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EFFECT OF DRYING ON NUTRITIONAL AND ANTI-NUTRITIONAL COMPOSITION OF SOLANUM TORVUM

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NOVEMBER, 2016

DECLARATION

STUDENT'S DECLARATION

I, BELINDA AGYEI-POKU, declare that, this dissertation, is the outcome of my research and that except portions where references contained in published work have been duly cited, is entirely my own original work, and that it has neither been submitted nor being concurrently submitted in any other institution.

SIGNATURE…………………………………………………

DATE………………………………………………………

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work were supervised in accordance with the guidelines for supervision of dissertation as laid down by the University of Education, Winneba.

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DATE: ……………………………………..

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DEDICATION

I dedicate this work to my beloved children Akua, Kwasi, Ama and Kwame Agyei-Poku so that they become greater scholars who will not only be able to understand different aspects of the world but also to change them in appropriate and positive ways. May Almighty God bless them all, Amen.

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ABSTRACT

The *Solanum torvum* fruits are used generally in Ghanaian food preparations because of the conviction that they are very nutritious and boost the blood level of lactating and nursing mothers, pregnant women and anemic patients. The post-harvest losses of turkey berry (*Solanum torvum*) are of higher rate in the country so this work sought to investigate how these post-harvest losses can be minimized by drying it and popularise the plant or crop so that farmers will cultivate it and get more money. The main aim of this work was to determine the physiochemical properties of *Solanum torvum* fruits. Proximate analyses of dried powdered fruits were therefore performed by using the AOAC (200) (Association of Official Analytical Chemists). Atomic Absorption Spectroscopy analysis of essential minerals was performed to ascertain the concentrations of iron, magnesium, phosphorus, and sodium in the fruit. The results indicated that the fruits possess high moisture content (78.34±1.22). The values for the other parameters checked were fat 0.57±0.03 %, fibre 4.34±0.94%, protein 3.01±0.11%, ash 1.04±0.05 % and carbohydrate 12.70%. The results for minerals were iron (12.90 to 14.85mg/100g), magnesium (0.019 to 0.036mg/100g), phosphorus (0.093 to 0.135mg/100g) and sodium (0.055 to 0.208mg/100g). The values for anti-nutrient are as follows tannins (0.61 to 0.75mg/100g), phytate (1.42 to1.65mg/100g), oxalate (0.34 to 0.50mg/100g) and saponin (0.48to 0.65mg/100g). The high iron content of the fruits proves the fact that the fruits truly have hematinic property. These results obtained show that *Solanum torvum* fruits when dry do not only conserve the fruits but also increase the nutritive composition per gram with the exception of moisture content.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Solanum torvum (family: *Solanaceae*) universally known as turkey berry has been called by several local names such as: Susraba (Ewe), Kwahu Nsusuwa (Kwahu), Yaa Asantewaa (Asante Twi), and Seseloatso (Ga-Adamgbe). This plant is found in tropical Africa, Asia and South America. The fruits have been found to contain phytoconstituents such as steroid glycosides and saponins, fixed oil; vitamin B group; vitamin C; iron salts, saponins and steroidal alkaloids. In Ghana, various parts of the plant have been used either as a haemostatic after childbirth or as a source of saponin for the hemi synthesis of cortisone and sex hormones or for compounding sedatives, diuretics or digestive tonics. Its leaves have been used in the treatment of abdominal pain, whitlow and whooping cough; its fruits are used in the treatment of anemia, inducing lactation, and treatment of wounds and snakebites. (Koffuor GA et al.,2011).

In most traditional Ghanaian homes, it has become normal to give to mothers, after childbirth, diets containing *Solanum torvum* fruits with the intention of enhancing vitality and reversing conditions of anemia. Though undocumented, it is generally observed that mothers who eat these fruits show enhanced health status. To date, there is little scientific evidence to support the traditional use of *Solanum torvum* in the management of anemia and immunodeficiency and the possible mechanisms involved.

In Ghana, and many other countries, *Solanum torvum* fruits are used for food. The leaves are used in many traditional medical practices in Africa (Adjanohoun *et al.*, 1996). The plant grows as short as about 2-4 m tall, erect shrub with lots of branches. *Solanum torvum* grows into a large thorny impenetrable thicket (Mohan and Bhandare, 2012). Some other species, which belong to the genus *Solanum,* are *Solanum ficifolium* and *Solanum ferrugineum* (Langeland and Burks, 1998). Turkey berry grows about 0.75 to 1.5 m in height per year. The species is not long-lived; most plants live about 2 years.

Mineral nutrition is a significant aspect of human life and it plays an essential role for healthy growth. These nutritional minerals have various sources. In many African countries, wild edible plants are used as food and hence contribute significantly to the nutritional needs of the people. In Ghana, *Solanum torvum* is used essentially for food. In the south of Ghana, especially, it is added to palm nut soup and some stews. It is a general belief in the Ghanaian society that the fruit of *Solanum torvum* is rich in minerals that help increase the amount of blood in the human body, hence, it is generally advised by locals to take the juice of *Solanum torvum* to prevent anemia. (Osei, A et al., 2015).

Notwithstanding these nutritional and health benefits, *Solanum torvum* due to its high moisture content has a very short shelf life. From observation, it usually loses its physical quality after 2 days of shelving. It is therefore important that measures such as drying are put in place to address its storage life. Anti-nutrients on the other hand are natural or synthetic compounds that interfere with the absorption of nutrients in terms of *Solanum torvum*, these anti-nutrients are the phytate, oxalate and tannins.

Drying is one of the oldest preservation methods. The moisture level of agricultural products is decreased to 10-15% so that the microorganisms present cannot thrive and the enzymes become inactive. Further dehydration is usually not desired, because the products then often become brittle. To ensure that the products do not spoil after being dried, they have to be stored in a moisture-free environment.

Solar food drying is a very simple, antique skill. It requires a safe place to spread the food where air in large quantities can pass over and beside thin pieces being heated by the sun. However at a slower rate, dry cold air from any source will dehydrate food (Fuller, 1991). In solar drying, solar dryers are used. Solar dryers are devices that use solar energy to dry substances. Whereas oven drying is the simplest way to dry food because no special equipment is needed. It is also faster than sun drying or using a food dryer. But 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. There are industrial oven as well which can dry a large amount of food items within few hours. Some fruits and vegetables which were subjected to drying and at the same time it nutrients were retain are mango, pineapple, okra, onion.

1.2 Statement of Problem

The post-harvest losses of turkey berry (*Solanum torvum*) are of higher rate in the country .This is evidenced in the face that the entire over. Also the populace have little knowledge of the nutritional and anti-nutritional content of turkey berry (*Solanum torvum*). Also, the health benefit of *Solanum torvum* is not utilized, for example curing/managing cough, cold, dog bite, headache and stomach ache.

Furthermore, studies on the effect of drying on the nutritional and anti-nutritional content of Solanum torvum have not been documented.

1.3 Significance of the study

This research will enlighten both consumers and non-consumers on health benefits of *Solanum torvum*. Also, it would contribute to the existing knowledge on the effects of dried *Solanum* *torvum* on anti-nutrients, macro and micro nutrients thereby enhancing the uses of *Solanum torvum*. In addition it will reduce post-harvest losses of *Solanum torvum* and popularise the plant or crop so that farmers will cultivate it and get more money.

1.4 Study Objectives

1.4.1 Main objective

The main objective of the study was

To determine the effect of drying on the nutritional and anti-nutrient in *Solanum torvum*.

1.4.2 Specific objectives

The specific objectives were to:

2. Determine the physiochemical properties of *Solanum torvum* as an index of drying.
3. Determine the proximate composition of *Solanum torvum* as a function of drying.
4. Determine the effect of drying on the minerals and anti-nutrient content on *Solanum torvum*.

1.5 The scope of the study

The scope is to find out the effect of drying on macro, micro and anti-nutritional value in *Solanum torvum*. It will also be used as a means of curing or managing diseases in our present country, since *Solanum torvum* is highly nutritious vegetable with a lot of medicinal values.

Finally, the study seeks to recommend the use of *Solanum torvum* be in fresh or dry state, since it is cheap and easy to come by.

1.6 Limitation of the study

Financial constraints in laboratory work and the frequent rain fall was the major problems for the research.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

A lot of research work has been done on *Solanum torvum* in several countries including Ghana, there is more information on it as a top health food, ways of using it on menu and pharmacological area. There is however not much information on effect of drying on the macro, micro and anti-nutrients in *Solanum torvum* in the catering industry; therefore this chapter will investigate the various works that has been done on *Solanum torvum* and also whether drying has effect on the nutritional composition on *Solanum torvum*.

2.2 Origin of *Solanum torvum*

The *Solanum torvum* (*Solanaceae*) plant is a common plant apparently native to Florida and southern Alabama through the West Indies and from Mexico through Central America and South America through Brazil (Little *et al.*, 1974), and in many tropical countries in Africa. It is also found in some parts of Asia.

There are about 2,000 species of *Solanum* in the world that are mainly distributed in the tropical and sub-tropical areas, with a small number in the temperate areas (Jennifer *et al.,* 1997). About 21 species and one variety in this genus are used as herbal medicines (Hu *et al.,* 1999). *Solanum torvum* is a small solanaceous shrub, distributed widely in Pakistan, India, Malaya, China, Philippines, and tropical America (Nasir, 1985). Among the major chemical constituents of *S. torvum* are steroids, steroid saponins, steroid alkaloids, and phenols. Pharmacological studies indicate that the stem and root of *S. torvum* have anti-tumour, anti-bacterial, anti-viral, anti-inflammatory, and other medicinally important effects. In Ghana, *Solanum torvum* is obtained from various forest zones especially in the Ashanti, Brong-Ahafo and some parts of Central region. The plants can also be found in the backyards of most homes.

According to Batianoff and Butler (2002), *Solanum torvum* was widely naturalised in the warmer coastal regions of northern and eastern Australia (i.e. in the northern parts of the Northern Territory and in northern and eastern Queensland). It is possibly also naturalised in the coastal districts of northern New South Wales. Also it was naturalised overseas in tropical Africa, Asia, southeastern USA (i.e. Florida and Alabama), Papua New Guinea and on several Pacific islands (e.g. American Samoa, Western Samoa, Fiji, Hawaii, New Caledonia, Niue, Palau and Tonga) (Cowie and Kerrigan, 2007).

2.3 The *Solanum torvum* plant

The plant grows as a short (about 2-4 m tall), erect shrub with lots of branches. *Solanum torvum* grows into a large thorny impenetrable thicket (Mohan and Bhandare, 2012). The fruits of *Solanum torvum* are clusters of tiny green spheres (about 1 cm in diameter) that become yellow when fully ripen. They are thin-fleshed and contain numerous flat, round, brown seeds (Howard 1989; Liogier 1995; Little *et al.*, 1974). Turkey berry grows about 0.75 to 1.5 m in height per year.

The species is not long-lived; most plants live about 2 years. Physical control of the shrub may be done by grubbing out the plants; lopping will not kill them. They can be killed by translocated herbicides applied to the leaves or the cut stumps (Pacific Island Ecosystems at Risk, 2001). According to Little *et al.* (1974), the *Solanum torvum* plant is usually 2 or 3 m in height and 2 cm in basal diameter, but may reach 5 m in height and 8 cm in basal diameter. The shrub usually has a single stem at ground level, but it may branch on the lower stem.

The stem bark is gray and nearly smooth with raised lenticels. The inner bark has a green layer over an Ivory color. The roots are white. Foliage is confined to the growing twigs. The fruits are berries that grow in clusters of tiny green spheres (1 cm in diameter) and looks like green peas.

Accord to Forest and Starr (n. d.), turkey berry is a broadleaved, evergreen shrub or small tree can grow to 16 ft. (4.9 m) in height. The stems are armed with stout, straight, or lightly curved prickles.

According to Plants Profile (2007), the younger stems are green or purplish in colour and sometimes sparsely covered in prickles or thorns (3-7 mm long). They are also densely covered is small star-shaped (i.e. stellate) hairs. Older stems become brown or greenish-brown and eventually lose their covering of hairs.

The relatively large, alternately arranged, leaves (7.5-25 cm long and 4-15 cm wide) are borne on stalks (i.e. petioles) 1-5 cm long. These leaves are broadly egg-shaped in outline (i.e. ovate) or almost rounded (i.e. orbicular) in shape with entire to shallowly-lobed margins. However, the leaves on younger plants may be more deeply-lobed (i.e. pinnatisect).

The leaf tips and lobes, when present, may be rounded or pointed (i.e. they have obtuse to acute apices). The leaves of adult plants do not have any prickles, however seedlings and young plants may have some small prickles on their upper surfaces. Both leaf surfaces, but particularly the whitish undersides, are covered in star-shaped (i.e. stellate) hairs. Also the small, white flowers occur in large, branched clusters. Plants flower uninterruptedly after reaching a height of 3.3 to 4.9 ft. (1 to 1.5 m).

According to 2012 fact sheet of *Solanum torvum*, the flowers are star-shaped of 25 mm across and are arranged in branched clusters (i.e. paniculate or corymbose clusters) on a main stalk (i.e. peduncle) 2-17 mm long. These clusters contain 15-100 flowers, each being borne on a stalk (i.e.

pedicel) 6-10 mm long. The flowers have five white petals (9-12 mm long), that are fused together at the base, and five densely hairy green sepals (2.5-6 mm long).

They also have five stamens with yellow anthers (6-7.5 mm long) and an ovary topped with a style (8-10.5 mm long) and stigma. The rounded (i.e. globular) berries (12-17 mm across) turn from green to yellow or yellowish-green as they mature (eventually brownish). They contain numerous white, pale yellow or dull brown flattened seeds (1.5-2.5 mm long). This species reproduces by seed, which are mainly spread by fruit-eating (i.e. frugivorous birds) that eat the berries.

According to Bostock and Holland (2007), *Solanum torvum* is regarded as an environmental weed in Queensland, and was recently listed as a priority environmental weed in at least one Natural Resource Management region.

2.4 Varieties

Other species which belong to the genus *Solanum*, are *Solanum ficifolium, Solanum ferrugineumgiant*, *Solanum chrysotrichum, Solanum lycocarpum, Solanum grandiflorum, Solanum bahamense* of Carl Linnaeus (*ersicifolium*), *Solanum chrysotrichum* of von Schlechtendal (*pleiotomum*), *Solanum ferrugineum* (*ferrugineum*, *hartwegianum*), *Solanum lanceolatum* of Cavanilles (*schiedeanum*), *Solanum macaonense* (*lasiostylum*), *Solanum rudepannum* (*fructipendulum*, *ochraceo-ferrugineum*), *Solanum scuticum* (*brasiliense*, *daturifolium*,. *genuinum*). (Langeland and Burks 1998).

2.5 Health benefits

In Ghana and many other countries, the fruits are used for food. The leaves are used in many traditional medical practices in Africa (Adjanohoun *et al.*, 1996).

Solanum torvum are used in traditional medicine, as tonic and haemopoietic agents and for the treatment of pains. In many parts of the North-West Province of Cameroon, the fruit juice is used for the treatment of abscesses, jigger wounds, skin infections such as ringworm and athlete's foot in man and dermatophilosis in animals.(K.F. Chah et al 2000.) The fruits have been found to contain phytoconstituents such as steroid glycosides and saponins, fixed oil; vitamin B group; vitamin C; iron salts: saponins and steroidal alkaloids.

In Ghana, various parts of the plant have been used either as a haemostatic after childbirth or as a source of saponin for the hemi synthesis of cortisone and sex hormones or for compounding sedatives, diuretics or digestive tonics. Its leaves have been used in the treatment of abdominal pain, colds, whitlow and whooping cough; its fruits are used in the treatment of anaemia, inducing lactation, and treatment of wounds and snakebites. The juice of the fruits is also used as appetizers. (Koffuor G. A. et al.,2011).

The fruits and leaves are widely used in Cameroonian folk medicine. The plant is cultivated in the tropics for its sharp tasting immature fruits. It is used in the treatment of stomach pain and skin infections (Siemonsma and Piluek, 1994). It possesses antimicrobial (Ajaiyeoba, 1999; Chah *et al.*, 2000), antiviral (Arthan *et al.*, 2002), immuno-secretory (Israf *et al.*, 2004), antiulcer (Nguelefack *et al.*, 2008a), anti-oxidant (Sivapriya and Srinivas, 2007), analgesic and anti-inflammatory (Ndebia *et al.*, 2007), cardiovascular and anti-platelet aggregation activities. *S. torvum* contains a number of potentially pharmacologically active chemicals like isoflavonoid sulfate and steroidal glycosides (Yahara *et al.*, 1996; Arthan *et al.*, 2002), For many decades, different ethnic groups have used the dried stem and root of this plant for treatment of various ailments. Its Chinese medicinal name is Jinniukou (Anonymous, 2000).

According to Chah *et al.* (2000), the methanol extract of *S. torvum* fruit showed interesting growth inhibiting activity against bacteria commonly associated with pyogenic infections. The observed activities may provide a support for some of the uses of the fruit juice in ethnomedicine.

According to Takahashi *et al.* (1990), diabetes mellitus is one of the most serious chronic diseases. It is caused by continual hyperglycemia and develops along with increases in obesity and aging in the general population (King *et al.*, 1998). One of the therapeutic approaches to decreasing postprandial hyperglycemia is to retard absorption of glucose by inhibition of carbohydrate hydrolyzing enzymes - amylase and glucosidase in the digestive organs and the fruit of *Solanum torvum* is inhibitor of sucrose and maltase. They did screening experiments for rat intestinal glucosidase (sucrase and maltase) inhibitors in 325 plants cultivated in Japan's southern island of Tanegashima, marked inhibition against both sucrase and maltase was found in the extract of the fruit of *Solanum torvum*.

Enzyme-assay guided fractionation of the extract led to the isolation of methyl caffeate as a rat intestinal sucrase and maltase inhibitor. They examined 13 caffeoyl derivatives for sucrase- and maltase-inhibitory activities. The results showed that methyl caffeate had a most favorable structure for both sucrase and maltase inhibition, except for a higher activity of methyl 3,4,5-trihydroxycinnamate against sucrose.

Yahara *et al.* (1996) indicate that *Solanum torvum* fruits have moderate inhibitory action against glucosidase which provides a prospect for antidiabetic. However, S. *torvum* exhibited some percentage of antioxidant activity and DNA repair capability on oxidative DNA damage caused by free radicals (Abas *et al.,* 2006).

Recently, a novel protein was isolated from the water extract of *S. torvum* seed and that proved to be an effective antioxidant, even at low dose, when compared to well-known standard synthetic antioxidants (Sivapriya and Srinivas, 2007). Nonetheless, aqueous extract of *S. torvum* exhibits potent anti-inflammatory and analgesic properties (Ndebia *et al.*, 2007). In Ghana, the leaves are used to treat cold and the fruits are used to boost the haemoglobin in pregnant women and persons suffering from anaemia.

2.6 Nutritional composition of *Solanum torvum*.

Solanum torvum (turkey berry) is composed of the following essential nutrients and minerals which are very helpful in preventing and curing the diseases: vitamin A, iron (24.5 mg), calcium (0.28 mg), fat (1.7 mg) and fiber (56.9 mg).

According to Osei Akoto *et al.* (2015) the fruits of *Solanum torvum* possess a very high moisture content (86.230%), carbohydrates 7.033%, proteins 2.322%, fats 0.278%, ash 0.143% and crude fiber 3.993%. They also did analysis for essential metal contents and had following results; iron 76.87 mg/kg, manganese 19.47 mg/kg, calcium 221.58 mg/kg, copper 2.64 mg/kg and zinc 21.46 mg/kg. In the determinations of the vitamins, 0.08 mg/100g and 2.67 mg/100g were obtained for vitamins A and C respectively.

In a similar study conducted in India, proximate composition analysis revealed a lower moisture percentage (80.5 %) but much higher ash content (12.3 %). Iron, copper and manganese were found to be below 0.5 μg/mL (which is equivalent to mg/kg or ppm). Calcium was the most abundant mineral as well in that study (Bhagyashree *et al.*, 2012).

2.7 Cuisine

The green fresh fruits are edible and used in Thai cuisine, as an ingredient in certain Thai curries or raw in certain Thai chili pastes (*nam phrik*) (http://www.thaitable.com/Thai/Ingredients/2.pea eggplant.htm). They are also used in Lao cuisine (Royal Horticultural Society, 2001) and Jamaican cuisine. The fruits are incorporated into soups and sauces in Côte d'Ivoire (Herzog and Gautier-Béguin, 2001).

In Tamil Nadu, India, the fruit is consumed directly, or as cooked food like sundaikkai sambar, sundaikkai poriyal, sundaikkai aviyal and sundaikkai pulikulambu. After soaking in curd and drying, the final product is fried in oil as sundaikkai vattral (available in all Tamil Nadu supermarkets), it is famous all around in Tamil Nadu. In siddha medicine, one of the traditional systems of India, sundaivattral choornam is used to improve digestion.

In Ghana it is used for preparing soups such as palm nut soup, groundnut soups, light soup and green soup (abunabunu). It is also used to prepare stews such as "nkontomire" (spinach) and garden eggs stew.

2.8 Food preservation

Food preservation is a process of retaining food over a period of time without being contaminated by pathogenic organisms or chemicals and without losing its colour, texture, flavour and nutritional value. The reasons for preserving food are the availability of food, and also to obtain different type of food at different locations. According to Dekker (2001), food preservation is very important for food safety and security. Unsuitable preservation and storage methods cause losses of food which range from 10 to 30% for cereals and 50 to 70% for fruits.

Methods of food preservation include; heat processing, dehydration, Chemical preservation, Canning, Pasteurization, solar drying, oven drying, smokehouse drying and Freezing drying.

2.8.1 Drying

Drying is a mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semi-solid or liquid. This process is often used as a final production step before selling or packaging products. For a product to be considered "dried", the final product must be solid, in the form of a continuous sheet (e.g., paper), long pieces (e.g., wood), particles (e.g., cereal grains or corn flakes) or powder (e.g. sand, salt, washing powder, milk powder). A source of heat and an agent to remove the vapor produced by the process are often involved. In bio products like food, grains, and pharmaceuticals like vaccines, the solvent to be removed is almost invariably water (Greensmith, 1998). Also drying is carried out through the application of heat or at ambient conditions. During drying under ambient temperatures, the product is spread thinly over pavement, tarpaulin or plastic sheet and exposed to the sun. Turning has to be complete regularly to avoid sun burns or scorching of product. When the water is forced out of the product, it is termed as dehydration.

Drying can be said to be one of the oldest preservation methods. The moisture level of agricultural products is decreased between 10-15% to prevent microbial growth or retard enzyme activities. According to Dennis (1997), food scientists have found that by reducing the moisture content of food to between 10 and 20%, bacteria, yeast, mold and enzymes are all prevented from spoiling food items. They have 1/3 to 1/6 the bulk of raw, canned or frozen foods and only weigh about 1/6 that of the fresh food product.

Drying is an ancient method of preservation of food which involves the removal of majority of the water normally present in the food by evaporation, or in other cases freeze drying by sublimation under vacuum to yield a dried product. This occurs under controlled conditions of temperature and pressure (Mazza and LeMaguer, 1980). This definition excludes the processes which involves the mechanical extraction of water out of food such as membrane concentration, gravity concentration, and mechanical separation and baking, as normally removes less water as compared to drying (Treybal, 1980). During drying, water is removed in the form of vapour as heat is supplied to the food material, therefore, heat and mass transfer occurs simultaneously. It requires a safe place to spread the food where dry air in large quantities can pass over and beside thin pieces (DeLong, 1979). Drying is achieved by the direct use of energy produced by the sun or from other means of heating such as electricity and fuel. Of these, the sun is the most abundant and economical (Treybal, 1980). Dehydration, or drying, is a simple, low-cost way to preserve food that might otherwise spoil. Drying removes water and thus prevents fermentation or the growth of moulds. It also slows the chemical changes that take place naturally in foods, as when fruit and vegetables ripen. Surplus grains, vegetables and fruit preserved by drying can be stored for future use. People have been drying food for thousands of years by placing the food on mats in the sun. This simple method, however, allows the food to be contaminated by dust, airborne moulds and fungi, insects, rodents, and other animals. Furthermore, open air-drying is often not possible in humid climates (DeLong, 1979). There are several types of drying methods including: sun (solar) drying, freeze drying, drum drying, tunnel drying, oven drying, smokehouse drying and microwave drying. The factors that normally affect drying product includes the following

i. Composition of raw material,
ii. Size, shape and arrangement of stacking of produce,
iii. Temperature, relative humidity and velocity of air and
iv. Pressure and heat transfer to surface.

2.8.2 Fundamentals of drying

Drying involves the removal of moisture and, in thermal drying; this is achieved through the application of heat to the product. The heat increases the vapor pressure of the moisture in the product above that of the surrounding air. Pressure and thermal gradients cause the moisture, both liquid and vapor, to move to the surface of the product. Evaporation takes place and water vapor is transferred to the surrounding air. This air may become saturated but the process of drying continues if this moist air is replaced by less saturated air (Fuller, 1991).

2.8.3 The drying process

When drying food, temperatures should be monitored closely at the beginning and end of drying period. Temperatures too low may result in the growth of bacteria on the food. Whereas high temperatures results in the food being cooked instead of dried. If the temperature is too high in the initial phase, a hard surface develops on the produce. This prevents the removal of moisture from the interior portion of fruit and vegetables and the moisture is trapped inside the food material. High temperatures at the end of drying period also cause food to scorch, losing its flavor and nutritional value. High temperatures may be used at the beginning, but should be reduced largely as food begins to dry. Turning of the food is vital, thus turning the trays while the food being dried is essential.

The importance of dried foods cannot be overestimated. They do not require any special storage equipment and are easy to transport. To ensure that the products do not rehydrate after being dried, they have to be stored in a moisture-free environment(). Dried foods are tasty, nutritious, lightweight, and easy to store and use. Drying is generally not difficult. Since the products lose water, they also become much lighter and thus easier to transport. The flavor and most of the nutritional value is preserved and concentrated. Vegetables, fruits, meat, fish and herbs can all be dried and can be preserved for several years in many cases. Basically there are two drawbacks, the products lose vitamins, and they change in appearance (Troftgruben, 1977).

The kitchens and food stores in any country will confirm the quantity and variety of dried foods in use. The grade of foods is remarkable. Drying is very important because it is the easiest and most common way of food preservation applied to various products. Dried products are becoming a highly attractive alternative to marketing fresh products.

Drying may be required for several reasons. Firstly and most often, water is removed from the fresh crop to extend its useful life. The dried product is later re-hydrated prior to use in order to produce a food closely resembling the fresh crop. Dried vegetables are an example of this drying application. Secondly, a crop may require drying so that it can be further processed. For example, many grains are dried so that they can be ground into flour. Finally, fresh crops are sometimes dried so that a new product, distinctly different from its original form, can be produced. Sultanas, the dried form of grapes, are an example of this drying application. In Ghanaian community, the most common preservation method used is drying and to be precise sun drying. This work sought to use both solar and oven drying.

2.8.4 Solar Drying

Salunkhe *et al.*(1991) distinct solar drying as the process of using solar radiation as the heat source for drying a product, where a system is either used to increase the radiation flux absorbed by the product or to transfer the absorbed radiation onto the product. In contrast to water heating and the generation of electricity, crop drying utilizes the sun's energy directly (Archuleta *et al.*, 1983, Gregoire *et al.*, 1981). Crops that are solar dried are nothing new in the tropics. Various edible and even cash crops such as cocoa and coffee beans have been dried on racks placed in the sun for decades. The sun is often used to provide the hot dry air for drying. Solar food dryers represent a major improvement upon this ancient method of dehydrating foods. Although solar dryers involve initial expenses, they produce better testing and more nutritious foods, enhancing both their food value and their marketability. They are also faster, safer and more efficient than traditional sun drying techniques. An enclosed cabinet-style solar dryer can produce high quality dried foodstuffs in humid climates as well as arid climates. It can also reduce the problem of contamination. Drying is completed more quickly, so there is less chance of spoilage. Fruits maintain a high vitamin C content. Because many solar dryers have no additional fuel cost, this method of preserving food also conserves non-renewable sources of energy. In contemporary years, attempts have been made to develop solar dryers that can be used in agricultural activities in developing countries. Many of the driers used for dehydration of foods are relatively low cost compared to systems used in developed countries. Solar drying is an advanced form of sun drying. In this case the direct radiation from the sun is prevented from having direct contact with the food, in effect; the radiation is filtered and collected into an appropriate chamber where drying and heat generation will be high.()

2.8.5 Principle and mechanism of Solar Drying

2.8.5.1 Principle of Drying

Envisage a close heated space in which a damp agricultural crop has been stored. Two things happen in the crop: the crop is warmed by the heat from the stove or fire and the air around the heat source is heated up-whereby it can take up a great deal of moisture and the air is rising and is continually replaced. As the crop is warmed up, including the air between the plant fibres, the water it contains quickly evaporates. Pretty soon the air within and surrounding the crop is saturated with water vapour. Fortunately the air moving alongside, warm and unsaturated can take up this moisture and transport it away. A small fan will of course help this process, but it is not strictly necessary. At a certain moment the air in the room or dryer has taken up so much moisture from the crop that the windows suddenly mist up (though this will depend on the outside temperature); the air against the cold windows has been cooled to below the ′dew point′. In this way the water in the crop is transferred to the window panes, where it can be wiped off, or allowed to fall into a gutter which leads outside the room. If, in this account, the heat source is replaced by sun, a solar drier has effectively been described. The cold window (which works as a condenser) is sometimes encountered in indirect drying, where the warming of the air and the drying of the crop are separate. Solar drying is a technique particularly suited to the warmer parts of the world, since; there is abundant sunlight, the air temperature is high and relatively constant over the whole year.() Kordylas (1991) outlined the following ideal conditions as most suitable for solar drying:

i. Food item must be out of direct sunlight,

ii. Food must not be heated directly but instead by warm air constantly moving across the food surface

iii. Moisture or water vapour must be constantly removed from the drying food

iv. A temperature range of 35-38ºC must be constantly maintained.

Of the total amount of energy released by the sun, only a fraction reaches the earth's surface after passing through the atmosphere. Of this, half is visible light and half is heat (Kordylas, 1991). The wavelength of the solar radiation at the earth surface ranges from 0.3 to 3.0 µm and called short waves. Though these are able to pass through clear substances, they are absorbed by black objects, which in turn emit heat radiation with wavelengths of more than 3.0 µm (long waves). Long wave radiation cannot pass through some clear materials .Thus if a black material lying on an insulated base and covered with such a clear material placed under the sun, it can act as a collector for solar radiation in the form of heat (Ihekoronye and Noddy, 1985). The heat collected is used for drying. In such a system, if a small amount of air is held in a confined chamber, it will get warmer no matter how much heat it received from the sun. This air will get hotter if less air is allowed to move through the chamber. In the chamber, warmer air will rise and be replaced by cooled air (Gregoire *et al.*, 1981). Thus convention current would be generated and this can carry away moisture from drying products to be discharged elsewhere (Ihekoronye and Ngoddy, 1985). The relative humidity of the chamber also influence the drying time. A high relative humidity increases the drying time.

2.8.5.2 Mechanism of Drying

Solar dryers use the energy of the sun to heat the air that flows over the food in the dryer. As air is heated, its relative humidity decreases and it is able to hold more moisture. Warm, dry air flowing through the dryer carries away the moisture that evaporates from the surface of the food (Archuleta *et al.*, 1983). As drying proceeds, the actual amount of moisture evaporated per unit of time decreases. In the first phase of drying, the moisture in the exterior surface of the food is evaporated. Then, once the outer layer is dried, moisture from the innermost portion of the material must travel to the surface in the second phase of drying. During the second phase of the drying process, overheating may occur because of the lessened cooling effect resulting from the slower rate of moisture evaporation. If the temperature is too high, the food will "case harden" or form a hard shell that traps moisture inside. This can cause deterioration of the food. To prevent overheating during this portion of the drying cycle increased airflows or less heat collection may be desirable.

2.8.5.2.1 Types of Solar Dryer

Solar dryer fall into two broad categories: active and passive. Passive dryers can be further divided into direct and indirect models. A direct (passive) dryer is one in which the food is directly exposed to the sun's rays. In an indirect dryer, the sun's rays do not strike the food to be dried (Exell, 1980). A small solar dryer can dry up to 300 pounds of food per month; a large dryer can dry up to 6,000 pounds a month; and a very large system can dry as much as 10,000 or more pounds a month (Gregoire *et al.*, 1981). Passive dryers use only the natural movement of heated air. They can be constructed easily with inexpensive, locally available materials. Direct passive dryers are best used for drying small batches of foodstuffs. Indirect dryers vary in size from home dryers to large scale commercial units.

Active dryers require an external means, like fans or pumps, for moving the solar energy in the form of heated air from the collected area to the drying beds. These dryers can be built in almost any size, from very small to very large, but the larger systems are the most economical (Gregoire *et al.*, 1981). Either air or liquid collectors can be used to collect the sun's energy. The collectors should face south if you are in the northern hemisphere (Exell, 1980, Gregoire *et al.*, 1981). At or near equator, they should also be adjusted east or west in the morning and afternoon, respectively. The collectors should also be positioned at an appropriate angle to optimize solar energy collection for the planned months of operation of dryer. The collectors can be adjacent to or somewhat remote from the solar dryer. However, since it is difficult to move air over long distance, it is best to position the collectors as near the dryer as possible. The solar energy collected can be delivered as heat immediately to the dryer air stream, or it can be stored for later use. Storage systems are bulky and costly but are helpful in areas where the percentage of sunshine is low and a guaranteed energy source is required; or in carrying out round-the-clock drying (Archulata *et al.*, 1983). In an active dryer, the solar-heated air flows through the solar drying chamber in such a manner as to contact as much surface area of the food as possible. The larger the ratio of food surface area to volume, the quicker will be the evaporation of moisture from the food. The sliced foods are placed on drying racks or on trays made of a screen or other material that allows drying air to flow to all sides of the food. For grain products, pipes with many holes are placed at the bottom of the drying bin with grain piled on top. The heated air flows through the pipes and is released upward to flow through the grain, carrying away moisture as it flows (Exell, 1980).

Passive solar food dryers use natural means of radiation and convection to heat and move the air. The category of passive dryers can be subdivided into direct and indirect types (Archuleta *et al.*, 1983, Ong, 1978).

In a direct dryer, food is exposed directly to the sun's rays. This type of dryer typically consists of a drying chamber that is covered by transparent cover made of glass or plastic. The drying chamber is a shallow, insulated box with holes in it to allow air to enter and leave the box. The food is placed on a perforated tray that allows the air to flow through it and the food. Solar radiation passes through the transparent cover and is converted to low-grade heat when it strikes an opaque wall. This low-grade heat is then trapped inside the box in what is known as the "greenhouse effect" Simple stated, the short wavelength solar radiation can penetrate the transparent cover. Once converted to low-grade heat, the energy radiates on a long wavelength that cannot pass back through the cover (Archuleta *et al.*, 1983).

The drying chamber can be constructed of almost any material; wood, concrete, sheet metal, etc. The dryer should be 2 m long by 1 meter wide and 23 to 30 cm deep. The bottom and sides of the dryer should be insulated, with 5 cm of an insulator. Blackening the inside of the box will improve the dryer efficiency, but be sure to use a nontoxic material and avoid lead-based paints. Wood blackened by fire may be a safe and inexpensive material to use (Archuleta *et al.*, 1983). The tray that holds the food must permit air to enter from below and pass through to the food. A wire or plastic mesh or screen will do nicely. Use the coarsest possible mesh that will support the food without letting food to fall through the holes. The larger the holes in the mesh, the easier the air will circulate through to the food. Air holes below the tray or mess will bring in outside air, which will carry away the moisture evaporated from the food (Gregoire *et al.*, 1981). As the air heats up in the dryer, its volume will increase, so either more or large holes will be required at the top of the box to maintain maximum air flow.

In indirect solar dryers, the black surface heats incoming air, rather than directly heating the substance to be dried. This heated air is then passed over the substance and exits upwards often through a chimney, taking moisture released from the substance with it (Heinz *et al.*, 2007). They can be very simple, just a tilted cold frame with black cloth to an insulated brick building with active ventilation and a back-up heating system (Robishaw; 1999; Weiss *et al.*, 2001). Also an indirect dryer is one in which the sun's ray do not strike the food to be dried. In this system, drying is achieved indirectly by using an air collector that channels hot air into a separate drying chamber. Within the chamber, the food is placed on mesh trays that are stacked vertically so that the air flows through each one (Gregoire *et al.*, 1981). The solar collector can be of any size and should be titled toward the sun to optimize collection. By increasing the collector size, more heat energy can be added to the air to improve overall efficiency (Gregoire *et al.*, 1981). Larger collector areas are helpful in places with little solar energy, cool or cold climates, and humid regions. Tilting the collector is more effective than placing them horizontally, for two reasons. First, more solar energy can be collected when the collector surface is more nearly perpendicular to the sun's rays. Second, by tilting the collectors, the warmer, less dense air rises naturally into the drying chamber. The drying chamber should be placed on support legs, but it should not be raised so high above the ground that it becomes difficult to work with. The base of the collector should be vented to allow the entrance of air to be heated for drying. The vent should be evenly spaced across the full width of the base of the collector to prevent localized areas within the collector from overheating. The vents should also be adjustable so that the air-flow can be matched with the operating conditions and/or needs. Solar radiation, ambient air temperature, humidity level, drying chamber temperature and moisture level of the food being dried must all be considered when regulating the flow of air. The top of the collector should be completely open to the bottom of the drying chamber. Once inside the drying chamber, the warmed air will flow up through the stacked food trays. The drying trays must fit snugly into the chamber so that the drying air is forced through the mesh and food. Trays that do not fit properly will create gaps around the edges, causing large volumes of warm air to bypass the food, and preventing the dryer from removing moisture evaporated from the food. As the warmer air flows through several layers of food on trays, it becomes moister. The moist air is vented out through a chimney (Archuleta *et al.*, 1983). The chimney increases the amount of air flowing through the dryer by speeding up the flow of the exhaust air. As the warm, moist air flows through the solar chimney, the additional solar energy entering the chimney warms the escaping air further. This added heat makes the air less dense and causes it to flow up through, and out of, the solar chimney at a faster rate, thereby bringing in more fresh air into the collector (Gregoire *et al.*, 1981).

One of the advantages of the indirect system is that it is easier to protect the food, or other substance, from contamination whether wind-blown or by birds, insects, or animals. Also, direct sun can chemically alter some foods making them less appetizing.

2.8.5.2.2 Advantages of Solar Dryers

The principal advantage of using solar energy is a free, available and limitless energy source that is also non-polluting. Dried foods are tasty, nutritious, lightweight, easy-to-prepare, and easy-to-store and use. Drying most foods in sunny areas should not be a problem. Most vegetables, for example, can be dried in 2-1/2 to 4 hours, at temperatures ranging from 43 to 63°C. Fruits take longer, from 4 to 6 hours, at temperatures ranging from 43 to 66°C. At this rate, it is possible to dry two batches of food on a sunny day. A solar food dryer improves upon the traditional open-air systems in five important ways (van Brakel, 1978):

i. It is faster. Foods can be dried in a shortened amount of time. Solar food dryers enhance drying times in two ways. First, the transparent glazing over the collection area traps heat inside the dryer, raising the temperature of the air. Second, the capability of enlarging the solar collection area allows for the concentration of the sun's energy.

ii. It is more efficient. Since foods can be dried more quickly, less will be lost to spoilage immediately after harvest. This is especially true of produce that requires immediate drying such as fruits with high moisture content. In this way, a larger percentage of food will be available for human consumption. Also, less of the harvest will be lost to marauding animals, vermin, and insects since the food will be in an enclosed compartment.

iii. It is safer. Since foodstuffs are dried in a controlled environment, they are, less likely to be contaminated by pests, and can be stored with less likelihood of the growth of toxic fungi also microorganisms are effectively killed when the internal temperature of food reaches 62.8°C (Herringshaw, 1997).

iv. It is healthier. Dried foods are high in fiber and carbohydrates and low in fat, making them healthy food choices. Drying foods at optimum temperature and in a shorter amount of time enables them to retain more of their nutritional value specially vitamin C. The nutritional value of food is only minimally affected by drying. Vitamin A is retained during drying; however, because vitamin A is light sensitive, food containing it should be stored in dark places. Yellow and dark green vegetables, such as peppers, carrots, winter squash, and sweet potatoes, have high vitamin A content. Vitamin C is destroyed by exposure to heat, although pretreating foods with lemon, orange, or pineapple juice increases vitamin C content. An extra bonus is that foods will look and taste better, which enhances their marketability.

v. It is cheaper. Using solar energy instead of conventional fuel demand can result in significant cost savings. Solar drying lowers the cost of drying, improving the quality of product, and reduces losses due to spoilage. The energy input is less than what is needed to freeze or can, and the storage space is minimal compared with that needed for canning jars and freezer container.

2.8.5.2.3 Disadvantages of Solar Dryers

Solar dryers do have shortcomings. They are of little use during cloudy weather. During fair weather they can work too well, becoming so hot inside at midday as to damage the drying crop. Only with close supervision can this be prevented. As temperatures rise (determined with a thermometer or by experience), the lower vents must be opened to allow great airflow through the dryer and to keep the temperatures down. Rice, for example, will crack at temperatures above 50ºC, seed grains can be dried at temperatures below 40 to 45ºC. Dried foods that are not completely dried are susceptible to mould.()

2.8.6 Oven Drying

Oven drying is the simplest way to dry food because no special equipment is needed. It is also faster than sun drying or using a food dryer. But 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.

The greatest efficiency and quality comes from using the right oven for the job, and drying ovens come in three main categories: batch, conveyor, and specialty. Combining the factors of heat, low humidity and air flow, an oven can be used as a dehydrator. Oven drying is slower than dehydrators because it does not have an in- built fan for the air movement. However, some convection ovens do have a fan. It takes about two times longer to dry food in an oven than it does in a dehydrator. Thus, the oven is not as efficient as a dehydrator and uses more energy (Harrison and Andress, 2000). Oven dried food is more brittle and usually darker and less flavourful than food dried in a dehydrator. Another disadvantage of oven drying is its energy cost. Oven drying takes two or three times longer than drying in a dehydrator. Before drying in an oven, test the oven temperature with an oven thermometer for about 1 hour. The oven should maintain a temperature of 55ºC to 65ºC. If the oven cannot maintain a temperature in this range, you will not have high-quality dried food (McCurdy, 2003).

2.8.6.1 Batch Drying Ovens

When a manufacturing process calls for drying items of inconsistent sizes, including large bulky objects, or when items need an extended drying time, batch drying ovens are often the right choice. Because they are manually loaded and unloaded, they also are suitable for processes where production volume is relatively low, and where capital budgets are tight.

2.8.6.2 Conveyor Drying Ovens

Where manufacturing processes require inline production or a high volume of items on conveyors, in continuous or indexed stop-and-go motion, conveyor drying ovens are the most efficient and effective solution. Though they normally require a greater capital investment than batch ovens, conveyor drying ovens promise a substantial return on investment over time from increased productivity.

2.8.6.3 Specialty Drying Ovens

Some types of manufacturing require a specialty drying oven designed and built from the ground up. Only the demands of the manufacturing process can determine the exact features and methods employed. Just a few of the types of products that have needed specialty ovens are fishing line, powders,

2.9 Nutritional values of dried vegetables

Vegetables are a good source of minerals and B vitamins such as thiamine, riboflavin, and niacin. Both fruits and vegetables provide useful amounts of the fiber (bulk) that he body need. The water used for soaking or cooking dried foods should be used in the preparation of soups, sauces and gravies this is because the water is nutrient-rich which contains the leached vitamins of B and C.

2.9.1 Types of food to dry

Dried foods that are consumed in large quantities around the world include grains such as rice, wheat, millet and sorghum.

Fruits like ripe apples, berries, cherries, peaches, apricots, sultanas' currents, mango, orange peels, and pears are hands-on to dry. Fruits are easier to dry than vegetables because moisture evaporates more easily. Vegetables such as peas, corn, peppers, okra, onions, tomatoes and green beans. Also spices, herbs, meat, fish, nuts and beverages such as tea and coffee can also be dried. (Keith, 1984)

2.9.2 Equipment for drying

Although the following equipment is not absolutely necessary, it will help you make 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 and a sulfur box for fruit (Keith, 1984).

2.9.3 Pre-treatment before drying

Although many fruits and vegetables may be dried and stores without pre-treatment, the pre-treatment generally improves quality and can make the food safe to eat. It preserves colour, minimizes nutrient loss, stop decomposition by enzyme action, ensure more even drying as well as extend storage life. Decomposition from enzyme action during storage is less a problem with fruits than it is with vegetables as they have higher sugar and acid, which counteract enzyme action (Harrison & Andress, 2000).

Blanching (heating in boiling water or steam) is the pre-treatment method of choice for vegetables. Almost all vegetables should be blanched before drying to destroy the enzymes that make vegetables deteriorate. Fruits, on the other hand, are usually not blanched prior to drying owing to their delicate nature and inherent acidity (Bruhn *et al.*, 2007). Some fruits and vegetables are blanched by immersion in hot water (95 to 100°C) or exposure to steam. According to Fellows (2009) blanching at 88ºC stop all life process, inactivates enzymes, fixes green colour and removes certain harsh flavours common in vegetables. It also clean and soften vegetables and makes them easier to rehydrate later. Sulfuring dried fruits must be closely controlled so that enough sulphur is present to maintain the physical and nutritional properties the product throughout its expected shelf life, but not so large that it adversely affects flavour (Harrison, and Andress, 2000).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1. Source of materials

Materials that were used are *Solanum torvum*, oven, solar drier, moisture design, Muffle furnace, Goveh crucible, Soxhlef apparatus, Kjeldahl apparatus, Sodium hydroxide (NaOH), Hydrochloric acid (HCl) and Sulphuric acid(H_2SO_4). Fresh samples of *Solanum torvum* were obtained from the local market in Gyinase, Agogo and Central markets, all in Kumasi, Ashanti Region of Ghana.

3.1.2 Sample preparation

The unripe fruits were removed from the stalk and well washed with distilled water. The fruits were then wiped to dry all the water around it.

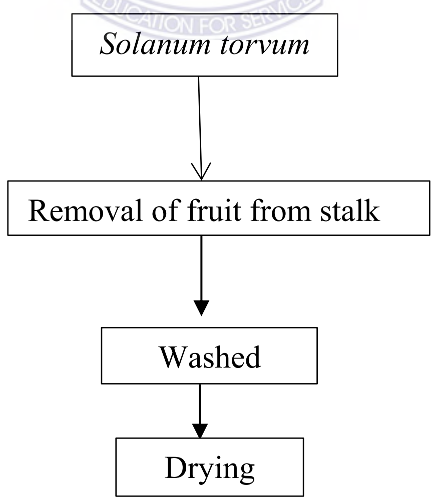

Figure 3.1: Flow chart for preparation of *Solanum torvum* prior to drying.

3.2 Laboratory Experiment

3.2.1 Introduction

Laboratory work was carried out in Kwame Nkrumah University of Science and Technology Food Science and Technology laboratory to determine the effect of drying on the macro nutritional parameters that were investigated include: moisture, ash, fat, protein, fibre, and carbohydrate. The micro nutritional parameters that were investigated include: iron (Fe), magnesium (Mg), sodium (Na), and phosphorus (P). The anti-nutritional parameters that were investigated include: phytate, oxalate, tannins and saponins.

3.2.2 Instrument for Data collection

The AOAC (Association of Official Analytical Chemists) methods of analysis were used to investigate the individual parameters outlined.

The analytical methods adopted by the AOAC are used by government agencies concerned with the analysis of fertilizers, foods, feeds, pesticides, drugs, cosmetics, hazardous substances, and other materials related to agriculture, health and welfare, and the environment. AOAC methods are also used by industry to check compliance of their products. The AOCS and AOAC have cooperated in the past in achieving common methodology for fatty acids, hydrocarbons and mineral oils and monoglycerides. AOAC is used for developing, testing, and validating methods of analysis.

3.2.2.1 Proximate Composition

All the proximate composition analysis was carried out according to AOAC (2000). Below is a description of how proximate analysis was done.

3.2.2.1.1. Moisture determination

A weight of 2.0±0.01g of fresh sample was accurately weighed in a clean, dried petri dish of a known weight (W_1). It was quickly placed in a conventional oven at 105 °C for 6 h. The petri dish was then placed in a desiccator for 30 min to cool. After cooling, it was weighed again (W_2). The percent moisture was then calculated using the following formula

$$\% \text{ moisture} = \frac{(W2 - W3) \times 100}{W2 - W1}$$

Where: W_1 = Weight of crucible,

W_2= Weight of crucible + slices,

W_3 = Weight of crucible + dry sample.

3.2.2.1.2. Crude protein determination

A weight of 2.0±0.01g of the sample was weighed into a digestion tube, 5 grams of catalyst and 1 glass bead together with 10 mL concentrated sulfuric acid was also added. Digestion tubes were placed in the digester. Digestion commenced initially at a temperature of 400ºC to prevent frothing and boiling until the solution was clear. A 250mL Erlenmeyer flask containing 50 mL of 4% boric acid with indicator was placed in a distillation unit and distillation commenced for 10 min whiles the tip of the condenser extended below the surface of the acid solution. A volume of 100 mL of water and 70 mL of 50% sodium hydroxide (excess) was added to the digests during the distillation process to ensure complete release of ammonia. Titration of the distillate was done with a standardized 0.1 N hydrochloric acid until the first appearance of the pink colour was obtained. Result was recorded to the nearest 0.05 mL volume and calculated. (Kirk and Sawyer, 1991).

$$\%\text{Total Nitrogen } (\%N) = 100 \times \frac{(sample\ titre\ value - Blank\ titre\ value) \times 0.1 \times 0.01401}{\text{sample weight} \times 10}$$

$$\%\ \text{Protein} = \%N \times 6.25$$

3.2.2.1.3. Crude fiber

Five (5) g of sample was taken from the zip lock bags and defatted using the AOAC standard before subjecting to analysis. Two (2) g of *Solanum torvum* samples were weighted into a flat bottom flask and 200 mL of boiling sulphuric acid (1.25%) was added for 30 min. The resulting solution was filtered through cheesecloth using a funnel and then washed with hot water until it was free from the acid. The residue on the cloth was transferred into a flask and 200 mL of boiling sodium hydroxide solution (1.25%) was added. The flask was immediately connected to the digestion apparatus and boiled for 30 min. The flask was then removed and immediately the solution was filtered and washed thoroughly with boiling distilled water until washing was no longer basic. The residue was rinsed with 15 ml of alcohol. It was transferred into porcelain crucibles and dried at 105°C in an oven for 24 hours. It was cooled to room temperature in a desiccator and weighed. The crucible and its weight were incinerated in a muffle furnace at 550°C. It was cooled to room temperature in a desiccator and weighed. The difference between the two weights was recorded and the percentage crude fiber calculated by using the following formula.

$$\%\text{Crude Fibre} = \frac{(\text{weight of sample before ashing} - \text{weight of sample after ashing}) \times 100}{\text{weight of flour sample}}$$

3.2.2.1.4 Crude fat determination

Dried samples from the moisture analysis was weighed placed in a fat free thimble and placed into the extraction tube. Extraction of fat beaker was weighed, filled to about three quarter with petroleum ether, fitted into the Soxhlet apparatus and extracted for 6 hrs at 60ºC. Extract was placed in a water bath for the remaining ether to evaporate; the dish was then placed in an oven at 105ºC for 2 hours and cooled in a desiccator. The percent crude fat was determined by using

$$\%\text{Fat} = \frac{(W2 - W1) \times 100}{W3}$$

Where: W_1 = Weight of empty flask

W_2 = Weight of flask + fat

W_3 = Weight of slices taken

3.2.2.1.5 Ashing

Clean empty crucible was placed in a muffle furnace at 600°C for an hour, it was cooled in a desiccator and then weighed and weight noted (W_1). Sample of 1g±0.01 was weighed and transferred into the crucible and noted (W_2). The sample was ignited over a burner with the help of blowpipe, until charred. Then the crucible was placed in a muffle furnace at 600°C for 6 hours for complete oxidation of all organic matter in the sample. After the process, crucible was cooled in the desiccator and the weight was noted (W_3). Percent crude ash was calculated and recorded.

$$\%\text{ Ash} = \frac{(W3 - W1) \times 100}{W2 - W1}$$

Where: W_1 = Weight of porcelain crucible, W_2= Weight of porcelain crucible + slices,

W_3 = Weight of porcelain crucible + Ash

3.2.2.2 Mineral analysis (AOAC, 1990)

Mineral analysis for iron (Fe), magnesium (Mg), sodium (Na) and phosphorus (P) were done by using Atomic Absorption spectrophotometer (AAS). About 1 g of the sample was weighed and 10-20 ml of nitric acid was added. The solution was digested till the volume reduced to almost half. About 10 ml sulphuric acids was added and digested until white fumes appeared and the solution cleared. About 10-20 ml of nitric acid was added and digested until the solution cleared. The solution was placed in the instrument where it was heated to vaporize and atomize the various minerals. A beam of radiation was passed through the atomized sample, and the absorption of radiation was measured and specific wave lengths corresponding to the mineral of interest. The type and concentration of the minerals present was obtained by measuring the location and intensity of the peaks in the absorption spectra.

3.2.2.2.1. Anti-nutrients

Protocols as described by Day and Underwood (1986) as cited by Chinma and Igyor (2007) was followed in the anti-nutrient determination,

3.2.2.2.2 Oxalate Determination

A gram of sample was weighed into 100ml conical flask. 75ml 3M H_2SO_4 was added and stirred for 1hr with a magnetic stirrer. This was filtered using a Whatman No 1 filter paper. After, 25ml of the filtrate was taken and titrated while hot against 0.05M $KMnO_4$ solution until a faint pink colour persisted for at least 30 sec. The oxalate content was then calculated by taking 1ml of 0.05m $KMnO_4$ as equivalent to 2.2mg oxalate.

3.2.2.2.3 Phytate Content Determination

A weight of 100g of the sample was extracted with 3% trichloroacetic acid. The extract was treated with $FeCl_3$ solution and the iron content of the precipitate was determined using Atomic Absorption spectrophotometer. A 4:6 Fe/P atomic ratio was used to calculate the phytic acid content (Okon and Akpanyung, 2005).

3.2.2.2.4 Tannin content determination

The tannins content of the raw and processed samples were estimated by taking 2 g of air dried *Solanum* extracted with 50 ml of 1% (v/v) HCl in methanol. The samples were shaken on a reciprocating shaker for 24 h at room temperature. Then the contents were centrifuged at 10,000 x g for 5 min and the supernatant was collected and used for further analysis. The tannins content was quantified by using Vanillin-HCL method. The vanillin reagent reacts with any phenol that has an unsubstituted resorcinol or phluroglucinol nucleus and forms a purple coloured product, which is measured at 500 nm. Average values of three separate determinations were expressed in g/kg DM basis (Doss *et al.*, 2011).

3.2.2.2.5 Saponin content determination

Content determination of saponins was carried out according to the method of Birk *et al.* (1968) modified by Hudson and El Difrawi (1979). According to this method, 1 g of the sample was dissolved in 20 ml of the ethanol 20% (ethanol-water) under the magnetic agitation for 12 h at

55°C. The solution was filtered on Whatman No.1 and adjusted with 40 ml then 20 mL of the filtered solution was added to diethyl ether followed by a vigorous manual agitation. The aqueous phase was adjusted to pH 4.5 with a hydrochloric acid solution 0.2 N. 60 mL of the solution of N butanol were added to this phase and the unit was washed with 10 mL of NaCl 5%. The organic phase was then evaporated to have the content of saponins. The saponin was determined by the difference between the weight of the container after evaporation and the tare weight of the same container.

3.3 Data Analysis

A complete random design of two factors (varieties) comprising of solar and oven drying was employed for the study. The experiment was carried out in triplicate and analysis of variance (ANOVA) was used to determine significant data obtained. The differences in means were evaluated with Least Significant Difference (LSD) test using Statistical Package for the Social Sciences (SPSS) version 17.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Proximate composition

The analytical methods adopted by the AOAC (Association of Official Analytical Chemists) are used by government agencies concerned with the analysis of fertilizers, foods, feeds, pesticides, drugs, cosmetics, hazardous substances, and other materials related to agriculture, health and welfare, and the environment. AOAC methods are also used by industry to check compliance of their products. This same method was used and the table below shows the result on the proximate composition of the *Solanum torvum.*

Table 4.1 Proximate composition of *Solanum torvum* cultivars

	Moisture	Fat	Fibre	Protein	Ash	Carbohydrate
Fresh	78.34±1.22	0.57±0.03	4.34±0.94	3.01±0.11	1.04±0.05	12.70
Oven Dried	6.32±0.45a	3.45±0.48a	7.35±1.02a	18.54±0.44a	4.34±0.02a	60.00±1.54a
Solar Dried	8.45±0.72b	1.44±0.29b	5.52±0.83b	13.56±0.98b	2.18±0.07b	68.85±1.02b

Values are mean ± standard deviation. Values in columns with different alphabets are significantly different at $p<0.05$.

4.1.1 Moisture content

The moisture content of the *Solanum* samples ranged between 6.32 to 8.45% with the oven dried sample having a lower than that of the solar dried sample, thus 8.45%.The comparatively higher moisture content in the solar dried sample is likely to reduce the shelf life as higher moisture content encourages and support microbial growth. This in turn may cause both physiological and chemical changes which are detrimental to safety of the sample for consumption .Drying or removal of water is one of the cheapest processing technique used to reduce moisture (loose water) or lower water activity and therefore increase the shelf life of the product. From the study, the oven dried samples will have a much stable shelf life as compared to the solar dried sample.

4.1.2 Protein content

The values obtained from the sun dried samples which was 13.56% differed from oven-dried samples of 18.54%.The variations in the protein values may be connected with more denaturation of proteins associated with the oven dried than with the solar dried method. Maillard reaction could be responsible for losses of protein as this also depends on the intensity of heat and temperature. Maillard reaction also known as non-enzymatic browning occurs when the carbonyl group of the sugar reacts with the amino group of the amino acid, producing N-substituted glycosylamine and water. The unstable glycosylamine undergoes Amadori rearrangement, forming ketosamines. These ketosamines further react to produce brown nitrogenous polyers and melanoidins (Nursten, 2005). Proteins are needed in the body for repair and replacement of worn-out tissues, serve as antibodies, primary sources of amino acids and the building block of cellular protein (Adebooye, 1996).

4.1.3 Fibre content

Owing to the different methods of drying employed, there were variations in the value for the both the solar dried and oven dried samples which were from 5.52% to7.35%. Sample dried by oven method recorded the highest value 7.35% crude fibre content followed by the solar dried sample recording 5.52% Crude fiber measures the cellulose, hemicelluloses and lignin contents of food. Crude fibre has been proved to aid peristalsis movement of food through the digestive tract (Adebooye, 1996). Increase in crude fibre contributes to the bulk density which could help in the bowel movement, lower blood cholesterol and helps prevent cancer of the colon (Hung *et al.*, 2004).

4.1.4 Fat content

The values obtained for fat ranges from1.44 to 3.45% with the oven dried sample recording the highest followed by the solar dried sample. The high fat contents observed in oven dried sample which could be associated with the removal of moisture during the drying procedures per unit mass of the samples (McGill *et al.*, 1974). Considering the fat content, it was observed that the lower the moisture content, the higher the fat content since water add up to the total mass of the samples.

4.1.5 Ash content

The results obtained in the fruit of *Solanum torvum* ranges from 2.18 to 4.34%.The ash content represents the total mineral content in the samples. The oven dried sample had the highest value of 4.34% followed by the solar dried sample of 2.18%. This result obtained is also an indication of the presence of organic nutrients in the samples. Since much more water was lost in the case of the oven dried sample than in the solar dried, equal weight of each sample implies more mass (organic nutrients) in the oven dried sample than that of the solar dried resulting in the higher value in the oven dried compared to the solar dried samples.

4.1.6 Carbohydrate content

The values obtained for carbohydrate ranged from 60.00 to 68.85%. The carbohydrate content observed in the solar dried samples was 68.85% which was higher than that of the oven dried value of 60.00%.The presence of carbohydrate in such amount indicate a quick source of metabolizable energy and also assist in fat metabolism. Carbohydrate deficiency causes depletion of body tissues. Barker, (1996) Sufficiency of Carbohydrate is however necessary for optimum functioning of the brain, heart, nervous, digestive and immune systems. Barker, (1996) Enwere (1998) reported that, in all the solid nutrients in roots and tubers, carbohydrate predominates. Carbohydrate supplies quick source of metabolizable energy and assist in fat metabolism.

4.2. Minerals content

Mineral nutrition is a significant aspect of human life and it plays an essential role for healthy growth of an individual. Data for effect of treatment on minerals are showed in Fig 4.2 and it can be deduced from the results obtained that the oven dried sample had an overall highest mineral content. Generally treatment had a significant effect ($p < 0.05$) on the mineral contents measured.

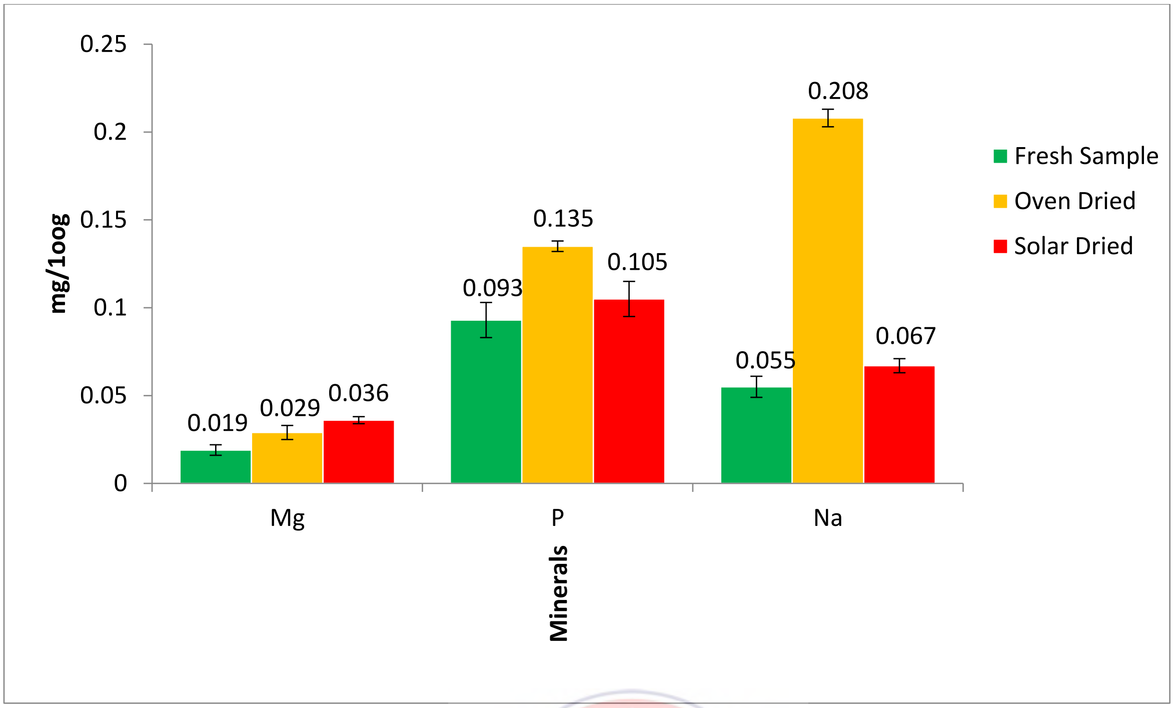

Figure 4.2: Effect of processing on minerals content of *Solanum torvum*.

4.2.1 Sodium content

The values obtained for sodium ranged from 0.055 to 0.208, with the oven dried sample recording the highest (0.208mg/100g), solar dried sample recorded (0.067mg/100g) while the fresh sample recorded the lowest (0.055mg/100g). The low values of sodium in the fresh sample could be attributed to the fact that there was high moisture content in the fresh sample which diluted the sodium. However, the relative concentrations of sodium in the oven and solar samples were because of evaporation of significant amount of water from the sample. In effect, the moisture content of the oven dried sample was much lower than the solar dried sample and this could have accounted for the highest sodium content in the oven dried sample.

Results obtained compliment works by Eromosele *et al.*, (1991) and Nazarudeen (2010) detected useful nutrient in wild fruits. Sodium is the principal cation in intracellular fluid and functions in acid base balance, regulation of osmotic pressure, muscle contraction and Na+ /K+ ATPase (Murray *et al.*, 2000).

4.2.2 Phosphorus content

The P concentration in the *Solanum* fruit analyzed varied from 0.093 to 0.135mg/100g with the oven dried sample recording the highest (0.135mg/100g). Solar dried sample recorded 0.105% while the fresh sample recorded the lowest 0.093mg/100g. The low values of phosphorus in the fresh sample could be attributed to the fact that there was high moisture content in the fresh sample than the dried ones.. In effect, the moisture content of the oven dried sample was much lower than the solar dried sample and this could have accounted for the highest phosphorus content in the oven dried sample. Phosphorus functions to buffer body fluids to maintain a normal pH, to temporarily store and transfer energy derived from metabolic fuels, and to activate many catalytic protein through phosphorylation (Mepba *et al.*, 2007). Also Phosphorus is needed for bone growth, kidney function and cell growth (Nzikou *et al.*, 2006).

In a similar study conducted in Nigeria the P concentration in the medicinal plants analyzed varied from 26.80 ± 0.42 to 59.90 ± 2.74 mg/L; *S. acuta* had the lowest while *P. reticulata* had the highest values. Phosphorus is needed for bone growth, kidney function and cell growth; it also plays a role in maintaining the body's acid-alkaline balance (Nzikou *et al.*, 2006). The level of P concentration was comparable in four of the samples: *M. charanta*, *S. podocarpa*, *G. hirsutum* and *O. gratissimum* in a range of 31.40 ± 3.13 to 36.00 ± 0.00 mg/L.

4.2.2 Magnesium content

The value obtained for magnesium ranged from 0.019 to 0.036%, with the solar dried sample recording the highest 0.036%, oven dried sample recorded (0.029%) while the fresh sample recorded the lowest (0.019%.) The low values of magnesium in the fresh sample could be attributed to the fact that there was high moisture content in the fresh sample which diluted the magnesium. In effect, the moisture content of the solar dried sample was much lower than the oven dried sample and this could have accounted for the highest magnesium content in the oven dried sample.

In a similar study conducted in Nigeria by Sam *et al.* (2012), *Solanum verbascifolium contained* magnesium of 10.143 which were higher than the values obtained for *Solanum torvum* though is not the fruit but they are all in the *solanaceae* family. Magnesium ions are known hormone activators in type 2 diabetes, their presence in leaves of this plant can be beneficial in managing this disease. More so, Magnesium plays important role in the structure and the function of the human body. The adult human body contains about 25 grams of magnesiu m. Over 60% of all the magnesium in the body is found in the skeleton, about 27% is found in muscle, while 6 to 7% is found in other cells, and less than 1% is found outside of cells

Manganese is part of enzyme involved in urea formation, pyruvate metabolism and the galactotransferase of connective tissue biosynthesis (Chandra, 1999).

4.2.3 Iron

The result of the elemental study of the *Solanum* fruit showed that the Fe concentration ranged from 12.90 to 14.85mg/100g of which, the solar dried sample was higher (14.85mg/kg) than the oven dried sample (12.90%). There was no significant difference between the iron content for fresh sample and solar dried, however oven dried sample were significantly different from the two other treatment ($p<0.05$). The changes observed in Iron content can be attributed to the oxidation of the Fe^{2+} which reduces as temperature is increased. Therefore in order to minimize the degradation of iron, fresh or solar dried samples are recommended. *Solanum torvum* is advocated especially for nursing mother and pregnant women in Ghana and some West African countries because of its ability to "increase blood level". This result validates the claim due to the high iron content determined as it is part of the heme of haemoglobin (Hb), myoglobin, and cytochromes (Chandra, 1990; Chinma and Igyor, 2007).

In a similar research conducted in Ghana and Indiaby Osei Akoto *et al.* (2015), and Bhagyashree *et al.* (2012).the iron content was 76.869mg/kg which was far higher than the obtained value, 14.85mg/kg.

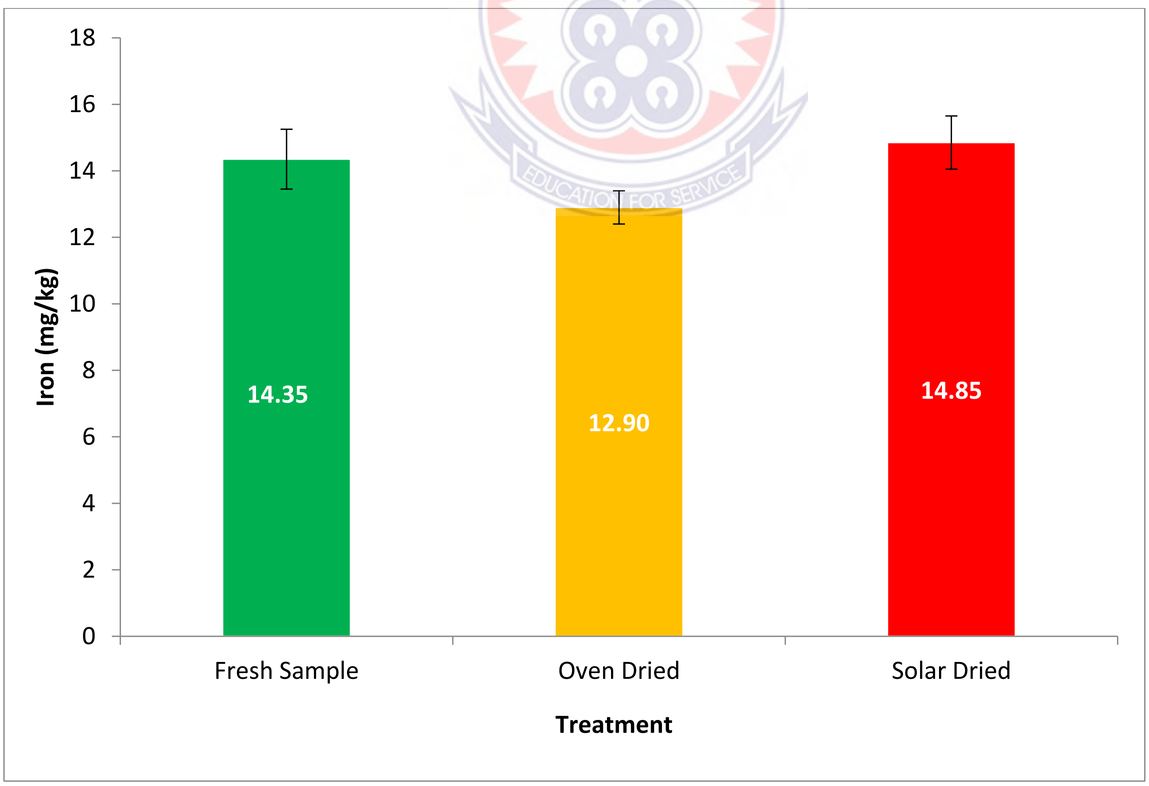

Figure 4.3 Effect of processing on Iron content of *Solanum torvum*

4.3 Anti-nutrients

The presence of inherent toxic factors or anti-nutritional components in plants has been one major obstacle in harnessing the full benefits of the nutritional value of plant food, vegetables inclusive (Lewis and Frenwick, 1987). This notwithstanding, many food processing techniques have been highlighted as possible means of reducing or totally eliminating the anti-nutrient levels in plant food sources to harmless levels that can be tolerated by animals and man (Fasuyi and Aletor, 2005). In a similar research on a fruit of *C. africanum* in Nigeria, the results show that *C. africanum* fruit has a high level of oxalates (4.99 mg/100g) and saponins (3.66mg/100g), a moderate level of cyanogenic glycoside (0.730mg/100g) with a low levels of phytate (0.032 mg/100g) and tannins (0.029 mg/100g). The oxalate value is higher than (1.06mg/100g) reported for *B. coricea* seeds and (0.159mg/100g) reported for *Pennsetum purpureum* but, lower than (58.81mg/100g) reported for seeds of *Solanum nigrum* and (109.00mg/100g) reported for *Gnetum africanum* seeds. The graph below shows the various amount of the analyzed anti-nutrient in the whole fruit of *Solanum torvum*;

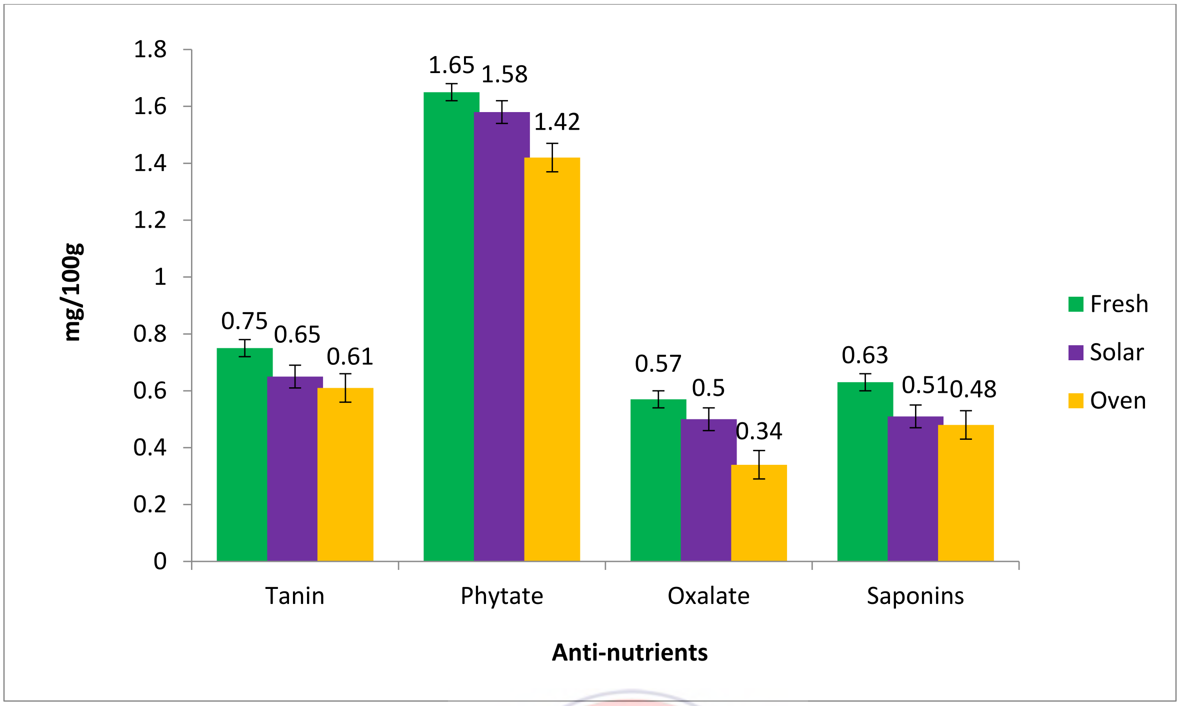

Figure 4.4. Effect of processing on Anti-nutrients content of S*olanum torvum*.

4.3.1. Phytate Contents

The results for the phytate were 1.58 mg/100g for solar dried sample against (1.42 mg/100g) for oven dried sample indicating a reduction as temperature rises. Phytate are widely distributed in plants, especially in seeds. The major role of the phytate may be to store phosphorus, which is gradually used up during germination (Nahapetian and Bassiri, 1976). Numerous studies have also indicated that phytate reduces the bioavailability of dietary Mg, Ca, Zn and Fe in monogastric animals (Bassiri and Nahapetian, 1977). This research has shown that lower water content is directly proportional to lower phytate content.

4.3.2. Tannin Content

The values obtained for tannin ranged from 0.61 to 0.75mg/100g, with the solar dried samples, the anti-nutrient for tannin was (0.65 mg/100g) compared to that of the oven dried, (0.61 mg/100g) indicating a reduction as temperature increases. According to Roeder (1995) and Hoseney *et al.*, (1981), the presence of tannin results in low digestibility, reduced mineral bioavailability, possible carcinogenic effect, lower palatability due to astringency, and lower growth rate in animals due to its ability to bind to proteins and starch, thereby making them insoluble and indigestible

In a similar work conducted in India the tannin content in the *Solanum torvum* fruit was 2.7mg/g (Sundari *et al.,* 2013) which is higher as compared to the values obtained may be due the geographical location and different agricultural practices.

4.3.3. Oxalate Content

The values obtained for the oxalate ranged from 0.34 to 0.50mg/100g. Solar dried sample of oxalate content was 0.50mg/100g compared to oven dried sample recorded oxalate content of (0.34 mg/100g) which also shows a significant reduction in value.

In a similar work conducted in Nigeria on the seed of *Solanum nigrum*, the oxalate content was 58.81mg/100g which is far higher than obtained value probably due the different species (Edem *et al.,* 2011).

4.3.4. Saponin Content

The results saponin content of *Solanum* fruit ranges from 0.48to 0.65mg/100g of which solar dried sample was 0.65 mg/100g recorded the highest whiles the oven dried sample was 0.48 mg/100g also indicating a decrease in value. The saponins are known to reduce the uptake of certain nutrients like glucose and cholesterols at the gut through intra-lumenal physicochemical interaction (Price, et al 1987). Also Ngozi *et al.* (2009) made mentioned that when saponins are consumed they may aid in lessening the metabolic burden that would have been placed on the liver and they are also known to inhibit structure dependent biological activities (Savage, 1993).

In general, results from the study of anti-nutrient content showed a decline or decrease in anti-nutrients which were analyzed with oven drying (higher temperature) as compared to the solar drying. Processing at high temperatures has been reported to reduce anti-nutrients in different food matrix as most of them a heat labile. However, the percentage of reduction is dependent on the chemical properties of the anti-nutrients and the food matrix.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Drying methods studied in this research had significant effect on the proximate composition of *Solanum torvum*. Moisture was significantly reduced in the oven dried samples from 78.03±1.22 to 8.45 ± 0.72 in the solar dried samples. However, fat, fibre, protein and ash content significantly increased after drying though there was a significant increase in oven dried samples then those which were solar dried.

The effect of the two methods of drying on the mineral (Na, P and Mg) content was as follows: oven drying resulted in increased Na, P and Mg content and solar drying also resulted in increased Na, P and Mg content even though the increase was not as marked as that of oven dried samples except in that of Mg content. This implies that drying generally increases the mineral content of *S. torvum*, with oven drying proving more effective.

Solanum torvum also recorded reduced anti-nutrient content when dried, with oven drying reducing their content more efficiently than solar drying in parameters measured (phytate, oxalate, tannins and saponins).Though both methods generally had similar effects on *S. torvum* they exhibited varying effects on the iron content of the samples. Oven drying reduced the iron content from 14.35 to 12.90 whiles solar drying increased it from 14.35 to 14.85. The advocate of *Solanum torvum* especially for nursing mothers and pregnant women in Ghana and some West African countries because of its ability to "increase blood level" can be attributed to the significantly high iron content in the fruit.

5.2 Conclusion

The result indicated that proximate analysis results show that dried *Solanum torvum* is a good source of important nutrients. The oven dried samples had the highest figures of minerals like the sodium, phosphorus, iron and magnesium which indicate good health promotion. Comparing the fresh and the dried samples, drying does not have any effects on the minerals. Rather, the quantitative analysis on the physiochemical properties revealed that, there was significant reduction of anti-nutrient content revealed that, there was a significant reduction of anti-nutrient such as tannins, saponins, phytate and oxalate which is a good indication for the body.

5.3 Recommendations

As *S. torvum* is always collected from the wild resources, there might be reduction in the population of this species with a subsequent reduction in the availability of the fruit. The issue with preservation is a factor that must be considered. With the use of the oven dried and solar dried methods of preservation, I recommend oven drying in this method, the temperatures can be control and this will not only preserve the fruit but also conserved other nutritive components which might be lost upon exposure to high temperature. Shelf life study can also be studied to elucidate how long the dried sample can last during storage.

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