
		Oven	Solar	-1.7679	.2179
			Shade	-6.7179	-4.7321
%Caloric value	LSD	Solar	Shade	-32.9245	8.1345
			Oven	-49.3945	-8.3355
		Shade	Solar	-8.1345	32.9245
			Oven	-36.9995	4.0595
		Oven	Solar	8.3355	49.3945
			Shade	-4.0595	36.9995
PH	LSD	Solar	Shade	-.1484	.4084
			Oven	-.2547	.3022
		Shade	Solar	-.4084	.1484
			Oven	-.3847	.1722
		Oven	Solar	-.3022	.2547
			Shade	-.1722	.3847
Fe	LSD	Solar	Shade	-1.8704	.6579
			Oven	-6.5704	-4.0421
		Shade	Solar	-.6579	1.8704
			Oven	-5.9641	-3.4359
		Oven	Solar	4.0421	6.5704
			Shade	3.4359	5.9641
Zn	LSD	Solar	Shade	-1.5976	1.5501
			Oven	-4.1289	-.9811
		Shade	Solar	-1.5501	1.5976
			Oven	-4.1051	-.9574
		Oven	Solar	.9811	4.1289
			Shade	.9574	4.1051
Polyphenols	LSD	Solar	Shade	.1137	.6238
			Oven	-.4313	.0788
		Shade	Solar	-.6238	-.1137
			Oven	-.8001	-.2899
		Oven	Solar	-.0788	.4313
			Shade	.2899	.8001
Beta Carotene	LSD	Solar	Shade	-9.2780	2.4155
			Oven	-13.3017	-1.6083
		Shade	Solar	-2.4155	9.2780
			Oven	-9.8705	1.8230
		Oven	Solar	1.6083	13.3017
			Shade	-1.8230	9.8705

*. The mean difference is significant at the .05 level.

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APPENDIX F4: STATISTICAL TABLES FOR SENSORY ANALYSIS

List of abbreviations

SoBO - Solar Blanched for *Oleifera*
SoUO - Solar Un-blanched for *Oleifera*
ShBO - Shade Blanced for *Oleifera*
ShUO - Shade Un-blanched for *Oleifera*
OUO - Oven Blanched for *Oleifera*
OBO - Oven Un-blanched for *Oleifera*
SoBS - Solar Blanched for *Stenopetala*
SoUS - Solar Un-blanched for *Stenopetala*
ShBS - Shade Blanced for *Stenopetala*
ShUS - Shade Un-blanched for *Stenopetala*
OUS - Oven Blanched for *Stenopetala*
OBS - Oven Un-blanched for *Stenopetala*

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	sample	N	Mean Rank
Colour	souo	15	76.33
	control	15	119.13
	Obo	15	110.10
	ouo	15	102.27
	Shus	15	80.00
	Sobo	15	90.43
	Shbs	15	102.43
	Shuo	15	83.50
	obs	15	109.23
	sous	15	73.73
	Shbo	15	100.70
	Ous	15	106.63
	Sobs	15	119.50
	Total	195	

Aroma	souo	15	97.70
	control	15	129.13
	Obo	15	107.77
	ouo	15	99.00
	Shus	15	75.13
	Sobo	15	107.77
	Shbs	15	86.33
	Shuo	15	70.10
	obs	15	111.50
	sous	15	78.87
	Shbo	15	83.90
	Ous	15	115.23
	Sobs	15	111.57
	Total	195	

After-taste	souo	15	82.47
	control	15	29.60
	Obo	15	130.80
	ouo	15	131.40
	Shus	15	76.40
	Sobo	15	116.50
	Shbs	15	91.80
	Shuo	15	82.77
	obs	15	126.07
	sous	15	59.87
	Shbo	15	106.00
	Ous	15	113.07
	Sobs	15	127.27
	Total	195	

Mouth feel	souo	15	88.50
	control	15	34.80
	Obo	15	113.10
	ouo	15	137.50
	Shus	15	85.17
	Sobo	15	120.03
	Shbs	15	99.90
	Shuo	15	75.43
	obs	15	117.50
	sous	15	82.23
	Shbo	15	113.10
	Ous	15	82.23
	Sobs	15	124.50
	Total	195	

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astringency	souo	15	94.53
	control	15	30.03
	Obo	15	116.87
	ouo	15	125.87
	Shus	15	84.20
	Sobo	15	112.40
	Shbs	15	112.30
	Shuo	15	79.57
	obs	15	105.03
	sous	15	84.83
	Shbo	15	115.47
	Ous	15	99.00
	Sobs	15	113.90
	Total	195	

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overall acceptability	souo	15	87.27
	control	15	37.40
	Obo	15	119.63
	ouo	15	117.17
	Shus	15	79.40
	Sobo	15	114.50
	Shbs	15	97.10
	Shuo	15	77.00
	obs	15	119.63
	sous	15	59.77
	Shbo	15	119.63
	Ous	15	112.03
	Sobs	15	133.47
	Total	195	

APPENDIX F5: MEAN SCORES OF SENSORY ATTRIBUTES

COLOUR

Duncan[a]

SAMPLE	N	Subset for alpha = .05
		1
SHUS	15	7.2000
SOUS	15	7.2667
SOUO	15	7.3333
SHUO	15	7.3333
OUO	15	7.4667
SOBO	15	7.4667
CONTROL	15	7.6000
OBO	15	7.6667
SHBS	15	7.6667
OUS	15	7.6667
SHBO	15	7.6667
OBS	15	7.7333
SOBS	15	7.8000
Sig.		.114

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 15.000.

AROMA

Duncan[a]

SAMPLE	N	Subset for alpha = .05		
		1	2	3
SHUO	15	6.3333		
SHUS	15	6.7333	6.7333	
SOUS	15	6.8000	6.8000	
SHBS	15	6.9333	6.9333	
SHBO	15	7.0000	7.0000	7.0000
SOUO	15	7.0667	7.0667	7.0667
OUO	15		7.2000	7.2000
OBS	15		7.2667	7.2667
OBO	15		7.3333	7.3333
SOBO	15		7.3333	7.3333
SOBS	15		7.4000	7.4000
OUS	15		7.4667	7.4667
CONTROL	15			7.8000
Sig.		.079	.096	.064

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 15.000.

AFTER TASTE

AFTERTAS

Duncan[a]

SAMPLE	N	Subset for alpha = .05			
		1	2	3	4
CONTROL	15	5.2000			
SOUS	15		6.2667		
SHUS	15		6.5333	6.5333	
SOUO	15		6.6667	6.6667	
SHUO	15		6.7333	6.7333	6.7333
SHBS	15		7.0000	7.0000	7.0000
SHBO	15			7.2000	7.2000
SOBO	15			7.3333	7.3333
OUS	15			7.3333	7.3333
OUO	15				7.5333
OBS	15				7.5333
OBO	15				7.6000
SOBS	15				7.6000
Sig.		1.000	.084	.067	.052

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 15.000.

ASRINGENCY

ASTRIN

Duncan[a]

SAMPLE	N	Subset for alpha = .05		
		1	2	3
CONTROL	15	5.4000		
SOUS	15		6.8000	
SHUS	15		6.9333	6.9333
SHUO	15		6.9333	6.9333
SOUO	15		7.1333	7.1333
OUS	15		7.2667	7.2667
OBS	15		7.3333	7.3333
SOBO	15		7.4667	7.4667
SHBS	15		7.5333	7.5333
SOBS	15		7.5333	7.5333
OBO	15		7.6000	7.6000
SHBO	15		7.6000	7.6000
OUO	15			7.7333
Sig.		1.000	.080	.080

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 15.000.

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MOUTH FEEL

MOTHFEL

Duncan[a]

SAMPLE	N	Subset for alpha = .05				
		1	2	3	4	5
CONTROL	15	5.5333				
SHUO	15		6.8667			
SOUS	15		6.9333	6.9333		
SHUS	15		6.9333	6.9333		
SOUO	15		7.0667	7.0667	7.0667	
SHBS	15		7.2667	7.2667	7.2667	7.2667
OBO	15		7.4667	7.4667	7.4667	7.4667
SHBO	15		7.4667	7.4667	7.4667	7.4667
SOBO	15		7.5333	7.5333	7.5333	7.5333
OBS	15			7.6000	7.6000	7.6000
OUS	15			7.6000	7.6000	7.6000
SOBS	15				7.6667	7.6667
OUO	15					7.8667
Sig.		1.000	.067	.070	.101	.101

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 15.000.

OVERALL ACCEPTABILITY

OA

Duncan[a]

SAMPLE	N	Subset for alpha = .05			
		1	2	3	4
CONTROL	15	5.8667			
SOUS	15	6.4667	6.4667		
SHUS	15		6.8667	6.8667	
SHUO	15		6.8667	6.8667	
SOUO	15		7.0000	7.0000	
SHBS	15			7.2000	7.2000
SOBO	15			7.4667	7.4667
OUS	15			7.4667	7.4667
OBO	15			7.5333	7.5333
OUO	15			7.5333	7.5333
OBS	15			7.5333	7.5333
SHBO	15			7.5333	7.5333
SOBS	15				7.7333
Sig.		.050	.112	.068	.141

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 15.000.

APPENDIX F6: CROSS TABULATION RESULTS OF DESCRIPTIVE ANALYSIS ON TEA SAMPLES

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OUTPUT- discriptive

Descriptive Analysis of Tea Samples

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Pdt * Flavour	195	100.0%	0	.0%	195	100.0%
Pdt * Colour	195	100.0%	0	.0%	195	100.0%
Pdt * Astrigency	195	100.0%	0	.0%	195	100.0%
Pdt * Aftertaste	195	100.0%	0	.0%	195	100.0%

Pdt * Flavour Crosstabulation

			Flavour			Total
			Stale	Pleasant	Herbal	
Pdt	obo	Count	1	6	8	15
		% of Total	.5%	3.1%	4.1%	7.7%
	ouo	Count	0	6	9	15
		% of Total	.0%	3.1%	4.6%	7.7%
	shuo	Count	1	5	9	15
		% of Total	.5%	2.6%	4.6%	7.7%
	sobo	Count	0	7	8	15
		% of Total	.0%	3.6%	4.1%	7.7%
	cont	Count	2	5	8	15
		% of Total	1.0%	2.6%	4.1%	7.7%
	sobs	Count	0	6	9	15
		% of Total	.0%	3.1%	4.6%	7.7%
	shus	Count	0	3	12	15
		% of Total	.0%	1.5%	6.2%	7.7%
	obs	Count	0	5	10	15
		% of Total	.0%	2.6%	5.1%	7.7%
	shbo	Count	1	6	8	15
		% of Total	.5%	3.1%	4.1%	7.7%
	sous	Count	1	1	13	15
		% of Total	.5%	.5%	6.7%	7.7%
	ous	Count	1	6	8	15
		% of Total	.5%	3.1%	4.1%	7.7%

	shbs	Count	0	5	10	15
		% of Total	.0%	2.6%	5.1%	7.7%
	souo	Count	0	2	13	15
		% of Total	.0%	1.0%	6.7%	7.7%
Total		Count	7	63	125	195
		% of Total	3.6%	32.3%	64.1%	100.0%

Pdt * Colour Crosstabulation

			Colour			Total
			Golden yellow	Brownish	Dark brown	
Pdt	obo	Count	15	0	0	15
		% of Total	7.7%	.0%	.0%	7.7%
	ouo	Count	15	0	0	15
		% of Total	7.7%	.0%	.0%	7.7%
	shuo	Count	1	12	2	15
		% of Total	.5%	6.2%	1.0%	7.7%
	sobo	Count	15	0	0	15
		% of Total	7.7%	.0%	.0%	7.7%
	cont	Count	1	13	1	15
		% of Total	.5%	6.7%	.5%	7.7%
	sobs	Count	15	0	0	15
		% of Total	7.7%	.0%	.0%	7.7%
	shus	Count	2	13	0	15
		% of Total	1.0%	6.7%	.0%	7.7%
	obs	Count	15	0	0	15
		% of Total	7.7%	.0%	.0%	7.7%
	shbo	Count	15	0	0	15
		% of Total	7.7%	.0%	.0%	7.7%
	sous	Count	11	4	0	15
		% of Total	5.6%	2.1%	.0%	7.7%
	ous	Count	15	0	0	15
		% of Total	7.7%	.0%	.0%	7.7%
	shbs	Count	15	0	0	15
		% of Total	7.7%	.0%	.0%	7.7%
	souo	Count	14	1	0	15

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		% of Total	7.2%	.5%	.0%	7.7%
Total		Count	149	43	3	195
		% of Total	76.4%	22.1%	1.5%	100.0%

Pdt * Astrigency Crosstabulation

			Astrigency			Total
			Slightly astrigent	Very astrigent	Not astrigent	
Pdt	obo	Count	6	1	8	15
		% of Total	3.1%	.5%	4.1%	7.7%
	ouo	Count	7	0	8	15
		% of Total	3.6%	.0%	4.1%	7.7%
	shuo	Count	13	1	1	15
		% of Total	6.7%	.5%	.5%	7.7%
	sobo	Count	8	0	7	15
		% of Total	4.1%	.0%	3.6%	7.7%
	cont	Count	5	10	0	15
		% of Total	2.6%	5.1%	.0%	7.7%
	sobs	Count	7	0	8	15
		% of Total	3.6%	.0%	4.1%	7.7%
	shus	Count	8	4	3	

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					15
	% of Total	4.1%	2.1%	1.5%	7.7%
obs	Count	10	0	5	15
	% of Total	5.1%	.0%	2.6%	7.7%
shbo	Count	11	0	4	15
	% of Total	5.6%	.0%	2.1%	7.7%
sous	Count	10	0	5	15
	% of Total	5.1%	.0%	2.6%	7.7%
ous	Count	8	0	7	15
	% of Total	4.1%	.0%	3.6%	7.7%
shbs	Count	6	0	9	15
	% of Total	3.1%	.0%	4.6%	7.7%
souo	Count	10	0	5	15
	% of Total	5.1%	.0%	2.6%	7.7%
Total	Count	109	16	70	195
	% of Total	55.9%	8.2%	35.9%	100.0%

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Pdt * Aftertaste Crosstabulation

			Aftertaste		Total

OUTPUT- discriptive

			Pleasant	Unpleasant	
Pdt	obo	Count	15	0	15
		% of Total	7.7%	.0%	7.7%
	ouo	Count	14	1	15
		% of Total	7.2%	.5%	7.7%
	shuo	Count	15	0	15
		% of Total	7.7%	.0%	7.7%
	sobo	Count	15	0	15
		% of Total	7.7%	.0%	7.7%
	cont	Count	4	11	15
		% of Total	2.1%	5.6%	7.7%
	sobs	Count	15	0	15
		% of Total	7.7%	.0%	7.7%
	shus	Count	10	5	15
		% of Total	5.1%	2.6%	7.7%
	obs	Count	15	0	15
		% of Total	7.7%	.0%	7.7%
	shbo	Count	15	0	15
		% of Total	7.7%	.0%	7.7%
	sous	Count	14	1	15
		% of Total	7.2%	.5%	7.7%
	ous	Count	15	0	15
		% of Total	7.7%	.0%	7.7%
	shbs	Count	15	0	15
		% of Total	7.7%	.0%	7.7%
	souo	Count	14	1	15
		% of Total	7.2%	.5%	7.7%
Total		Count	176	19	195
		% of Total	90.3%	9.7%	100.0%

KNUST

APPENDIX G: HPLC PEAKS OF ß-CAROTENE CONTENTS OF THE SAMPLES

KNUST

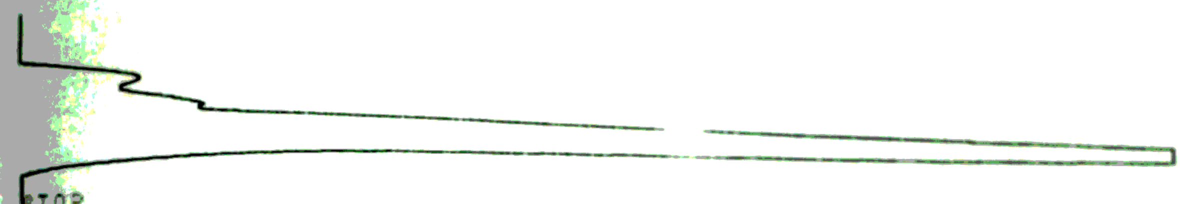
... CALIBRATION (β-CAR)

NAME	TIME	BAND	FACTOR	CONC
B-CAR	[illegible]	3.2	[illegible]	[illegible]

END

CALIB 3

START



STOP

CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45836
STANDARD 3

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	3.023	191527		1		B-CAR
	TOTAL	191527				

START

STOP

CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45837
STANDARD 2

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	3.003	191021				B-CAR
	TOTAL	191021				

START

STOP

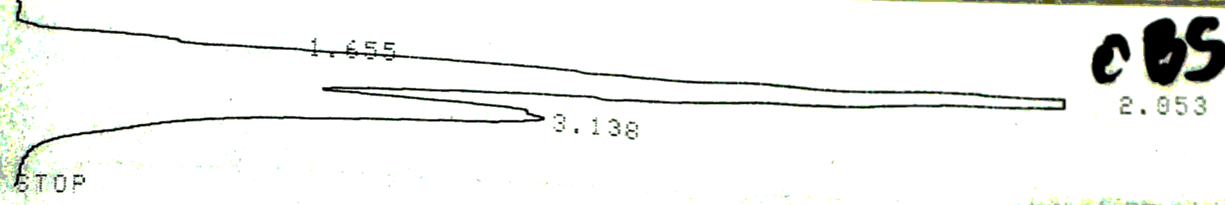
CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45838
STANDARD 1

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	3.033	200244				B-CAR
	TOTAL	200244				

CALIBRATION MADE IN IDENTIFICATION FILE 4
MODE 1

IDNO	NAME	TIME	BAND	FACTOR	CONC
1	B-CAR	3	5.0	0.0132671	2527 [illegible]

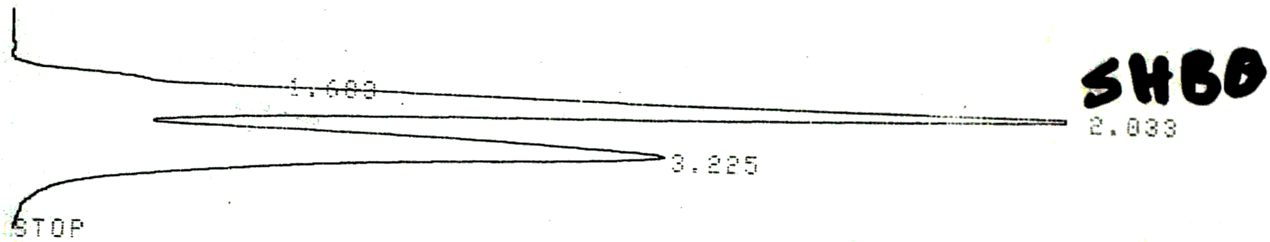


CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45856

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	1.655	[illegible]				
2	2.053	[illegible]	V			
3	3.138	[illegible]	V	1	1199.2292	B-CAR
	TOTAL	259136			1199.2292	

ZERO
START

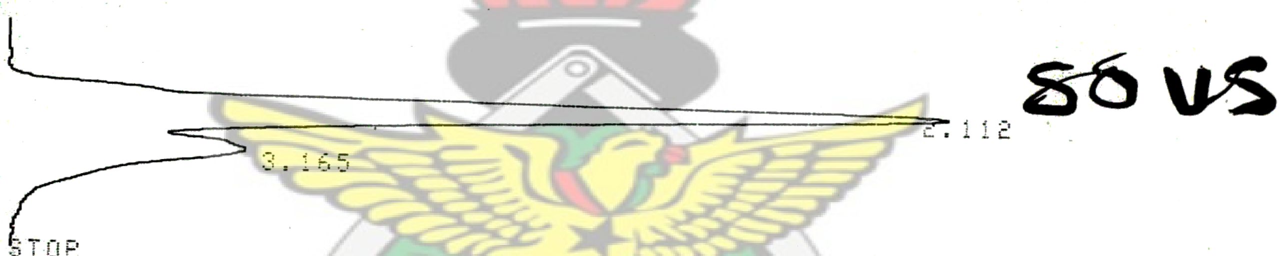


CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45857

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	1.683	5128				
2	2.033	128131	V			
3	3.225	116049	V	1	1539.6237	B-CAR
	TOTAL	249307			1539.6237	

ZERO
START

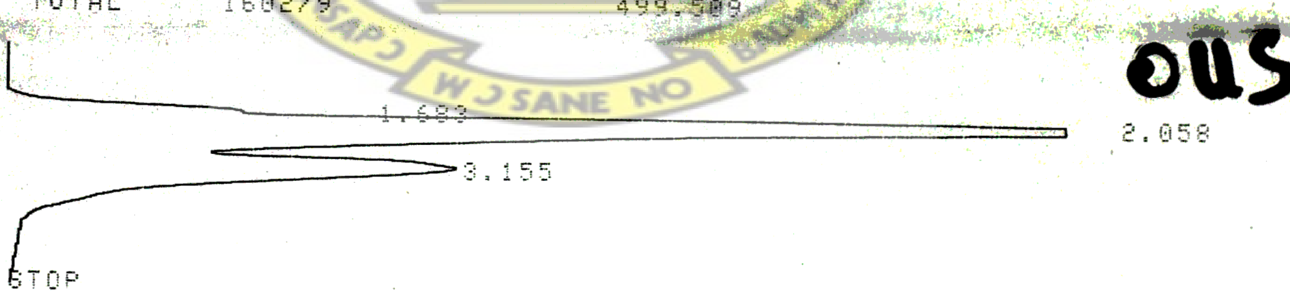


CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45858

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	2.112	122629				
2	3.165	37650	V	1	499.509	B-CAR
	TOTAL	160279			499.509	

ZERO
START



CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45859

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	1.683	[illegible]				
2	2.058	[illegible]	V			
3	3.155	67892	V	1	898.076	B-CAR
	TOTAL	227237			898.076	

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CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45852

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	2.105	308704				
2	3.147	60063	V	1	796.8634	B-CAR
TOTAL		368767			796.8634	

ZERO
START

CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45853

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	2.138	233021				
2	3.17	79615	V	1	1056.2521	B-CAR
TOTAL		312635			1056.2521	

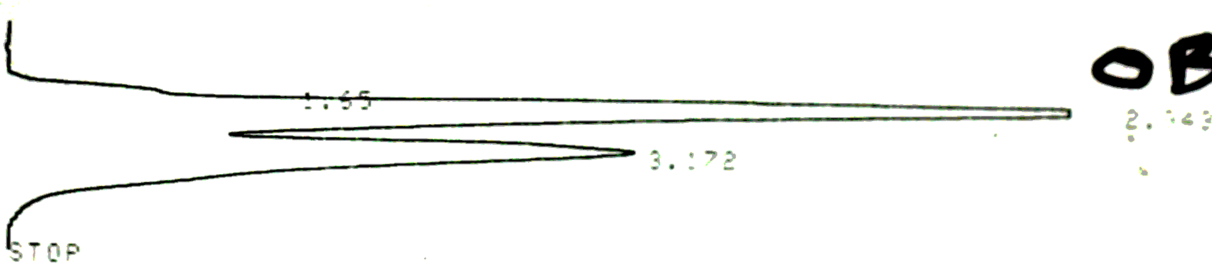
ZERO
START

CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45854

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	2.115	241383				
2	3.167	106585	V	1	1414.0665	B-CAR
TOTAL		347968			1414.0665	

ZERO
START

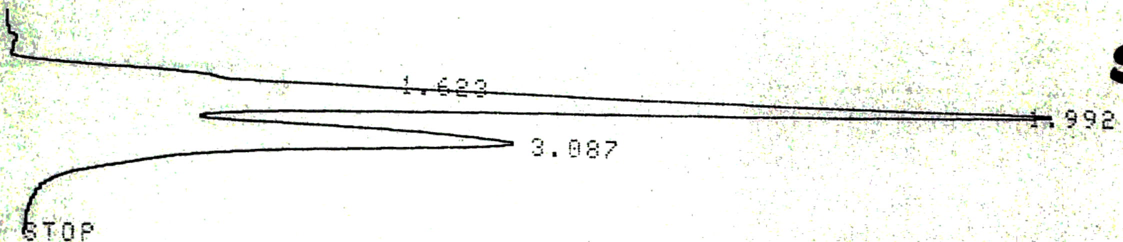


CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45855

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
[illegible]	[illegible]	[illegible]				
[illegible]	[illegible]	[illegible]	V	1	[illegible]	B-CAR
TOTAL		[illegible]			[illegible]	

SHBS



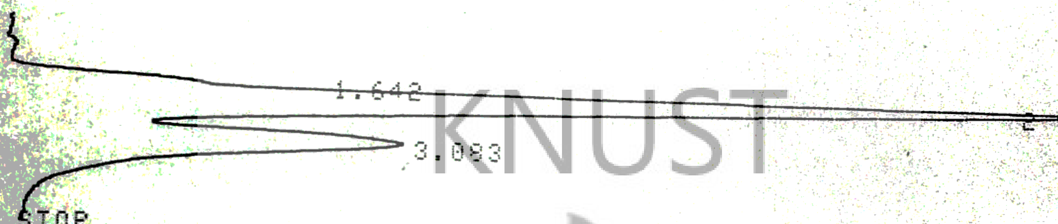
CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45841

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	1.623	[illegible]				
2	1.992	[illegible]				
3	3.087	[illegible]	V	1	1034.975	B-CAR
	TOTAL	205042			1034.975	

ZERO
START

SOBS



CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45842

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	1.642	[illegible]				
2	2	113267	V			
3	3.083	56846	V	1	754.174	B-CAR
	TOTAL	177029			754.174	

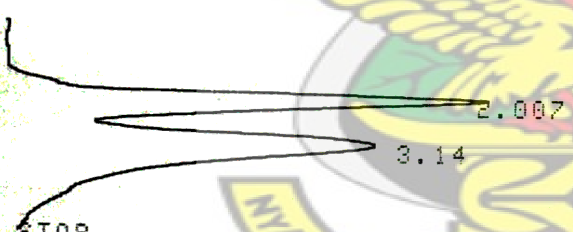
REPORT NO 45845

METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	[illegible]	[illegible]				
2	3.027	[illegible]	V	1	516.8538	B-CAR
	TOTAL	77570			516.8538	

ZERO
START

control



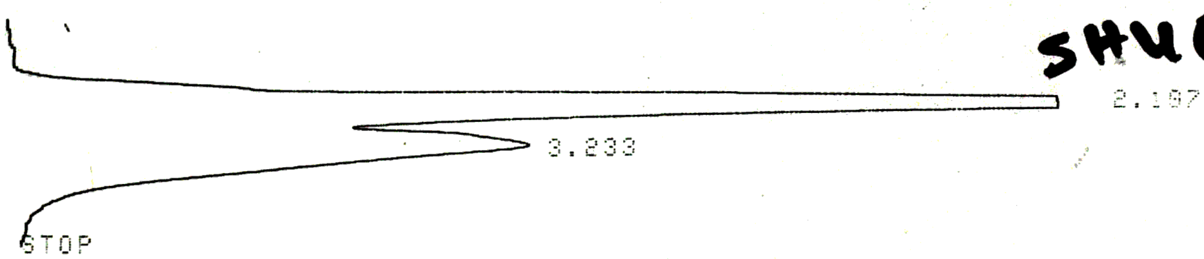
CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45846

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	2.007	40086				
2	3.14	52802	V	1	700.5238	B-CAR
	TOTAL	92888			700.5238	

ZERO
START

SHUO



CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45847

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	2.107	231661				
2	3.233	107113	V	1	1421.0216	B-CAR

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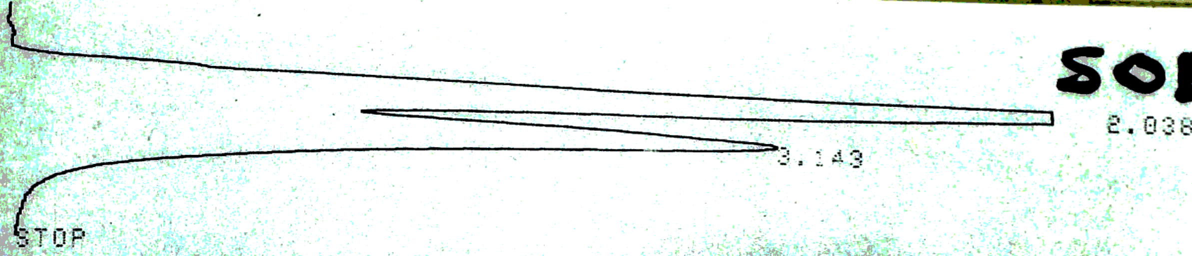
SOBO



CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45849

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	2.038	208629				
2	3.143	146455	V	1	1943.0302	B-CAR
	TOTAL	355084			1943.0302	

ZERO
START

KNUST

CHROMATOPAC C-R6A
SAMPLE NO 0
REPORT NO 45850

FILE 4
METHOD 44
SAMPLE WT 100

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	1.667	3082				
2	2.115	114693	V			
	TOTAL	117775			0	

NYANSAPƆ WƆSANE NO BADWENMA