Addis Ababa University

College of Natural Sciences

Center for Food Science and Nutrition

EFFECT OF PROCESSING METHOD ON THE PROXIMATE COMPOSITION, MINERAL CONTENT, ANTINUTRITIONAL FACTORS AND FUNCTIONAL PROPERTY OF YEHEB NUT (*Cordeauxia edulis hemsley*) GROWN IN SOMALI REGION, ETHIOPIA

BY

MOHAMED HUSSEIN

Supervisor: Dr. Dawd Gashu, Ph.D

A THESIS SUBMITTED TO THE SCHOOL OF GRAGUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE IN FOOD SCIENCE AND NUTRITION

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Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other University, and that all sources of materials used for the thesis have been fully acknowledged.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
IUCN	International Union for the Conservation of Nature
NAS	National Academy of Science
FAO	Food and agriculture organization of the United Nations
SATG	Somali agricultural technical group

Abstract

Protein-energy malnutrition and food insecurity are among the most serious problems facing the rural community of the Somali region where the crop grows widely. Also contributing to this problem is the underutilization of yeheb crops found in Somali region. Yeheb nut is a nut producing wild plant with multipurpose usage. It is an underutilized crop and little is known about its proximate and micro-element composition, anti-nutritional factors and functional properties of the raw, boiled and roasted products. The aim of this study was to determine the proximate composition, level of anti-nutrients, mineral composition and functional properties of raw and processed yeheb seeds. Raw Yeheb flour had protein content of 15.9%, 8.8% of crude fat, 15.5% of crude fiber, 3.9% of ash, 7.2% of moisture, 77.9% of utilizable carbohydrate, and 383.0 kcal of gross energy. There was significant difference ($P < 0.05$) in the levels of protein, crude fat, gross energy crude fiber, and crude ash content between the processed and raw yeheb nut. Raw yeheb seeds contained 1.65mg of phytic acid, 0.054mg of tannin and0.47 mg of oxalate. Analyses of the anti-nutrient composition show that the roasted and boiled yeheb flour had significantly low level of phytate 20.59 % and 38.24 %, oxalate 58.6 % and 47.7 %, and tannins 12.9 % and 33.3 % compared to the raw yeheb flour. The mean values of minerals such as iron, magnesium, zinc and calcium contents for the raw sample was 4.3, 80.6, 3.02 and 243.9 mg, respectively on dry weight basis. The value for functional properties was in the range of 3.75 to 1.97 g/g for water absorption capacity, 0.82 to 0.59 g/ml for bulk density, 2.83 to 2.64 % for Swelling power, 24.65 to 14.75 % for Solubility index, 8.49 to 4.72 % for foaming capacity and 118.42 to 104.72 % for foaming stability. The results indicated that boiling and wet roasting were the most effective and recommendable technique in reducing anti-nutrients. Boiling and wet roasting of yeheb seeds were found to be the best cooking methods for healthy eating.

CHAPTER 1

1. INTRODUCTION

1.1. Background

Plants are the most important source of food for human beings. Among plant sources, legumes and legume products are the richest source of food proteins. Food legumes have exceptional, immediate potential for alleviating human malnutrition in tropical countries by virtue of its nutritional and agronomic advantages. Most legumes have a distinct advantage over other food crops because of their simplicity of preparation and multiplicity of edible forms (Salunkhe and Kadam, 1989). Because of their high protein and lysine content, they also represent good sources of supplementary protein when added to cereal grains and root crops, which are low in essential amino acids. Legumes are shown to be particularly useful in decreasing blood glucose responses compared with other high-fiber foods. These beneficial effects of legumes are thought to be derived from various components of the beans including their slow starch digestion and their fiber content (Jenkins et al., 1980; Jenkins et al., 1981).

Cordeauxia edulis Hemsl, of the family Leguminosae and the subfamily Caesalpinioideae is locally known as Yeheb (Ali, 1988). It is among the priority edible wild food plants in Ethiopia (Teketay and Eshete, 2004). The species is a much branched ever green shrub or small tree up to 2.5 m height, and is endemic to restricted localities in eastern Ethiopia and parts of central Somalia (Chiovenda, 1929 as cited by Ali, 1988).

Cordeauxia edulis (yeheb) produces a nutritious and tasty nut with a chestnut like flavor (El-Zeany and Gutale, 1982). Traditionally, all people living in the Somali hinterlands rely on it for subsistence. It is a staple food of nomads and sometimes the only food plant left surviving during periods of drought in the Ogaden desert (Vietmeyer, 1985).

The seeds or nuts are often eaten after boiling or roasting (Ismail, 1975). The water in which the seeds are boiled is sweet, and is drunk traditionally by Somalis (El-Zeany and Gutale, 1982). The nuts are relished by the people that the encouragement of people to work is very commonly given by quoting an old Somali proverb “Fadhi iyo fuud yicibeed lays la waa” which means “one who sit idle will not get yeheb” (Kazmi, 1979).

The nut constitutes one of the staple foods of the nomads of the regions, where it occurs (Bally, 1966). Furthermore, Brink (2006) emphasised that it is quality food that the local people prefer to stable crops such as maize and sorghum. Yeheb is a long-lived (estimated in excess of 200 years), endemic, semi-arid shrub, which can withstand extreme drought. It’s a multipurpose plant used as dry season animal feed, firewood, building material and leaf. It is also used for dyeing of textiles for garments. Most importantly, yehebs seeds are used as an energy rich, valuable food (especially in droughts condition) for the local population in the border areas of Somalia and Ethiopia (Booth and Wickens, 1988).

Compared to other legumes, the seeds are methionine deficient (Miège and Miège, 1978). But it is rich in essential lysine and arginine, but deficient in tryptophan and isoleucine. Seeds with 17% moisture content consist of 13% protein, 10-11% lipids, 31-34% starch, 20% sucrose, 2% reducing sugars, 3% ashes and 2% fiber. The major components of the fatty acids are palmitic, oleic and linoleic acid together with stearic acid (26-31%, 32%, 25-30% and 12-13%, respectively). There are only traces of linoleic acid (El-Zeany and Gutale, 1982).

1.2. Statement of the problem

Yeheb is a small bush growing in eastern Ethiopia and central Somalia. It is drought resistant and a source of food to both animals and humans especially during drought condition (NAS, 1979). Yeheb was considered as in danger of extinction within a few years by Allen & Allen (1981). Yeheb is listed as rare plant in the 1997 International Union for the Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Plants. The definition of rare is “taxa with small world populations that are not at present considered endangered or vulnerable, but are at risk” (Brink & Belay, 2006). The Yeheb bushes are more widespread on the Ethiopian side of the border where mostly Somali people live.

Yeheb seeds are edible and can be eaten fresh, roasted, boiled or dried. Since yeheb seeds are easily damaged by fungi or insect attacks they are usually roasted for quality maintenance. Compared with other leguminous seeds, yeheb seeds are rich in fats (10- 13 %) and sugars (12-25 %) but contain lower protein (11-16 %) and carbohydrate (31-41 %) levels. The seed yield of individual yeheb shrubs can be 5-8 kg per year, or none in drought years (Brink 2006). Somalis drink the sweet water remaining from boiled seeds and leaves are used for tea. In addition, seeds may be used as a coffee substitute. Wood is used as fuel wood by villagers and nomads (Booth and Wickens, 1988).

Although yeheb seed is widely available in warder zone, it is an underutilized crop and drought resistant. It is food security alternative because it create money as cash crop to the local community, yet very little was known about the proximate composition, mineral content and the level of anti-nutritional factors of the raw, boiled and roasted products commonly used. This information gap does not allow intensive utilization of yeheb seed as a value added product (food/feed) in the country. There is no information available for farmers, processors and end-users in utilization of the resource capacity of yeheb seeds in the Ethiopian context. It is upon this background that this study sought to investigate the effect of processing method on the proximate composition, mineral content, functional property and anti-nutritional factors of yeheb nut grown in Somali region, Ethiopia.

2. Objectives

2.1. General objective

- ✓ To determine the effect of processing method on the proximate composition, mineral content, functional property and anti-nutritional factors of yeheb nut from Somali Region

2.2. Specific objectives

- ✓ To determine the nutrient and anti-nutrient content of yeheb nut from Somali Region
- ✓ To investigate the effects of processing on the nutrient and anti-nutrient content and the mineral composition of yeheb nut from Somali Region.
- ✓ To evaluate the effect of processing (boiling and roasting) on functional property of yeheb flour from Somali Region.

CHAPTER 3

3. Literature review

3.1. Importance of wild indigenous seeds in Ethiopia

Ethiopia has diverse flora and fauna. In addition, it is rich in indigenous knowledge in managing and processing both domesticated and wild plants. The use of wild plants in the native diet, traditional medicine and religious ceremonies is very common. Several types of food can be obtained from wild plants. They add flavor, minerals and vitamins to the staple. Some leaves also have high protein content. Seeds and nuts are also used in various side dishes and sauces. Fruits are a seasonal food supply and are often eaten as snacks. Roots and tubers provide carbohydrates and minerals, and are especially valuable dry-season and famine-period foods. Some Acacia species yield edible gum, and the sap from other trees is used in various ways. The bark of some trees can also be eaten. Many of the wild food plants are sources of pollen and nectars used by bees to produce honey, which is used in the household or sold to generate income.

Wild plants provide several important dietary elements that the crop agriculture can't adequately provide. In many areas, dietary deficiencies and monotony of normal diets are reduced or avoided, through the introduction of wild plants in to the meal. For most of the plants and, hence, fruit trees/shrubs, the edible parts, e.g. fruits/seeds, are still collected from the wild and consumed directly by the households. Thus, food from the wild can make supplemental, seasonal and emergency contributions to household food supplies, thereby contributing to the food security of communities. Such food items are also taken in to markets in both rural and urban areas, thereby generating income for households (Pol, 2002).

The consumption of wild plants seems more common and widespread in food insecure areas, including most dry land areas, where a wide range of species is consumed, leading to the notion that is described as "famine-foods", that are consumed at times of food stress, namely drought, war and other hardship periods (Amare, 1974; Asfaw, 1997; Asfaw & Mesfin .T, 2001; Guinand & Dechassa, 2002; Pol, 2002). Hence, the consumption of wild plants is a necessary part of the strategies adopted by people in order to survive in harsh environments and periods. For instance, of the 120 species recorded as wild food plants in Ethiopia, 50 species have been listed and classified as typical "famine-food" plants (Guinand & Dechassa, 2002).

3.2. Legumes as a world food crop

Legumes are the most important plant species in the family of Leguminosae. They are second only to cereals in providing food crops for world agriculture (Duranti, 2006). Legumes are recognized as a crop that plays an important role in the agriculture, as well as a major source of dietary nutrients for many people in the developing countries. According to the FAO estimations the world production of legume seeds, was about 58 million tons in 1994 and of this, the major part, was produced by developing countries (Adebowale et al., 2005). According to FAO data, a summary of distribution and production of legumes are shown in the table below.

Table 3.2. Worldwide distribution (%) of grain legumes seed production.

Land	Total area (%)	Production (Million Tons)	Production (%)
Africa	26.2	8.0	14.5
North America	8.3	8.0	14.5
South America	7.6	4.0	7.3
Asia	50.0	26.0	46.8
Europe	5.3	7.0	13.4
Australasia	2.6	2.0	3.5
World	100.0	55.0	100.0

Sources: calculated from FAO data (2000)

3.2.1. Nutritional importance of legumes

Legumes are significant among the food crops due their high nutritional value. Awareness on nutritive value and health benefits of legumes is of vital importance to increase consumption of legumes in daily diet of the human (Bhat and Karim 2009).

Legumes are known for their protein content ranging from 20 to 40% of their dry matter (Baudoin et al., 1999). In most of legumes fat content is relatively small (<1% of their dry matter) (Bravo et al., 1999). A few species such as soya, ground nut and lupine have higher amount of fat (5- 20% in range). Dietary fiber fraction plus total starch and soluble sugars, ranged from 59 to 67% of the dry matter (Bravo et al., 1999).The B-vitamin is mainly found in legumes and these contents increase with germination (Sierra et al., 1997). It is a very good source of folates (Dang et al., 2000). High levels of both α- and γ- tocopherol (8.2 and 7.9 mg per 100g, respectively) were found in peanuts (wyatt et al., 1998). According to a study on a 100g dry weight basis of some commercial bean varieties, the mean vitamin values of thiamin 0.99 mg, riboflavin 0.20mg, niacin 1.99 mg, pyridoxine 0.49 mg, folic acid 0.30 mg. Retention of water-soluble vitamins during cooking averaged between 70 and 75% (Augustin et al., 1981) . Vitamin A and vitamin C content of legumes vary depending on the species. They range from 12-90 μg of beta carotene per 100g and 1-5 mg per 100g of legume seeds respectively for commonly consumed legumes (USDA, 2004). Bravo et al. 1998 have reported that black gram as the legume with the darkest seed coat, had the highest polyphenolic content (3.98% of their dry matter). Since the discovery of the role of polyphenols as anti-oxidants (Xu et al., 2007). It is also can be considered an important nutrient.

3.2.2. Health benefits of legumes

Legume proteins contribute energy and amino acids, which are essential for growth and maintenance. According to (Liao et al., 2007) consumption of legumes proteins could reduce plasma low density lipoproteins and help in reducing weight also (Singh et al. 2008) have reviewed that soy protein lowers blood cholesterol.

Apart from being a valuable source of protein, consumption of legumes has also been linked to reduced risk of diabetes and obesity, coronary heart disease colon cancer, and gastrointestinal disorders (Bazzano et al., 2001). Legume starch causes less changes in plasma glucose and insulin upon ingestion as it has identified as low glycaemic index and therefore, it is a very good source of nourishment for controlling diabetics (Phillips et al., 2003; Wang et al., 2008).

Consumption of legumes may also have a protective effect against prostate cancer in humans. The phenolic compounds present in these legumes are known to exhibit strong antioxidant, antimutagenic, and anti-genotoxic activities Furthermore, isoflavoness, a class of phytochemicals found in soybeans contributes towards cancer prevention. Soybean is an alternative source of protein for people who are allergic to milk protein and also highly digestible (92 to 100%) (Xu et al., 2007).

It contains all essential amino acids. Although relatively low in methionine, it is a good source of lysine. Soy-protein products contain a high concentration of isoflavones, up to 1g/kg (Singh et al., 2008).

Since health and nutrition is the most demanding and challenging field, legumes can play an important role, not only to the dietary pattern of low income groups of people in developing countries, but also for the people in rest of the world as it has lot of health benefits. The contribution of legumes towards a global healthy population therefore cannot be underscored.

3.3. Eco-biology of yeheb nut

Taxonomy

Cordeauxia edulis Hemsley is a leguminous plant (Fabaceae) from the genus Cordeauxia. The genus Cordeauxia is closely related to Caesalpinia and Stuhlmannia. The common name of C. edulis is Yeheb-Nut (English) or Yeheb (French) (Belay, M. Brink, G. (2006). Other names are Yebb, Hebb, Ye'eh, Yi-ib, Yehib or Yicib (Baumer, Michel (1983). In amharic it is called Ehb, Qud or Quda (Birnie, Tengnäs, Bo (1993).

Botanical and morphological description of yeheb nut

Yeheb, *Cordeauxia edulis Hemsley*, is an evergreen, multi-stemmed and thick crowded shrub (Ali, 1988), usually dwarf and not taller than 1, 6 m because of grazing of tender shoots and leaves by livestock. In sheltered locations, where the plants are not grazed, yeheb can reach 3-4 m classified as a small to medium sized tree (Kazmi, 1979). Plants that are heavily browsed sprout profusely from the base. Yeheb is single stemmed in the early stages of growth. The leaves are pinnate, 2-8 cm long, with 2-4 pairs of leaflets that are oval to oblong, 1.7-3.6 cm long and 0.43-2.0 cm wide (Ali, 1988). They are leathery, olive green above and lighter on the underside with numerous purple to orange red glandular hairs on both sides (Bally, 1966; Miège and Miège, 1978; Ali, 1988). The glands contain a red pigment, cordeauxiaquinon, which by handling or when touched stains the hands red (Lister et al, 1955; Bally, 1966; Yahya, 2002.).

Stomates occur both on the adaxial and abaxial surfaces of the leaflets. Both sides of the leaf are covered by an extremely thick cuticle. All of the mesophyll cells consist of 'concertina' palisade cells. These are suggested to shrink under water stress, and thereby causing the cell walls to fold (Curtis et al, 1996), which leads to curling of the leaves.

This happens as soil moisture content drops. At the onset of the first rain, indicating the end of the drought period, the leaves uncurl and regain their turgidity (Ali, 1988). The leaves exist for more than one season, but the lifespan of individual leaflets are not known (Curtis et al, 1996).

Floral and vegetative auxillary buds develop apically and laterally from the branchlets (Ali, 1988). The inflorescence is a few-flowered corymb that forms at the end of the branchlets. The flowers are 2-5 cm in diameter, with five bright yellow, spatula petals, 1.5 cm long and five green sepals, which are about 1 cm long and covered with red glands, like the leaves. The ten stamens are hairy at the base of the filaments and the ovary is shortly stalked, heavily glandular and surmounted by an obtuse stigma (Bally, 1966; Miège and Miège, 1978). Flowering occurs throughout the year, but is more profusely during the rainy season. The fruit, which is a pod, is 4-6 cm long, rather leathery and compressed ovoid. The walls are fairly hard and terminate in a protuberant break. Each pod contains 1-4 seeds (Miège and Miège, 1978). The seed weights about 2-3 g each (TSW 2000-3000 g) (Nerd et al., 1994).

The root system is dominated by a central taproot, which reaches a depth of >2 m. Lateral roots form 10 and 40 cm below the soil surface, and spread horizontally a distance of 2.3 m according to Ali (1988).

Habitat and geographical distribution of yeheb nut

Yeheb (*Cordeauxia edulis Hemsley*) is a small bush (see picture 5) growing in eastern Ethiopia and central Somalia that is hardy to drought and a source of food to both animals and humans (NAS, 1979). Yeheb belongs to the family Leguminosae, subfamily Caesalpinioideae, and is the only species within the genus Cordeauxia.

The area where Yeheb grows is one of the most important livestock producing areas in Somalia (SATG, 2004). Yeheb used to be a very dominant bush and constituted up to half of the woody vegetation in many areas of the Somali hinterland in the 1930s, but since then it has been reduced and is threatened by droughts, grazing, removing of seeds and wars (NAS, 1979). Usually, all seeds are harvested, which makes it difficult for the plant to regenerate (FAO, 1988). The Yeheb bush is also valuable as a building material as it does not become attacked by termites (Asha Yahya, personal communication). Therefore people from other parts of Somalia drive into the area and cut down the bushes to bring with them. In 1981,

Figure 1: Yeheb bushes

Yeheb was considered as in danger of extinction within a few years by Allen & Allen (1981).in addition, it was listed as rare in the 1997 International Union for the Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Plants. The yeheb bushes are widespread Somali region of Ethiopian.

Figure 2: Pods containing a variable number of seeds (1 - 4), and seeds
(Source: Miège and Miège, 1978)

Environmental conditions of yeheb nut

Yeheb is well adapted to arid and semi-arid conditions (Drechsel & Zech, 1988). In Somalia and Ethiopia there are two rainy seasons; the south-western monsoon from March/April to May/June and the north-eastern monsoon from October to November, when most of the rain falls in a few days. The annual precipitation is 150-200 mm and the average temperature 28°C, with a small monthly range of four to six degrees. The plant grows on an altitude of 100-1000 meters (Roti-Michelozzi, 1957; Drechsel & Zech, 1988; FAO, 1988; NAS, 1979). Yeheb never grows close to the water (Brilli & Mulas, 1939) and the plants are frost sensitive (FAO, 1988).

Yeheb grows in a particular soil and vegetation, which is called the "Haud" by the natives (Glover 1950; Drechsel & Zech, 1988). It is a region in the north-eastern corner of Ethiopia and there also exist "Haud-type" regions in Somalia where Yeheb occur (Hemming 1966; Watson et al., 1982 In

Drechsel & Zech, 1988). Haud refers to landscapes consisting of red-coloured sandy soils, red sandstones and breccia. This soil is of continental non-salty origin while the surroundings are marine sediments (Merla et al., 1979; Mohr 1962, as cited in Drechsel & Zech, 1988). The Haud is covered with grassland and dense clumps of dominant Yeheb bushes, shrub species and some taller trees (Bally 1966; Hemming 1966; Watson et al., 1982, as cited in Drechsel & Zech, 1988). Deep soils are favourable for Yeheb's establishment; they are extremely poor in nutrients (NAS, 1979) and sandy to loamy-sandy covered with loose sand (Drechsel & Zech, 1988; NAS, 1979). The water holding capacity of the loamy subsoil is relatively high (Drechsel & Zech, 1988) with a water table at 6.5-25.5 meters (Ecocrop, 2009). The deep red sands have a pH of 6.7-8.4 and are extremely low in nitrogen (FAO, 1988).

Growth and development of yeheb nut

Yeheb reseeds itself, unless the seeds are harvested, and the germination takes about two weeks (FAO, 1988, as cited in Ismail, 1975) and much water is needed for establishment (FAO, 1988). Thereafter the root grows fast while the aerial parts are slower (Brink & Belay, 2006). During favourable conditions it can reach a height of four meters (FAO, 1988) but normally it only grows 1.6 meters tall (NAS, 1979).

The bushes blossom during the rainy season, once or twice if the rainfall is abundant (Orru, 1988), or all year round, but mainly during the rainy season (FAO, 1988 with reference to Gaertner et al., 1982). The flowers are yellow and at an age of three to four years it starts to produce pods, which contains one to four seeds (NAS, 1979). The pods are four to six centimetres long and the nuts weigh about 1.6 gram (FAO, 1988). The nuts take 10-14 days to mature depending on the rainfall (Brilli & Mulas, 1989), if the rain is absent the fertilized ovule remain undeveloped for 4-5 months and may ripen in 5-6 days during the next rainfall (FAO, 1988 with reference to Ismail, 1975). The seed viability is maximally a few months and the seeds often become insect infested (FAO, 1988). The longevity of the plant is estimated to exceed 200 years (FAO, 1988 with reference to Ismail, 1975).

Figure 3: The Haud is marked as the green area

Utilization of yeheb nut

Yeheb is one of few species worldwide that is suited for hot and dry environments. Thus it is considered as a potentially valuable source of food and protein in other regions with similar conditions (FAO, 1988). The nut is marketable worldwide as a delicacy and could become an ingredient in food or medicine. C. edulis has the potential to be used for soil conservation, mulching and hedgerow (Von Carlowitz 1986). The oil is used for soap making, the wood is used as firewood (Brink & Belay, 2006) and the dye is used as a mordant to dye fabrics (NAS, 1979). The leaves may be used as a substitute for tea (FAO, 1988).

In the rangeland where Yeheb grows, most plants are deciduous and Yeheb is therefore of great importance to the livestock (Kuchar 1987; Ali, 1988). The plant is the largest component of high-quality feed available in the dry season, and it comprised 16.9 percent of all available feed and 85 percent of the good-quality feed in a study area 200-300 km north of Mogadishu. Other evergreen plants exist but they never represent more than two percent of the canopy cover (Kuchar, 1987).

Uses

Uses of yeheb seeds

Yeheb is a multi-purpose plant where most parts of the plant are used (Booth and Wickens, 1988). Seeds from yeheb, which are sometimes called nuts, are eaten fresh or boiled, occasionally roasted. They are mostly consumed locally and are considered as a staple food for the people of the region where it occurs (Bally, 1966). The seeds have a thin easily cracked testa and a chestnut-like flavour, eaten fresh, or boiled for sweet liquor, occasionally roasted, and make nourishing and balanced food (FAO, 1988; Miège and Miège; 1978; El-Zeany and Gutale, 1982). The water, in which the seeds have been boiled, is sweet and is sometimes used as a beverage (El-Zeany and Gutale, 1982). The plant has recently attracted much interest as a potential food crop for arid areas (N.A.S, 1979). In times of drought and famine, the nuts may be one of the few natural foods available for Somali nomads (Anonymous, 2004). Guinand and Lemessa (2002) reported that yeheb nuts are of high economic value and are considered as 'famine food' in times of exceptional drought conditions, even though the plant needs some rain in order to develop its fruits (Ali, 1988). Wildlife, such as baboons also eat the seeds (Ali, 1988).

3.3. Proximate Composition of yeheb seeds

Yeheb produces a nutritious and tasty pulse, usually called “seed” or “nut” (NAS, 1979). The seeds can be cooked or eaten raw and are consumed as a supplement to the diet of rice and dates among the poorer people. During the dry season it is sometimes the only source of food for the nomads. Some nuts are also collected and sold at the market as they are of high economic value. The seed taste like cashew or chestnut and can also be dried or roasted (Ismail, 1975, as cited in FAO, 1988), the roasting turns them from sour to sweet (Brink & Belay, 2006). The nuts are used as a substitute for coffee and the water remaining after boiling them is used as a sweet drink (FAO, 1988). The demand for the seeds exceeds the supply because of the diminishing plant population (El-Zeany & Gutale, 1982). The seed production has been shown to be up to 1527 kg/ ha per year (Ali, 1988; Yahya et al., 1993).

The nuts are of high nutritional value (Polhill & Thulin, 1989; Bekele et al., 1993; Guinand and Lemessa, 2002). The seeds are rich in energy containing 31-41% starch, 12-25% sugars, 11-16% protein, 10-13% fats and various minerals (Miege and Miege, 1978; Seegeler, 1983; Booth and

Wickens, 1988). The main characteristics of the seeds are their high sugar and fat contents compared to other seeds of species in the Fabaceae family (N.A.S, 1979). El-Zeany and Gutale (1982) stated that yeheb seeds provide balanced diet, especially in areas where the usual legumes are impossible to grow. The energy value, 4460 kcal per kg, is twice that of the carob, Ceratonia siliqua, and as much as that of soya, Glycine max (N.A.S, 1979). Seeds are low in anti-nutritional factors and are free of toxic phytohemagglutinins, lectins, alkaloids and glycosides, however, trypsin inhibitors are present in similar proportions to Lablab purpureus (hyacinth bean) (Miège and Miège 1978). The major components of the fatty acids are palmitic, oleic and linoleic acid together with stearic acid (26-31%, 32%, 25-30% and 12-13%, respectively. There are only traces of linolenic acid. The oil is a non-drying type of oil (El-Zeany and Gutale, 1982).

Table 3.3 Proximate composition of the seed of Cordeauxia edulis and other food crops (g/kg)

Item	C.edulis	Maize	Sorghum	Wheat	Rice
Moisture	80 – 100	56	46	51	38
Crude protein	110 - 160	82	108	165	123
Crude oil	100 - 120	33	36	44	129
Ash	22 – 37	25	26	50	57
Total nitrogen	25	16	18	19	13
Sucrose	116 - 216	49	46	39	35
Cellulose	27 - 33	16	21	14	12
Reducing Sugar	23 - 53	-	-	-	-
Tests for Alkaloids & Glycosides	Negative	Negative	Negative	Negative	Negative

(Source: Seegeler, 1981; Burns, 1971)

Production levels

Studies carried out on *C. edulis* from Central Somalia showed an average forage availability of 322-453 kg ha-1 and seed production of up to 1527 kg ha-1 year-1 (Ali, 1988; Yahya and Durand, 1993). Considering the dry conditions and poor management at which C. edulis grows, its yield in forage and particularly in seeds may be considered high (Yahya, 2004).

Harvesting and processing

The fruits of *Cordeauxia edulis* are picked (harvested) from the plant, the fruit wall is peeled off and the seeds are placed in sacks. The nomads compete with each other for the yeheb seeds, and are often harvested before maturity, fearing someone else may harvest ahead of them (Ali, 1988). This may be a factor in the low seed viability often encountered. Usually all seeds are removed from the plant at the same time, hampering regeneration of natural stands. Fruits can be harvested twice a year, provided rainfall is adequate during both rainy seasons (Brink, 2006).

To prevent fruit from being attacked by insects, nuts are processed in such a way that, freshly picked seeds are roasted or boiled to kill insects and harden the seed coat. In this form they fetch a higher price on the market, but the practice contributes to the difficulty of obtaining viable seed for planting (Ismail, 1975).

Marketing

The seeds of *Cordeauxia edulis* are mostly consumed locally, but are also sold in local markets. From Ethiopia the seeds are exported to Somalia and Arab countries, but no quantitative information is available. Seeds have export potential for European market as 'dessert nuts' (Brink, 2006). There is a high demand for them; to the extent that exceeds supply because of rapidly diminishing plant populations (Anonymous, 2004). In Mirafadle settlement in Boh Woreda, Warder Zone, Somali National Regional State (SNRS), a tin full of nuts was sold for 1.25 US $ .in July 2001. As the nuts have a nice taste, the tree has a considerable potential as a food crop in the driest of the semi-arid areas in the Horn of Africa (Guinand & Lemessa, 2002).

Bally (1966) also confirmed that the seeds are sold on the local market and exported to the coastal area, where they are much in demand. However, according to Kazmi (1979), relatively small quantities of the nuts ever enter the commercial trade, and are brought to the markets in Somali towns. It is usually sold by volume measured by "kombo" a container which holds about 500 g.

Other uses

Foliage: The species is 'evergreen' and produces abundant fodder for camels and goats during the dry season (Anonymous, 2004). Plants may contribute up to half the biomass of the area and it is used by camels and goats as an important dry season browse. The estimated average forage production is 325-450 kg ha-1 (1.4-2 kg/plant) (Brink, 2006). Some of the livestock coming from the Central Zone of Somalia, are highly appreciated especially for the taste of their meat by domestic and foreign consumers, have a characteristic pink colour on their bones. To most Somali consumers this is a mark of quality meat from animals that have browsed C. edulis. Most probably the pigment found in glands in the leaves of C. edulis, Cordeauxiaquinone or its metabolites bring about this phenomenon as only animals that feed on C. edulis get this pink colour on their skeleton. This natural pigment Cordeauxiaquinone, with a brilliant pink colour, is not known elsewhere in the plant kingdom (Lister et al., 1955; Harborn et al., 1971).

Yeheb foliage is rich in energy when compared to standard energy content of good quality fodder available in tropical areas but, some mineral levels (P, Mg, Mn and partly Zn) would not satisfy the demands of animals if yeheb were the only source of fodder (Drechsel and Zech, 1988).

Leaves have been used to dye cloths, calico and wool since the cordeauxiaquinone forms vividly colored and insoluble combinations with many metals (Booth and Wickens, 1988). This pigment is easily extracted from the leaves and easily crystallized: from 380 g dry matter of leaves about 2.7 g Cordeauxiaquinone can be obtained in crystal form. The crystallised pigment can be dissolved in Chloroform, Benzol, Ethanol, but little in Ether or water. Cordeauxiaquinonedose not contain nitrogen, sulphur or halogens and its molecular formula was elucidated as $C_{14}H_{12}O_7$ (Lister et al., 1955). They are used by the Somalis and were used by the Italians in wartime, when there was a shortage of aniline dyes as a dye. The Somalis use approximately ½ 1b (0.2 kg) of pulverized leaves to dye 10 yards (9.1 m) of 36 inch (91.4 cm) wide calico (Bally, 1966). The leaves can also be infused to make a tea (Greenway and Raymond, 1947).

Construction and fire wood: The hard wood is used as fire-wood for cooking (Vietmeyer, 1985). The twigs are also used as constructing material for houses. As yeheb is resistant against termite attacks, houses and fences made of yeheb persist for decades. The plant also protects the soil from erosion (Liew, 2003).

Medicine: Yeheb nuts is used medicinally to stimulate hemopoiesis (blood cell formation). It is used to regulate gastric secretion and for treatment of ulcers. It is also believed that the nuts can be used to alleviate anemia by augmenting the number of red blood (Anonymous, 2004; Brink 2006). Animals fed on yeheb nuts before export to foreign countries or to the slaughterhouses, do not show any noticeable anomalies in their appearance and when examined for the most common diseases (Gutale and Ahmed, 1984).

Oil: Yeheb seed is used to produce oil. It is intermediate between liquid oils and solid fats, tastes less pleasant than olive oil, possibly useful for soaps, with a byproduct that can be used for fodder or manure (Davis et al, 1983).

Other uses: the species is used for various purposes, including, bee forage, mulch, and nitrogen fixation (Bekele et al., 1993).

3.4. Anti-nutritional factors in yeheb nut

Anti-nutrients have been defined as substances, which by themselves, or through their metabolic products arising in living systems, interfere with food utilization and affect the health and production of animals (Francis et al., 2001).

In common with those of other grain legumes,). Yeheb Seeds are low in anti-nutritional factors and are free of toxic phytohemagglutinins, lectins, alkaloids and glycosides, however, trypsin inhibitors are present in similar proportions to Lablab purpureus (hyacinth bean) (Miège and Miège 1978).

3.4.1. Trypsin inhibitors

Trypsin inhibitors (TI) have a wide distribution in the plant kingdom and are present in most legume seeds and cereals (Francis et al., 2001). In comparison with most edible legumes, trypsin inhibitor activity (TIA) in yeheb seed similar proportions to Lablab purpureus (hyacinth bean) (Miège and Miège 1978).Trypsin inhibitors inhibit growth by interfering with the digestion of protein in the intestine of animals thereby causing hypertrophy of the pancreas (Oke, 2007). The major physiological effect of trypsin inhibitor is to cause the enlargement of the pancreas and secretion of excessive amounts of pancreatic enzymes much of which is lost to the animal in faeces (Aletor et al., 1994).

3.4.2. Phytate

Phytate, which is also known as inositol hexakisphosphate, is a phosphorus containing compound that binds with minerals and inhibits mineral absorption. The presence of phytate in foods has been associated with reduced mineral absorption due to the structure of phyate which has high density of negatively charged phosphate groups which form very stable complexes with mineral ions causing non-availability for intestinal absorption (Walter et al., 2002).

Phytates are generally found in food high in fiber especially in wheat bran, whole grains and legumes (Lori et al., 2001). The major concern about the presence of phytate in the human diet is its negative effect on mineral uptake. Minerals of concern in this regard include zinc, iron, calcium, magnesium, manganese and copper (Lopez et al., 2002). The formation of insoluble mineral-phytate complexes at physiological pH values is regarded as the major reason for the poor mineral bioavailability, because these complexes are essentially non absorbable from the human gastrointestinal tract. Furthermore, the human small intestine has only a very limited capability to hydrolyse phytate due to the lack of endogenous phytate degrading enzymes and the limited microbial population in the upper part of the digestive tract. Solubility and stability of myo-inositol phosphate--mineral complexes have been found to decrease as the number of phosphate residues on the myo-inositol ring decreases. Therefore, removal of phosphate residues from phytate results in a reduced impairment of intestinal uptake of essential dietary minerals (Sandberg et al., 1999).

In isolated form only myo-inositol pentakisphosphate suppressed absorption of iron, zinc and calcium in humans, while myo-inositol tetrakis- and trisphosphates had no effect in the concentrations under investigation. In the presence of higher phosphorylated myo-inositol phosphates, however, myo-inositol tetrakis- and trisphosphates were shown to contribute to the negative effect of phytate on iron absorption. Because a strong negative correlation was found between zinc absorption and the sum of myo-inositol tris- through hexakisphosphate from cereal and legume meals, such a contribution is probably also true for zinc absorption (Sandberg, 1991).

Phytic acid binds trace elements and macro-elements such as zinc, calcium, magnesium and iron, in the gastrointestinal tract are making dietary minerals unavailable for absorption and utilization by the body. It can also form complexes with proteins, proteases and amylases of the intestinal tract, thus inhibiting proteolysis. Moreover, the phosphorus in phytate has been considered to be largely unavailable to the organism because of the limited capacity of monogastric species to hydrolyse phytate in the small intestine (Drewnowski and Gomez-Carneros, 2000).

Phytate is also known to form complexes with proteins at both acidic and alkaline pH. This interaction may affect changes in protein structure that can decrease enzymatic activity, protein solubility and proteolytic digestibility. However, the significance of protein-phytate complexes in nutrition is still under scrutiny. Strong evidence exists that phytate-protein interactions negatively affect protein digestibility in vitro and the extent of this effect depends on the protein source (Cheryan, 1980).

3.4.3. Tannins

Tannins are polyphenol components prevalent in food legumes. Studies have shown that tannins interact with proteins, enzymes or nonenzymes, and form tannin-protein complexes, which decrease protein digestibility and protein solubility. This decrease in protein digestibility may be caused by either the inactivation of digestive enzyme or the reduction of the susceptibility of the substrate proteins after forming the complex. Polyphenols are found to interact with proteins and cause either inactivation of enzyme such as trypsin and chymotrypsin or make protein insoluble. Polyphenols inhibit several enzymes including α-amylase, lipases, pectin esterases, cellulases and β-galactosidase (Salunkhe et al., 1985). In addition to this, tannins reduce the bioavailability of vitamins and minerals (Chavan et al., 1986).

Chickpea seeds (whole seed) contain 78 to 272 mg tannins per 100 g seeds; while the cotyledons have only 16 to 38 mg per 100 g seeds. Tannins are mainly located in the seed coat. There is a considerable variation in seed coat color among the various chickpeas cultivars. The polyphenols in cultivars, which have darker testa color, inhibit the digestive enzyme activity more than cultivars with lighter testa color. These components impart astringent flavors, which are not always desirable. Some processing treatments such as dehulling and cooking considerably reduce the level of tannins in legume. As such, chickpea seeds with light color are preferred for whole seed consumption (Chavan et al., 1986).

3.4.4. Oxalates

It is a dicarboxylic acid which forms an insoluble calcium salt with a 1:1 molar stoichiometry. Oxalic acid and its salts occur as end products of metabolism on a number of plant tissues. When these plants are eaten they may have an adverse effect because oxalates bind calcium and other minerals while oxalic acid is a normal end product of mammalian metabolism. The consumption of additional oxalic acid may cause stone formation in the urinary tract when the acid is excreted in the urine (Noonan et al., 1999). The distribution of oxalate within plants is also uneven. In general oxalate content is the highest in leaves followed by the seeds and it is the lowest in the steams. Oxalic acid concentrations tend to be higher in plants than in meats, which can be considered oxalate free planning low oxalate diets.

Oxalic acid forms water soluble salts with Na^+, K^+, and $NH_4{}^+$ions it also binds with Ca^{2+},Fe^{2+}, and Mg^{2+}rendering these minerals unavailable to animals. However Zn^{2+} appears to be relatively unaffected. In plants with a cell sap of approximately pH 2, such as some species of Oxalis and rumex oxalate exists as the acid oxalate (HC2O4), primarily as acid potassium oxalate. In plants with a cell sap of approximately pH, 6, such as some plants of goosefoot family it exists as oxalate $(C2O_4)^{2-}$ ion usually as soluble sodium oxalate and insoluble calcium and magnesium oxalates. Calcium oxalate is insoluble at a neutral or alkaline pH, but freely dissolves in acid (Noonan et al., 1999).

The concentration of calcium oxalate changes as a result of processing (Noonan, Savage, & Reg Nutr, 1999).Boiling and Soaking may cause considerable skin rupture and facilitate the leakage of soluble oxalate into cooking water (Bhandari & Kawabata, 2004). It is reported that, boiling reduces oxalates significantly (82.1%) reduction after boiling for 40min as opposed to roasting and steeping which reduce 61.9% after 40-45 min and 43.3% after 24years respectively (Adeyeye et al., 2000). Although cooking proved to be most effective in terms of the reduction of total oxalate, water soluble minerals also leached out at the same time.

3.5. Functional properties

Functional properties indicate the ability of the proteinaceous material to hold oil or fat and water, to emulsify the same and to form products having a firm consistency upon heating and cooling include viscosity, dispensability, emulsify, and form gels, foam, produce films and absorb water and /or fat.

3.5.1. Water absorption capacity

Water absorption capacity describes flour – water association ability under limited water supply (Oladele and Aina, 2007). It gives an indication of the amount of water available for gelatinization. Water binding capacity is a useful indication of whether flour or isolates can be incorporated into aqueous food formulations (Udensi and Okoronkwo, 2006). Moreover, the oil and water holding capacity could be a function of the protein composition, not only due to the hydrophilic and lipophilic groups exposed but also due to the physical entrapment of oil.

3.5.2. Oil absorption capacity

Oil absorption is an important property in food formulations because fats improve the flavor and mouth feel of foods (Odoemelam, 2005).

3.5.3. Foaming capacity and stability

The foam ability of flours has been shown to be related to the amount of native protein. Native protein gives higher foam stability than the denatured protein. It is related to the amount of solubilized protein (Odoemelam, 2005)

3.5.4. Bulk density

Bulk density is a measure of heaviness of a flour sample. It gives an indication of the relative volume of packaging material required. Generally, higher bulk density is desirable for the greater ease of dispensability and reduction of paste thickness (Udensi and Okoronkwo, 2006).

3.5.5. Swelling Power

The swelling power or swelling index is the measure of the ability of starch to imbibe water and swell. It can also be defined as the swollen sediment weight (g) per gram of dry starch. Swelling can also be positively related to the amount of soluble solids leached outside the granules during heating. The initial granule size also influences the swelling and determines the onset of gelatinization. Starch with higher amylose content has significantly lower swelling power. Leach et al., (1959) reported that the amylose acts both as diluent and inhibitor of swelling.

Sanni et al., (2005) reported the swelling of granules reflect the extent of associative forces with the granule, therefore the higher the swelling index, the lower the associative forces. Values for swelling powers at higher temperatures should represent progressive relaxation of the bonding forces within the granules. Dengate (1984) explained that, differences in swelling behavior appeared to be caused by differences in lipid and amylose content as well as granules organization. Li and Yeh (2001) studied various starches and concluded that the thermal and dynamic rheological characteristics are essential to investigate the swelling phenomenon. Temperature has a significant impact on the swelling power. Swinkels (1985) reported yam bean starch has a lower swelling power than that of cassava starch. The high swelling power of potato would be due, among others, to the high phosphate content because the negative charges allowed easier water entrance into the granules.

3.5.6. Solubility

The solubility values of starch ranged from 4.25 to 5.96%. Ikegwu et al., (2009) observed a range of water absorption capacity (59.75 – 68.02%) of different starches analyzed. The ability of food materials to absorb water is sometimes attributed to their protein content (Kinsella, 1976). Solubility of starch depends on the type and origin of the starch. Solubility of the starch provides evidence of non-covalent bonding between molecules within the starch granules. Many factors may influence the degree and kind of association at the molecular level. These factors include the ratio of amylose to amylopectin, the characteristics of each fraction in terms of molecular weight/distribution, degree and length of branching, and conformation (Hoover, 2001; Leach et al., 1959). Rickard et al. (1991) reported that temperature of an aqueous suspension of starch is raised above the gelatinization range, hydrogen bonds holding the starch granules continue to be disrupted. Water molecules become attached to the liberated hydroxyl groups and the granules continue to swell, and as a direct result of swelling, there is a parallel increase in starch solubility.

3.6. Effects of traditional processing on anti-nutritional factors

Khokhar and Chauhan (1997) reported the anti-nutritional factors in Moth Bean (Vigna aconitifolia).The dry seeds were given different treatments including soaking, sprouting and cooking and the changes in the level of the anti-nutritional factors were estimated. Soaking the seeds in plain water and mineral salt solution for 12 hr decreased phytic acid to the maximum (46–50%) whereas sprouting for 60 hr had the most pronounced saponin lowering effect (46%). The cooking method of processing was less effective in reducing the levels of these anti-nutritional factors.

In general, diet-related factors have a greater influence on the bioavailability of the micronutrients in plant foods, particularly Ca, Fe and Zn, than on the macronutrients. The absorption of Ca, Fe and Zn is particularly affected. The net effect on the nutrient bioavailability depends on the balance between factors that either inhibit or enhance nutrient absorption and/or utilization in the whole diet (Sandstrom, 2001).

3.7. Effect of traditional processing on reducing anti-nutritional factors

Soaking

Soaking is often used as a pretreatment to facilitate processing of legume grains and cereal seeds. Soaking may last for a short period, about 15 to 20 minutes, or for a very long period, usually 12 to 16 hours. In household situations cereals and legumes are typically soaked in water at room temperatures overnight. Because phytate is water soluble, a significant phytate reduction can be realized by discarding the soak water. In addition, action of endogenous phytases contributes to phytate reduction. Temperature and pH value have been shown to have a significant effect on enzymatic phytate hydrolysis during soaking. If the soaking step is carried out at temperatures between 45 and 65 °C and pH values between pH=5.0 and 6.0, which are close to the optimal conditions for phytate dephosphorylation by the intrinsic plant phytases, a significant percentage of phytate (26–100 %) was enzymatically hydrolysed (Greiner and Konietzny, 2006).

Moreover, soaking removes some of the non-nutritional compounds, which can be partly or totally solubilised and eliminated with the discarded soaking solution (Frias et al., 2000). Some previous studies reported in the literature have analyzed the effect of the soaking conditions on the main quality parameters in the final product (Frias et al., 2000; Sayar et al., 2001). Frias et al (2000) concluded that the seed coat controls water absorption up to a certain level of moisture. Frias et al. (2000) also concluded that the differences in water absorption might be due to the differential solubilisation of the starch during soaking which is caused mainly by differences in starch structure, seed size and membrane permeability.

Roasting

Roasting consists of dry heat to the seed material by conduction or convection and heat radiations. In conduction equipment heating can be indirect through a granular medium, or direct through a metallic surface heated with a burner or electric resistances. In convection equipment, like drum-drier, the seeds are heated by hot air and infrared radiations generated by a gas-fired burner. Residence time can be adjusted from 1 to 10 minutes as a function of the slope of the drum.

There are many types of roasting techniques such as rotary drum dryer, salt-bed roasting and conventional grain dryer. The most commonly used roasting systems are the rotating drum, fluidized bed models, cascade roasting, jet-sploding, micronizing and microwave treatments. The key difference between these methods is the manner in which the heat is applied (dry or moist) as well as the use of subsequent lamination or expansion. Most of these methods provide non uniform cooking of legume with uneven temperature distributions (Prachayawarakorn et al., 2006).

Roasting methods involve the treatment of soybean with a temperature varying between 110 to

170 ^{o} c (Cheong, 1997) and for other legume like grass pea with temperature varying between 150 to 210 ^{0}c (Teklehaimanot et al., 1993). Ganesh and Grieve (1990) indicated that roasting processes under commercial conditions tend to be at relatively lower temperatures (125 to 150oc bean temperature). Finally, the type of heat treatment should be properly defined because of the plethora of methods used. For definition of roasting, the temperature of the beans at roasting, the time spent

at this temperature, the cooling rate, and any kind of processing before or after roasting should be stated (Ganesh and Grieve, 1990).

CHAPTER 4

4. MATERIALS AND METHODS

4.1. Description of the study area

Geographical Location

The study was carried out in Boh District, Warder Zone, Somali National Regional State (Ogaden) of Ethiopia. It is the only place where yeheb population currently found in Ethiopia.

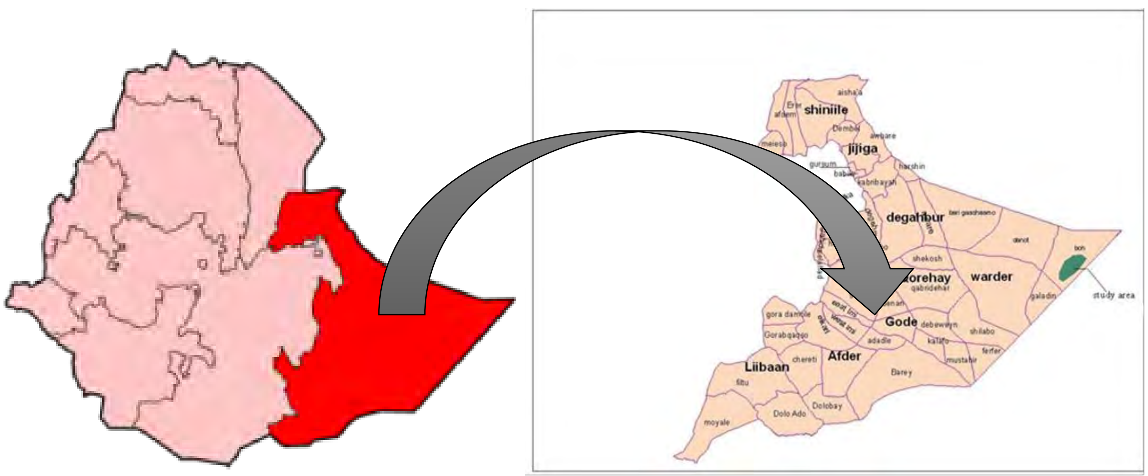

Figure 4. Map of Somali Regional State (Ogaden) of Ethiopia showing study site

Climate and Topography

the study area is classified as a semi-desert region, where rainfall is only 150-200 mm a year The rainfall in the natural habitat of yeheb is bimodal, in which there are two main rainy seasons, of varying reliability in April-June and October-November, and two pronounced dry seasons (Yahya, 2004). The southwestern monsoon brings the main rains in a few days in March/April to May/June; the northeastern monsoon, the short rains from October to November. Mean annual precipitation at the site does not exceed 220 mm (FAO, 1977). The amount of rainfall is higher in April and October of the two wet season. Daily rainfall pattern is unevenly distributed that of high in one day and low in the other day (Zerihun, 1999).

According to Kazmi (1979), the study area is situated at altitude ranging between 300 and1000 m.a.s.l. The relative humidity at 8.00 am is about 75% and at 14.00 pm about 55-65%. The local monthly range of relative humidity is ± 4% (FAO, 1977; Hunt, 1951). The mean monthly wind speed is 2 - 3 km h-1 except during the southwestern monsoon, when they are 4 - 5 km h-1. Mean annual potential evapotranspiration varies between 1,700 - 2,600 mm (FAO, 1977; Griffiths, 1972).

4.2. Sample collection and preparation

A seemingly healthy yeheb nuts were purchased from the local markets of Boh District, Warder Zone in Somali Regional state of Ethiopia. The seeds were cleaned manually to remove foreign matters, immature and damaged seeds

a) Preparation of raw sample

The cleaned seeds were washed with tap water, rinsed with distilled deionized water and immediately dried in oven (model: DHG-9055A) at 55 °C for 12 h, under air circulation, and then milled by electric miller (model no.: NM-8300, Electrical Grinder-NIMA) to pass through a 0.425 mm sieve, the flour was packed in tight plastic bag and stored at room temperature (in the shelf) until analysis.

4.3. Traditional processing methods yeheb seed

4.3.1. Boiling

Cleaned seeds were soaked in distilled water (1:2 w/v seed to water) for 3 h. the soaking water was decanted. Again, seed were washed with distilled water, then placed in 2L of distilled boiling water at 96 °C and cooked for 60 min until it becomes soft. The cooked seeds were immediately dried in drying oven (model: DHG-9055A) at 55 °C for 12 h. Then dried seeds milled by miller (model no.: NM-8300, Electrical Grinder-NIMA) to pass through a 0.425 mm sieve, The flour was packed in air tight plastic and stored at room temperature until required for analysis.

4.3.2. Wet roasting

Cleaned seeds were washed with tap water, rinsed with distilled deionized water, soaked with distilled water (1:5 w/v) at 28 ^{0}C (in water bath) for 20 hr, then roasted at 200 °C for 40 min in baking oven (model name: SEVERIN) while regularly stirring and turning with a fork. The roasted seed were milled with an electric miller (model no.: NM-8300, Electrical Grinder- NIMA) to pass through a 0.425 mm sieve. Packed in air tight plastic and stored at room temperature until required for analysis.

4.4. Laboratory analysis

4.4.1. Proximate

Moisture content, total ash, crude protein, crude fiber, and crude fat were determined according to AOAC (2000) using the official methods of 925.09, 923.03, 979.09, 962.09, and 4.5.01, respectively.

4.4.1.1. Determination of moisture

Moisture of the flour was determined according to the AOAC (2000) using the official method 925.09. Empty aluminum dish and its lid were dried in an oven at 100^{0}C for 1h and cooled in a desiccator. The dried and cooled dish together with the lid was weighed. About 5g of the prepared yeheb nut samples (raw, roasted and boiled) were weighed and dried in drying oven with air circulation at 105 ^{0}C for 3hrs, cooled in a desiccator and then weighed. The amount of moisture was calculated by using the following formula.

$$\text{Moisture}(\%) = \frac{W_2 * 100}{W_1}$$

Where W_1= weight (g) of sample

W_2= loss of weight (g)

4.4.1.2. Determination of total ash content (AOAC 923.03, 2000)

Ash was determined by incineration of known weights of the samples in a muffle furnace at 550^0C (Gallenkamp, size 3) until a white ash was obtained. Organic matter was burned off and the inorganic material remaining was cooled and weighed. Heating was carried out by phases, first to derive the water, then to char the product thoroughly and finally to ash at 550^oC in a muffle furnace. The ashing dishes (made of porcelain) were placed into a muffle furnace for 30 min at 550^0C. The dishes were removed and cooled in a desiccator (with granular silica gel) for about 30 minutes to room temperature. Each dish was weighed . About 2.000g of flour sample was added into each dish. The dishes were placed on a hot plate under a fume hood and the temperature was slowly increased until smoking ceases and the samples become thoroughly charred. The dishes were placed inside the muffle furnace at 550^0C for 4 hours, and removed from the muffle and then placed in a desiccator for 1hr to cool. The ash was clear white in appearance. When cooled to room temperature, each dish. Weight of total ash was calculated by difference and expressed as percentage of sample. The amount of ash was calculated by using

The following formula.

$$Ash(\%) = \frac{w_2 * 100}{w_1}$$

Where W_1= weight (g) of sample

W_2=weight (g) of ash

4.4.1.3. Determination of crude protein

Protein content was determined according to AOAC (2000) using the official method 979.09. A digestion flask containing about 1 g of sample, to which 6 ml of acid mixture (conc. Sulphuric acid and conc. orthophosphuric acid) and about 3g of catalyst mixture (K2SO4 and Selenium) were added and exposed to about 370 oc in order to allow digestion. Then, distillation took place by adding 25 ml of 40% NaOH and using 25 ml of boric acid with 10 drops of indicator solution. Finally, the distillate was titrated with standardized 0.1N sulphuric acid to a reddish color. The crude protein content was estimated using the formula:-

$$\text{Total nitrogen percent by weight} = \frac{(V_2 - V_1) \times N \times 14.007 \times 100}{W}$$

Where, V_2 = Volume in ml of the standard sulphuric acid solution used in the titration for the test material

V_2 = Volume in ml of the standard sulphuric acid solution used in the titration for the blank determination

N= Normality of standard sulphuric acid

N=Weight in grams of the test material

Crude protein content percent per weight =total nitrogen x 6.25

4.4.1.4. Determination of crude fat

Crude fat content of the yeheb flour samples was determined according to the AOAC (2000), using the official method 4.5.01.

The flasks used for the extraction were cleaned by placing them in Memmert drying oven (Memmert, Germany) at 70 ^{0}c for 1 hr and cooled in desiccators. The masses of the cooled flasks were measured by Adventurer analytical balance of model AR2140 (M1). About 2 g of the yeheb flour was weighed in to each of the thimbles lined with cotton at their bottom. The thimbles with the sample content were placed in to the Soxtec soxhlet extraction apparatus of model 2055. 70 mL of diethyl ether was added in to each flask used for the extraction. The extraction process was done for about 3 hr and then after the flasks with the contents were removed from the soxhlet and placed in drying oven at 70 ^{0}c for 1 hr .The flasks were then placed in desiccators for 30 min. The masses of each flask together with its fat contents were measured (M_2).

The crude fat content was calculated from the equation:

$$\text{Crude fat content (\%)} = \frac{M_2 - M_1}{W} \times 100$$

Where, M_2=mass of flask and lipid extracted

M_1=mass of dried flask

W=sample weight.

4.4.1.5. Determination of crude fiber content

Crude fiber content of the yeheb flour samples were determined according to AOAC (2000), using the official method 920.169.

About1.6 g of the sample was weighed in each of 600 mL beaker. 200 mL of 1.25% sulfuric acid solution was added to each beaker and allowed to boil for 30 min by rotating and stirring periodically. During boiling the level was kept constant by addition of hot distilled water. After 30 min 20 mL of 28% potassium hydroxide solution was added in to each beaker and again allowed to boil for another 30 min. The level was still kept constant by addition of hot distilled water. Then after 30 min the solution found in each of the beaker was filtered through crucibles containing sand by placing each of them on Buchner funnel fitted with No.9 rubber stopper. During filtration the sample was washed with hot distilled water. The final residue was washed with 1% sulphuric acid solution, hot distilled water, 1% sodium hydroxide solution and finally with acetone. Each of the crucibles with their contents was dried for 2 hr at about 1300c and cooled in desiccators and weighed (M1). Then again they were ashes for 30 min at 5500c in furnace and were cooled in desiccators. Finally the mass of each crucible was weighed (M).

The crude fiber content was determined by using the formula

$$\text{Crude fiber (\%w/w)} = \frac{M_2 - M_1}{W}$$

Where: M_1=mass of the crucible, the sand and wet residue,

M_2=mass of the crucible and the sand

W= sample weight.

4.4.1.6. Determination of crude carbohydrate

The crude carbohydrate was calculated by difference. The mathematical expression is as follow:

Crude carbohydrate (%) = 100-(%crude fiber + % crude protein + % crude fat +% total ash).

4.4.1.7. Determination of gross energy

Gross energy was determined by formula from fat, carbohydrate and protein contents using the Atwater's conversion factors; 16.7 kJ/g (4 kcal/g) for protein, 37.4 kJ/g (9 kcal/g) for fat and 16.7 kJ/g (4 kcal/g) for carbohydrates and expressed in calories (Guyot et al.,2007).

4.4.1.8. Mineral analysis

Calcium, magnesium, zinc and iron were determined using atomic absorption spectrophotometer method of Osborne and Voogt (1978). The ash obtained after dry ashing at 550 ^{0}C was treated with 5 ml of 6N HCl to wet it completely and carefully dried on a low temperature hot plate. 7 ml of 3N HCl was added and the dish was heated on the hot plate until the solution just boils. Then, it has been cooled and filtered through a filter paper in to a 50mL volumetric flask. Again 7 ml of

3N HCl was added to the dish and heated until the solution just boils. Finally, cooled and filtered into the volumetric flask. For the determination of calcium, lanthanum chloride (1% w/v) was added to both standards and samples to suppress interference from phosphorus. Using atomic absorption spectrophotometer (Varian, spectra-10/20, Australia) a calibration curve was prepared by plotting the absorption or emission values against the metal concentration in mg/100g. Reading was taken from the graph, which depicted the metal concentrations that correspond to the absorption or emission values of the samples and the blank. The Concentration contents were calculated by using the formula and the result is shown in

$$\text{Concentration (mg/100g)} = \frac{(A\text{–}b) \times V}{10 \times \text{wt. of sample}}$$

Where; A = concentration in ppm of sample solution

B = concentration in ppm of blank solution

V = volume in mL of the extract

4.4.2. Functional properties

4.4.2.1. Determination of water and oil absorption capacity

Water and oil absorption capacity of flour samples (raw, roasted and boiled) were determined according to (Oladele and Aina, 2007).

About 1 g of the grounded yeheb flour was mixed with 10 mL of distilled water (density of 1 g/cm3) in a centrifuge tube and allowed to stand at room temperature 30 ^{0}c for 1 hr. It was then centrifuged at 200 rpm for 30 min and the supernatant was noted in a 10 mL graduated cylinder.

Water and oil absorption capacity was calculated from the equation:

Water absorption capacity $= 10 - V$

Where V= volume of water or oil left unabsorbed after centrifugation.

4.4.2.2. Determination of bulk density

Bulk density of the yeheb nut flour samples was determined according to Oladele and Aina, (2007).

About 50 g grounded yeheb flour was put in a 100 ml measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density was calculated as weight of the grounded yeheb nut (g) divided by its volume (ml).

$$\text{Bulk density} = \frac{\text{Weight of ground yeheb flour}}{\text{Volume}}$$

4.4.2.3. Determination of foaming capacity and stability

Foaming capacity and stability of yeheb nut samples (raw, roasted and boiled) were determined according to (Odoemelam, 2005). About 1 g of the grounded yeheb nut was dispersed in 50 mL distilled water. The resulting solution was vigorously whipped for 30 min in a kenwood blender and poured into a 100ml graduated cylinder. The volume before and after whipping was recorded and the foaming capacity was calculated as percentage volume increase

The foaming capacity was calculated from the equation:

$$\text{Volume increase(\%)} = \frac{\text{volume after whipping—volume before whipping}}{\text{volume before}} \times 100$$

Foaming stability was determined as the volume of foam that will be remained after 8 hour expressed as a percentage of the initial volume.

The foaming stability was calculated from the equation:

$$\text{Volume of foam(\%)} = \frac{\text{Volume of foam left after 8 hrs}}{\text{Initial foam volume}} \times 100$$

4.4.2.4. Swelling power and solubility

Swelling power and solubility determinations were carried out in the temperature range of 60-90°C (using the method of Leach et al., 1959). One gram of yeheb flour sample was accurately weighed and quantitatively transferred in to a clear dried test tube and weighed (W1). About 15 ml of distilled water was added and mixed gently at low speed for 5 min. The slurry was heated in a thermostatic water bath (Memmert model DIN 2005), at 80°C for 30 min with regular mixing. The test tube was cooled with its content rapidly to 20 °C. During heating, the slurry was stirred gently to prevent lumps forming in the flour. The cool paste was centrifuge at 2200 g for 15 min. The supernatant was decanted immediately after centrifuging into a pre-weighed evaporating can and dried at 100°C to constant weight approximately for 4 hours. The weight of the sediment was taken and recorded as (W2) or swollen mass.

Swelling power = (Wt of sediment)/ (sample Wt-Wt of soluble)

Solubility index (%) = (Wt of soluble/Wt of sample) x 100.

4.4.3. Anti-nutritional factors

4.4.3.1. Determination of phytate Content

Phytate content of yeheb nut samples (raw, roasted and boiled) were determined according to Latta and Eskin (1980).

About 2 g of samples were extracted with 10 mL 2.4% HCl in mechanical shaker for 1 hr at an ambient temperature and centrifuged at 3000 rpm for 30 min. The clear supernatant was used for phytate estimation. 1 mL of Wade reagent (containing 0.03% solution of $FeCl.6H_32O$ and 0.3% of sulfosalicilic acid in water) was added to 3 mL of the sample solution (supernatant) and the mixture were mixed on a vortex mixer (Thermolyne model, 37600) for 5 seconds. The absorbance of the sample solutions were measured at 500 nm using spectrophotometer model Du-64.

A series of standard solution were prepared containing 10, 20, 30, 40, 50, 60 μg/ml of phytic acid (analytical grade sodium phytate) in 2.4% HCl. A 3 mL of standard were added into 15 mL of centrifuge tubes with 3 mL of water which were used as a zero level (blank). A 1 mL of the wade reagent was added to each test tube and the solution was mixed on a vortex mixer for 5 seconds. The mixture was centrifuged for 10 min and the absorbance of the solutions (both the sample and standard) were measured at 500 nm by using water to calibrate the spectrophotometer.

The phytate content was calculated from the equation:

Phytic acid in mg/100g = (absorbance-intercept) 3/ (slope x ρ x wt. of Sample x10)

Where, ρ is density

4.4.3.2. Determination of tannin Content

Tannin was determined by the modified Vanillin assay (Butter et al., 1982). About 2g ground yeheb was weighed and then extracted with 10 ml absolute methanol for 20 min in rotating screw cap culture tubes (13 x 100mm). The mixture then centrifuged (Nüve, bench-top centrifuge,NF 800R, 2001, Ankara,Turk) for 10min at 3000 x G and the supernatant was used in the analysis. About 0.0 - 1.0 ml aliquots of catechin standard was dispensed into two sets of culture tubes and each sample was brought to 1.0 ml by the addition of absolute methanol.

Incubate the tubes in the water bath (BüCHI water bath B-481, BüCHI, Switzerland). 5 ml of the working vanillin reagent was added at 1min interval to one set of standards, and 5 ml of the 4% HCl solution was added at 1min intervals to the second set of standards. The samples in a water bath were kept for exactly 20 min, and then removed and the absorbance at 500nm was read using spectrophotometer. The absorbance of the blank was subtracted from the absorbance of the corresponding vanillin-containing sample. A standard curve has been constructed (Absorbance vs. catechin) and the linear portion of the curve was extrapolated to produce the standard curve. Finally, the tannin contents were calculated. Values of tannins were expressed in milligram of D-catechin equivalent per gram of sample.

The tannin content was calculated from the equation:

Tannin in mg/100g = (absorbance-intercept)/ (slope x density x weight of samplex10)

4.4.3.3. Determination of oxalate Content

The oxalate content was determined using the method originally employed by Ukpabi and Ejidoh (1989). The procedure involves three steps: digestion, oxalate precipitation and permanganate titration.

• **Digestion:** At this step, 2 g (db) of flour was suspended in 190 ml of distilled water contained in a 250-ml volumetric flask; ten ml of 6M HCl was added and the suspension was digested at 100°C for 1 hr, followed by cooling, and the solution was made up to a final volume of 250 ml before filtration.

• **Oxalate precipitation:** Duplicate portions of 125 ml of the filtrate were measured into a beaker and four drops of methyl red indicator was added. This step was followed by the addition of concentrated NH_40H solution (drop wise) until the test solution changed from its salmon pink colour to a faint yellow colour (pH 4-4.5). Each portion was then heated to 90^0C, cooled and filtered to remove precipitate containing ferrous ion. The filtrate was again heated to 90°C and 10 ml of 5% $CaCl_2$ solution was added while being stirred constantly. After heating, it was cooled and left overnight at 5°C. The solution was then centrifuged at a speed of 2500 rpm for 5 min. The supernatant was decanted and the precipitate was completely dissolved in 10 ml of 20% (v/v) $H2SO_4$, solution.

• **Permanganate titration:** At this point, the total filtrate resulting from digestion of 2 g of flour was made up to 300 ml. Aliquots of 125 ml of the filtrate were heated until near-boiling, and then titrated against 0.5M standardized $KMnO_4$, solution to a faint pink colour which persisted for 30. The calcium oxalate content was calculated using the formula.

$$\text{Oxalate} = \frac{T \times (Vme)\,(DF) \times 103}{(ME) \times mf}\ (mg/100g)$$

where **T** is the titre of $KMnO_4$ (ml), **Vme** is the volume - mass equivalent (i.e. that 1 cm^3 of 0.05 **M** $KMnO_4$, solution is equivalent to 0.00225 g anhydrous oxalic acid), **DF** is the dilution factor VTA (2.4, where VT is the total volume of filtrate (300ml) and A is the aliquot used (125 ml)), ME is the molar equivalent of $KMnO_4$ in oxalate ($KMnO_4$, redox rxn. (5)) and **mf** is the mass of flour used.

4.5. Statistical analysis

The results are expressed as means + standard deviation. One-way analysis of variance (ANOVA) was conducted to see the effect of processing on nutrition content of the study samples. Least Significant Difference (LSD) was used for mean separation. Statistics at $p < 0.05$ was considered significant was performed using SPSS version 20 software for windows to compare the difference between treatment means.

CHAPTER 5.

5. RESULTS AND DISCUSSION

The proximate and anti-nutritional factors, mineral content and functional properties and the effects of processing (boiling and roasting) on the levels of certain anti-nutritional factors (phytates, tannins, and oxalates) related to the samples of yeheb seeds which were collected from bokh district local market, were studied.

5.1. Proximate composition

Moisture content, total ash, crude fat, crude protein, crude fiber, total carbohydrate and total energy of yeheb seeds were analyzed and the results are presented in Table 5.1. Yeheb nuts were presented in three forms, which are the raw, boiled and roasted samples.

The proximate composition of raw Yeheb flour is shown in (Table 5.1;) raw Yeheb flour had protein content of 15.9%, crude fat 8.8%, crude fiber 15.5%, ash 3.9%, moisture 7.2%, utilizable carbohydrate 77.9%, and gross energy 383.0 Kcal/100g . The proximate composition of roasted yeheb flour was: protein 17.7 %, fat 12.5%, fiber 8.0%, and ash 3.2%, moisture 8.40% total CHO 79.8%, and gross energy of 410.73 K cal/100 g. The proximate compositions of boiled yeheb flours are also indicated in table 5.1. Boiled yeheb contained protein of 17.16 %, crude fat 12.1 %, crude fiber 6.5%, moisture content of 8.60% total CHO 80.92% and gross energy 412.45Kcal/100 g.

5.2. The effect of processing on proximate composition of Yeheb nuts

Table 5.1. Comparison of effect of processing on proximate composition of Yeheb nuts

Parameters	**Raw %**	Roasted %	Boiled %
Moisture	7.20±0.00^{a}	8.40±0.00^{a}	8.60±0.00^{a}
Crude protein	15.97±0.13^{a}	17.72±0.13^{c}	17.16±0.134^{b}
Crude fiber	15.45±0.64^{a}	8.00±0.00^{c}	6.50±0.71^{b}
Total ash	3.99±0.00^{c}	3.20±0.02^{b}	2.40±0.00^{a}
Crude fat	8.75±0.354^{a}	12.45±0.071^{b}	12.10±0.141^{b}
Crude carbohydrate	77.92±2.079^{a}	79.82±1.082^{a}	80.92±1.12^{a}
Gross energy (Kcal/100g)	383.00±6.50^{a}	410.73±1.55^{b}	412.45±3.24^{b}

Values are means of duplicates analysis ± standard deviations

$^{A\text{-}c}$ values with different superscripts in the same row are significantly different at $P<0.05$

Moisture content

Moisture content determination is an integral part of the proximate composition analysis of food. Moisture content in yeheb flour determines its stability. During processing treatment, there are no significant ($P<0.05$) differences among each processing methods. The results indicated that, the maximum and minimum moisture content was observed in raw and boiled seed 7.20 ± 0.0, 8.60± 0.0% respectively,

The values of the moisture content are not significantly different from one another. There were 16.67 % and 19.44 % increasing in moisture content of wet roasted and boiled respectively. This result implies that the raw sample has high shelf life and storage capacity than the roasted and boiled samples. Due to high moisture content of the boiled samples, they can easily get spoiled because water provides enabling environment for microbial growth. This result was in agreement with the one obtained by Musa (2010).

Total ash

Determination of the ash content in Table 5.1 shows that, the percentage of total ash varied from 2.40±0.00 to 3.99±0.02 % which corresponds to boiled and raw respectively. The percentage of total ash for wet roasting was determined to be 3.20±0.00 %. The raw samples has the highest ash content of 3.99±0.02 % when compared with boiled sample, which has the lowest ash content of 2.40±0.00 % . The percentage of ash determined in this study closely agrees with values reported by Booth and Wickens (1988), 2.2-3.8%, and Seegeler (1981) 2.2 – 3.7 %.

When we compare the processing effect, there was a significant difference ($P<0.05$) in the total ash content. There were 19.79 % and 39.85 % decrease in total ash content of roasted and boiled respectively. Loss in ash might be due to leaching of soluble inorganic salts into the processing water during the soaking of the sample followed by processing (roasting, boiling and cooking) (Esenwah and Ikenebomeh, 2008). The decrease in the ash content by both processing methods is in agreement with the finding of (Bradbury and Holloway, 1988) that reported, in every case, the ash content will be significantly reduced by boiling which was consistent with the loss of water soluble minerals, K, Na, P and S, presumably as potassium and sodium phosphates and sulfates.

Protein

The percentage of protein for the three samples (raw, wet roasted and boiled) of yeheb seed are given below under Table 5.1. For yeheb seed, the highest percentage of protein was recorded to be 17.72±0.13 and the minimum was found to be 15.97±0.13 for boiling and raw yeheb flour respectively. The mean value of the percentage of protein content for wet roasting was 17.16±0.134. The protein content of raw yeheb seed was found 15.97±0.13 %, which was in agreement with the finding of Booth and Wickens (1988), Seegeler (1981) and Musa (2010) reported 11 % to 16 % of protein.

The protein content of Cordeauxia seed is high when compared with some other wild fruits such as Baobab Adansonia digitata (3.1%), Vitellaria paradoxa (8.4 - 8.8%), Tamarindus indica (4.1%)

and Ziziphus Mauritania (4.1%) (Saka and Msonthi, 1994; Teketay et al., 2003). Moreover, comparison of nutritional content with some cultivated fruit shows that C. edulis is also superior in protein contents to banana (1.2 % and 0.3 % respectively), guava (0.9 %), mango (0.6 %) and Papaya (0.6 %) (Srivastava and Kumar, 1998).

When we see the effect of the processing methods there was a significant difference ($P<0.05$) in the crude protein content of processed as compared with raw yeheb seed. There were 7.45 % and 10.95 % increasing in protein content of roasted and boiled respectively. The observed increase in protein content of roasted and boiled samples might be due to loss of soluble solids during soaking. It might also be attributed to a net synthesis of enzymatic protein during soaking and also might be from the release of protein from the protein complexing agent (Urga and Gebretsadik, 1993).. A similar increase in protein content has been reported for Terminalia catappa seeds roasted at a high temperature (Ezeokonkwo, 2005).

Crude fiber

The results of crude fiber determination are presented in Table 5.1. The value were 5.45±0.6 %, 6.50±0.7 % and 8.00±0.0 % for raw, boiled and wet roasted. Wet roasting had the highest percentage of crude fiber content and the lowest percentage of crude fiber belongs to raw (5.45±0.64).

It was observed that raw yeheb seed contained 5.45 % crude fiber, in contrast to the finding (2.1 %) of El-Zeany & Gutale, (1982) and Musa (2010) that reported higher range of crude fiber content (10 to 25 %). When we see the processed samples, roasted and boiled had 8.0 and 6.5 % crude fiber content respectively. The processing method (roasting and boiling) applied in this study have a significant difference ($P<0.05$) in the crude fiber content. There were 46.87 % and 19.27 % increasing in crude fiber content of roasted and boiled respectively.

The result shows that dietary fiber increased very substantially after boiling and roasting which were considered to be due to the formation during boiling and roasting of some enzyme- resistant starch. Boling or conventionally, cooking solubilizes starch and makes it more available and these starches are enzymatically non degradable starches contributing to a larger proportion of fiber after boiling. As reported in chapter 3, local people use seed of yeheb medicinally to relieve stomach constipation, since consumption of food with high fiber has been reported to help prevention and treatment of stomach constipation (Weickert and Pfeiffer, 2008).

Crude fat

From Table 5.1, above the result of fat determination in yeheb seed in three different forms, raw, boiled, and roasted samples are presented. From the Table, the percentage of fat for yeheb seed was in the range of 12.1±0.14 to 12.5±0.1 %, which corresponds to boiling and roasting respectively. The percentage of fat for raw is 8.75±0.35 %. The maximum content of fat was observed in wet roasting (12.45±0.071 %) and the minimum value corresponds to raw (8.75±0.35%) seeds.

Raw yeheb seed was found containing 8.75 % of crude fat a value lower than previously reported by Musa (2010) 12.58 %. However, the present finding is in agreement with El-Zeany & Gutale, (1982) which range from 9.9 to 10.8 %.

When we compare the results of the present study, there was a significant difference ($P<0.05$) in the crude fat content of roasted and boiled samples with raw yeheb seed. There were 42.89 % and 38.29 % increase in fat content of roasted and boiled samples respectively. The increased result might be due to soaking and boiling of the sample that led to the cleavage of the protein-lipid or carbohydrate-lipid linkages thereby, facilitating the easy extraction of the oil by the extracting solvent (Esenwah and Ikenebomeh, 2008). In most of legumes fat content is relatively small (<1% of their dry matter) (bravo et al., 1999). A few species such as soya, ground nut and lupin have closely amount of fat (5- 20% in range).

Crude carbohydrate

The carbohydrate content of yeheb flour ranges from 79.82 % to 80.92 % and are given in Table 5.1. The carbohydrate content of raw yeheb flour was 77.92 %.The maximum value is indicated for boiled yeheb flour (80.92 %). The processing methods increased the content of crude carbohydrate as compared to the raw sample.

Due to the traditional processing methods there was increasing effect on the content of crude carbohydrate. There were 2.44 % and 3.85 % increase in crude carbohydrate content of roasted and boiled seeds respectively. The carbohydrate content determined in the present study is by far greater than the carbohydrate content of yeheb seed reported by Musa (2010) (36%). In yeheb seed, boiling has increased the carbohydrate content of yeheb samples to some extent which results from solubilization of starch which makes it much more available and increase in the carbohydrate content of processed sample. Boiling of yeheb seed may cause formation of maltose and other simple sugars by breaking down of starch, increasing the carbohydrate content.

Gross energy

The caloric value was calculated by multiplying the mean valves of crude proteins, crude fat and total carbohydrate by Atwater's conversion factor of 4, 9 and 4, respectively. The result of gross energy determination in yeheb seed in three different forms, raw, boiled, and roasted samples are presented. In Table 5.1, the percentage of gross energy for yeheb seed varied from 383.00, 410.73 to 412.45 %, which corresponds to raw, roasted and boiled respectively

There were no significant differences ($P>0.05$) among each processing treatments. The calorific value (Kcal/100g) was highest in boiled followed by roasted samples. The range of values obtained for gross energy (GE) (383.00 to 412.45 Kcal/100g) were comparable to the GE of maize and higher than GE of cassava, Irish potato, yam, sweet potato and taro (Serge Treche, 1996)

5.3. Anti-nutrients composition

Table 5.3. The results of anti-nutritional factors (phytates, tannins and oxalates) content.

Sample type	Phytate (mg/100g)	Tannin (mg/100)	Oxalate (mg/100g)
Raw	1.65± 0.014^{a}	0.054±0.001^{b}	0.47±0.021^{c}
Wet roasted	1.40± .064^{c}	0.043± 0.001^{a}	0.34±0.014 ^{b}
Boiled	1.05± .028^{c}	0.036± 0.001^{a}	0.21±0.042 ^{b}

Values are means of duplicates analysis ± standard deviations

a- c values with different superscripts in the same column are significantly different at $P<0.05$

Phytate

The Table above shows the result of phytate determination in the three samples of yeheb flour. The levels of phytates for three samples are given to be 1.65 mg/100g, 1.40 mg/100g and 1.05 mg/100g for raw , boiled and roasted respectively and this shows that the phytate content is the highest for raw (1.65 mg/100g) which is control or unprocessed sample, and minimum for boiled (1.05 mg/100g) samples.`

The phytate value recorded for raw yeheb nut (1.65 %) was lower relative to 8.25 and 4.25% reported for white sesame seed and black millet respectively (Odumodu et al., 1992).but higher than 0.18% reported for locust bean (Eka, O.U., 1980.).

The processing methods reduced the content of phytate to varying extents. Roasting and boiling lowed the level of phytate to the extent of 20.59 % and 38.24 % respectively over the raw sample. The loss in phytates in roasted and boiled samples of yeheb may be due to leaching of phytate ions during soaking into the soaking water under the influence of a concentration gradient (difference in chemical potential) which governs the rate of diffusion. In addition, it may be ascribed to the activation of the endogenous phytase during the long soaking treatment and possible enzyme action continued during drying step.

Both roasting and boiling of the yeheb flour caused a significant reduction ($p < 0.05$) in the phytate content. However, boiling was more effective in reducing the phytate content of the yeheb flour than boiling. Wet roasting is higher heat treatment process and it degrades phytate to large extent. This enzyme is capable of hydrolyzing phytate (Oboh et al., 2003), thereby decreasing the phytate content of the yeheb flour.

The high content of phytate is of nutritional significance as not only is the phytate phosphorous unavailable to human, as its presence lowers the availability of many other essential dietary minerals (Siddhuraju and Becker, 2001). Therefore, reduction of phytate is expected to enhance the bioavailability of proteins and dietary minerals of yeheb. However, there is evidence that dietary phytate at low level may have beneficial role as an antioxidant, anticarcinogens and likely play an important role in controlling hypercholesterolemia and atherosclerosis (Phillippy et al., 2004).Thus moderate amount of this anti-nutrient role in a food may be benefit currently.

Tannins

From Table 5.3, the values of oxalates were 0.054 %, 0.047 % and 0.036 % for raw, boiled and wet roasted yeheb nut samples, respectively. The value was lower than 0.28% reported for Mucuna pruriens seeds (Vijayakumari et al., (1998), and 1.3% and 1.9% reported for cashew nut and full-fat pumpkin seed flours (Fagbemi et al., (2005). (Ahmed et al., 2006) reported 1.75% of tannins for Guar gum seeds. In addition, 0.15% and 0.07% were reported for soybean and brown millet (Odumodu et al., 1992).

The processed yeheb samples showed no significant difference ($P<0.05$) in the tannin content. In the present study tannin content decreased by 12.9 % and 33.3 % in wet roasted and boiled samples, respectively. Loss of tannin may be due to solubility in water and its sensitivity to heat. Since polyphenolic compounds are water-soluble in nature and mostly located in the seed coat, the decrease in the level of phenolics and tannins during soaking may be attributed to leaching into the soaking medium (Vijayakumari et al., 2007). Tannins affect nutritive value of food by forming a complex with protein (both substrate and enzyme) thereby inhibiting digestion and absorption (Oboh and Elusian, 2007).

The higher content of tannins is known to inhibit the activity of the digestive enzymes and, thus, interfere with the digestion and absorption of dietary proteins, carbohydrates, minerals and other nutrients, such as vitamin B12. They may also cause damage to the mucosa of the digestive tract and hence, they are undesirable for human consumption from a nutritional point of view (Vijayakumari et al., 2007).

Oxalates

Oxalate contents of raw, boiled and roasting yeheb flour are shown in Table5.3. The values of oxalates were 1.0 mg/100, 0.34 mg/100 and 0.21 mg/100 for raw, boiled and wet roasted, respectively. For raw yeheb flour is 15.86 mg / 100 g on dwb. The oxalate content was recorded lowest (6.56 mg/100) on dwb for roasting and highest (15.86 mg/100 g) on dwb for raw.

The processing methods used in this study reduced the content of oxalates to varying extents. Wet roasting and boiling reduced the level of oxalate by 58.6 % and 47.7 % respectively. over the control value. The reduction of oxalates during boiling may be due to its solubility in boiling water. Albihn and Savage, (2001), reported that boiling may cause considerable skin rupture and facilitate the leakage of soluble oxalates into cooking water. Similarly, the same reason can be stated for the observed high reduction in oxalate level upon boiling in the present study samples.

According to the study reports by (Albihn and Savage, (2001) and Wanasundera and Ravindran, (1992), oxalate can have deleterious effects on human nutrition and health. This is particularly associated with decreasing calcium absorption and aiding the formation of kidney stones (Noonan and Savage, 1999). Therefore, the reduced oxalate content due to processing could have positive impact on the health of consumers, particularly as the reduction of oxalate levels on boiling and roasting enhance the bioavailability of essential dietary minerals of the yeheb food products, as well as reduce the risk of kidney stones occurring among consumers.

5.4. Effect of processing treatment on mineral contents of yeheb nut

The mineral contents of yeheb flour were shown in Table 5.4. The values of mineral contents were different slightly from raw samples in all the processing samples. The total iron content showed significant difference ($p < 0.05$) in each processing samples. During boiling and wet roasting decreased by 8.6% and 6.9% respectively. This reduction could be attributed due to the minerals leached from the yeheb seeds in to the water at different rates during cooking treatments. The results of the present study also showed that the seed of yeheb is very rich in iron (4.3 mg/100g) which is higher than some cereals such as rice (1.8mg/100g), wheat (3.5mg/100g) and maize (2.7mg/100gm) (Léder, 2004). Local people claim that the fruit can be used to cure anemia problems strengthening the finding of the present study because iron is essential to enhance red blood cell in human body (Andrews, 1999).

The total zinc content was significantly different ($p<0.05$) among processed samples. Wet roasting slightly increase by 4.64% and 7.28% reduced in boiling sample. Similarly, comparing the processing effect there was a significant difference ($P<0.05$) in the calcium content of roasted with that of raw yeheb. 38.45 % and 14.34 % of calcium content was decreased respectively in boiled and roasted. There was no a significant difference ($P>0.05$) in the calcium content of roasted and raw yeheb nut. Loss in calcium content might be due to dehulling as minerals are more concentrated in the test rather than in the cotyledon (Agbede and Aletor, 2005). Similar results were reported on Canavalia ensiformis and Mucuna pruriens seed flours by Agbede and Aletor, (2005). There was no a significant difference ($P>0.05$) in the calcium content of roasted and raw yeheb. The processed yeheb samples showed a significant difference ($P<0.05$) in the Magnesium content. In the present study Magnesium content increased by 1.81 % and 5.33 % in roasted and boiled respectively. However, there was no significant difference ($P > 0.05$) between the level of Mg in both roasted and raw samples.

Table .5.4. Calcium, magnesium, iron and zinc contents of the raw and processed sample.

Sample type	C a mg/100g	Zn mg/100g	Fe mg/100g	Mg mg/100g
Raw	243.87±0.792^{a}	3.02±0.007^{b}	4.295±0.035^{b}	80.55± 0.743^{a}
Wet roasted	290.16±4.363^{b}	3.16±0.014^{c}	4.59±0.127^{c}	82.01±0.799^{a}
Boiled	250.31±1.711^{a}	2.80±0.028^{a}	3.92±0.078^{a}	84.84±0.318^{b}

Values are means of duplicates analysis ± standard deviations

a- c values with different superscripts in the same column are significantly different at P<0.05

5.5. Functional Property

These are bulk density, water and oil absorption capacity, foaming capacity, foaming stability, swelling power and solubility index.

Table 5.5. The functional properties of flour from the yeheb seeds.

Parameters	Raw	Roasted	Boiled
Bulk density (g/ml)	0.59±0.014^{a}	0.67±0.007^{b}	0.82±0.014^{c}
Water absorption capacity (ml/g)	3.75±0.071^{c}	3.03±0.021^{b}	1.97±0.092^{a}
Foaming capacity (%)	4.72± 1.34^{a}	8.49± 1.33^{a}	5.02± 1.43^{a}
Foaming stability (%)	101.91±0.021^{a}	118.42± 1.15^{b}	104.72± 1.34^{a}
Swelling power (%)	2.83±0.05^{a}	2.75±0.014^{b}	2.64±0.04^{a}
Solubility index (%)	24.65±2.05^{b}	20.15±1.20^{ab}	14.75±1.91^{a}

Values are means of duplicates analysis ± standard deviations. $^{a-c}$ values with different superscripts in the same row are significantly different at P<0.0

Bulk density

The bulk density of raw yeheb flour was found to be 0.59 %, which was in agreement with the other legume like wheat flour (0.57g/ml) (Ade-ornowaye et al., 2008) while that of jack fruit flour is 0.61g/ml (Odoemelam, 2005). Yeheb flour exhibited significantly different bulk densities attributed to processing. Samples having higher bulk density are a direct manifestation of their moisture content as moisture is the measure of bulk density of the flour.

Bulk density is a measure of heaviness of a flour sample. It gives an indication of the relative volume of packaging material required. Generally, higher bulk density is desirable for the greater ease of dispersibility and reduction of paste thickness. Flour from boiled flour was found to have the highest bulk density while raw flour was found to have the lowest. So, boiled flour was found to have high dispersibility in water and need lower volume packaging material compared to the other two samples. Raw flour on the other hand was found to have low dispersibility and need higher volume packaging material compared to the other two samples. Moreover, higher bulk density is desirable for the greater ease of dispersibility and reduction of dough thickness which is an important factor in convalescent child feeding (Udensi and Okoronkwo, 2006).

Water absorption capacity

The water absorption capacity of the yeheb flour samples are presented in Table 5.5. The water absorption capacity of yeheb flour of sample ranges from 3.75 to 1.97 ml/g.

It was observed that raw yeheb flour contained 3.75 % WAC, which is in agreement with the finding by (Odoemelam, 2005) that reported 2.3ml/g of WAC for jack fruit flour.while that of water yam variety is found to have 3.65 ml/g (Udensi et al., 2008). The flour of tigernut variety is also found to have 1.37 ml/g WAC (Oladele and Aina, 2007).

There were 19.7 % and 48 % reduction in WAC of yeheb nut flour due to roasting and boiling respectively. The observed decrease in WAC of roasted and boiled samples might be due to the gelatinization of the starch molecules. In addition, change in the fat content of the samples could be other plausible reason behind this pattern of change as fat is hydrophobic. Water absorption capacity is a useful indication of whether flour can be incorporated into aqueous food formulations especially those involving dough handling (Okorie and Bello, 1988; Giami, 1993). The less water absorption capacity results obtained suggest that yeheb flours may not be comparable with others which have high WAC in food systems such as bakery products which require hydration to improve handling characteristics. The water absorption capacity of flour has been observed to be dependent on the starch and protein concentration in the material coupled with the size of the particles. Generally, the water absorption characteristics of the root flour is very important depending on the ultimate product to which the flour is intended to be converted which may include snack foods, extruded foods, and in bakery products (Mbofung et al., 2006).

Foaming capacity

The foaming capacities of the flour of study flour samples are presented in Table 5.5. The foaming capacity varies from 4.7 %, 8.5 % and 5.0 % representing the foaming capacity of raw, boiled and wet roasted respectively. The foaming properties of these roasted and boiled sample varieties studied fall within the range of values for the African bread fruit seed flour (2.30 to 70.80%) reported by Fasasi et al. (2007).

In general, there was no significant difference ($P<0.05$) in the foaming capacity. Upon processing, foaming capacity reduced by 36.73 %, and 68.97 % due to roasting and boiling. During boiling, proteins will be denatured irreversibly by heat treatment and result in reduction of protein content of the flour. Therefore, the result of foaming capacity of yeheb flour for boiled sample obtained in this study is agreement with this fact. Foaming of the flour is the manifestation of protein content. The decrease in protein content of boiled sample may cause reduction in the foaming capacity of the flour. Roasting on the other hand has significantly decreased the foaming capacity of the flour. The most probable reason for decreased in the foaming capacity of flour is due to its mucilage (a soluble glycoprotein) content and it is negatively affected by heating (Tagodoe and Nip, (1994).

Foaming properties of oil seeds proteins are important for the domestic market to be used in the preparation of various food products. Foam formation and stability are a function of the type of protein, pH, processing methods, viscosity and surface tension (Yasumatsu et al., abs1972). Foam ability of the proteins was concentration dependent (Sathe and Salunkhe, 1981).

Foaming stability

The foaming stability of yeheb flour are indicated in Table 5.5. The foaming stability ranges from 101.91 to118.42 % which refers to boiled and roasting respectively. Maximum determination was obtained for raw (101.91%) and the minimum determination was found to be 118.42% for roasting.

The results showed that, both boiling and roasting have significantly affected ($P<0.05$) the foaming stability of the yeheb flour in both sample. Roasting has significantly reduced ($p<0.05$) the foaming stability of yeheb flour. Foam stability (FS) is important since success of whipping agent depends on its ability to maintain the whip as long as possible (Lin and Humbert, 1974). According to Deland et al. (1994), the protein film at the air-liquid interface provides foam ability but this requires some denaturizing of the protein during whipping and also rearrangement of the hydrophilic and hydrophobic groups; suggesting that the amino acid composition and conformational structure might develop foam with an adequate volume. However, they might not be enough to stabilize the foam.

Swelling power

Roasted flour of yeheb nut was found to have the lowest swelling power 2.75 % compared to the other two yeheb flour. The swelling power of raw and boiling flour of yeheb is given to be 2.83 % and 2.64 % respectively. The swelling power obtained in this study for the three samples are less than the value reported by other legumes like Ahipa flour (Doporto et al. , 2011) reported swelling power values of about 800 g/100g sample and Swinkels (1985) reported that yam bean starch has about 10.62%. As swelling refers to absorption of water, it may be inhibited by the lipid content of the flour (Hood et al., 1998). The Value of swelling power in this study for yeheb nut was determined to be the lowest in roasted flour which has the highest percentage of lipid content 1.05%.

Comparing the processing effect there was a significant difference ($P<0.05$) in the swelling power of boiled and roasted with that of raw yeheb.

Solubility index:

The solubility index of yeheb flours are indicated in Table 5.5. The solubility index of yeheb nut for the three treatments ranges from 20.15 % to 14.75 % which correspond to boiled and roasted, respectively. The solubility index for raw was 24.65 %.

Processing had significant difference ($P<0.05$) on the solubility index of roasted and boiled with raw yeheb flour. High solubility index is associated with high content of amylose, which is believed to leach out easily during the swelling process (Soni et al., 1993). Also high amylose content is linked with low swelling power due to greater reinforcement of the amylose molecules (Hoover, 2001). Highly associated starch granules with an extensive and strongly bonded structure also exhibit resistance to swelling (Leech et al., 1959).

Chapter 6

6. Conclusion and Recommendations

6.1. Conclusions

Yeheb nut (*Cordeauxia edulis*) is an extremely useful species for the local community in every aspect including food, forage, construction (home and fence), fuel wood, and medicine and it is the first study on the effect of processing methods on nutritional, anti-nutritional and mineral evaluation of raw, roasted and boiled seed of yeheb nut of ethiopia. Processing (roasting and boiling) had significant positive influence on nutritional quality of yeheb nut. The study result revealed that yeheb nut is nutritionally better in both roasted and boiled form.

This study has demonstrated that the processing of the yeheb nut using the methods of roasting and boiling resulted in a significant reduction of phytic acid, tannin, and oxalate contents. These results clearly indicate that these processing methods are useful for improving the nutritional quality of the yeheb nut with respect to protein, carbohydrate and mineral.

The present finding uncovered information on anti-nutritional factors (phytate, oxalate and tannin) of raw, roasted and boiled yeheb nut collected from warder zone. The results of this study showed that raw yeheb nut contains low levels of anti-nutrients (oxalate and tannin) except phytate, when compared to other reported raw legumes. Moreover, there were further reductions of the anti-nutritional factors during boiling and roasting process. Among the processing methods, roasting was found to be the best method to reduce 20.59 % and phytate, followed by boiling yeheb 38.24 % seeds. Regarding the tannin content, boiling is the best method12.9 % followed by roasting 33.3 %. The results also indicated that such processing methods may be useful for improving the nutritional quality of the yeheb nut with respect to crude protein, crude fat, crude fiber, total ash and utilizable carbohydrate as well as mineral sand can be used as supplement to the rural areas.

It could be concluded that, chemical composition, functional properties and mineral content of yeheb flour were affected by different processing methods (boiling and roasting). Different treatment for yeheb flours increase the content of protein in all processed yeheb flours. Mineral content values of all processed flours decreased in boiling and roasting as compared with raw flour.

All values of functional properties for processed flour were high compared with those of raw flours.

The results from this study showed that processing is needed before yeheb nut could be consumed as shown by the nutritional and anti-nutritional qualities of raw, roasted and boiled yeheb nut.

6.2. Recommendation

Based on the results of the present study the following general recommendations are made.

- ❖ In order to develop new market opportunities to stimulate economic growth in the region, one would have to expand alternative utilization or processing methods in agri-food systems, and strengthen farmers-research linkages. This would help implementation of new and potential technologies in the countries like Ethiopia. Further researches and development program which can be integrated into currently ongoing research activities are necessary.
- ❖ C. edulis is a wild plant found in an extremely remote and isolated area. As a result little research has been conducted on it so far and much remains to be learned about the plant.
- ❖ Studies should be undertaken for new product development like weaning food mixes, and cookies etc. using yeheb nut.
- ❖ As other legumes, yeheb nut is low in sulfur containing amino acids, it is better consume with cereals to obtain well essential amino acids.
- ❖ It is recommended that education is given to local communities to increase their awareness about the importance of this resource and the consequence of its extinction on their livelihood and encourage conservation of the species by controlling browsing, excessive seed harvesting and cutting and establishing reserves with good management.
- ❖ It is recommended that further investigation is needed on the Sensory characteristics of processed yeheb nut product

- Combined methods such as soaking in water and then boiling should be used to reduce the anti-nutrients effectively.

- Government legislation is required by putting in place the appropriate policies that provide sustainable utilization and conservation to protect and save the species; resource use and environmental policy.

- The claim by the local community on the benefit of yeheb nut for hypertension or diabetics should warrants further investigation.

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