The importance of Yeheb (*Cordeauxia edulis*) for Somali livestock production and its effects on body tissues when fed to Swedish domestic goats

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ABSTRACT

This master thesis was conducted in order to investigate the effects of the browsing species Yeheb on animal tissues in Swedish landrace goats and to make a literature review in order to increase the knowledge of the importance of this plant for livestock production in Somalia. The evergreen Yeheb bush is a very important feeding source for grazing and browsing animals in Somalia during the dry period. Yeheb contains cordeauxiaquinone that stains the bones of the animals red/pink, which has been an increasing problem when exporting meat to foreign countries. In an experiment, two goats were fed dry and fresh leaves from the Yeheb bush for one and two months, respectively. The goats did not feed the intended amount of dry leaves, since the supply and palatability was not as high as estimated. Results show that cordeauxiaquinone and/or its derivatives was found in the rumen liquid and the level of cordeauxiaquinone accumulated in the goat plasma by time; an increased absorption was measured with a spectrophotometer in the interval of 440-580 nm. The skeleton did not turn reddish, possibly due to the relatively short exposure time or the relatively low intake compared to that of goats in Somalia. For future studies, both qualitative and quantitative methods have to be established for cordeauxiaquinone analyses in body tissues and in plants.

SAMMANFATTNING

Den här mastersuppsatsen utfördes för att undersöka effekten av betesväxten Yeheb på olika vävnader hos svenska lantrasgetter och för att genom en litteraturundersökning öka kännedomen om betydelsen av denna växt för betesdjur i Somalia. Yeheb är grön året om och en mycket viktig födokälla för djuren i Somalia under torrperioden. Yeheb innehåller cordeauxiaquinone som färgar djurens skelett rött/rosa, vilket har påverkat exporten av kött till andra länder. Under det här försöket utfodrades två getter med torkade och färska blad under en respektive två månader. Getterna åt inte så mycket torkade löv som beräknat, eftersom tillgången och smakligheten inte var så hög som först antagits. Efter försöket kunde Cordauxiaquinone och/eller dess metaboliter påvisas i våmvätskan och cordeauxiaquinone ackumulerades i getternas plasma med tiden; en ökad absorption uppmättes spektrofotometriskt i intervallet 440-580 nm. Skelettet färgades inte rött/rosa, möjligtvis på grund av den relativt korta exponeringstiden eller det relativt låga intaget jämfört med det hos somaliska getter. För framtida studier krävs att metoder utvecklas för att analysera cordeauxiaquinone, både kvalitativt och kvantitativt i olika djurvävnader och i växter.

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INTRODUCTION

Somalia is a developing country situated in the African horn. The climate in Somalia is mainly arid to semi-arid and moderate and severe droughts occur regularly. The land has a history as a trading point and from the 1880s it was a colony until it became independent when the Somali republic was formed in 1960. The Somali civil war broke out in 1991 and the situation in Somalia today is still very turbulent and reliance on food aid is widespread.

Agriculture and livestock production is the largest sector in Somalia and live animals are a significant source of export income. A majority of the Somali population is nomadic and moves seasonally with the livestock depending on availability of pasture and water. The people rely on milk and meat as a source of staple food and cash income. The pastoralists are highly dependent on the environment and its natural resources and are threatened by droughts, political marginalization, food shortages etc.

Yeheb is an evergreen shrub growing on sandy soils with low nutrient value in eastern Ethiopia and central Somalia. It is an important source of food to both animals and humans and produces a nutritious nut. Yeheb belongs to the family *Leguminosae* but it is not known if the plant is able to fixate atmospheric nitrogen. The number of Yeheb bushes has been reduced during the last decades but cultivation and conservation projects are carried out to preserve the plant. Especially the Yeheb leaves, but also the seeds, contain the red dye cordeauxiaquinone that stain the skeleton of livestock red/pink. The metabolism of cordeauxiaquinone and its interactions in different animal tissues is not well known and few studies have been conducted within the area.

In Somalia, the livestock population consists of 28 million sheep and goats, six million cattle and six million camels. The export of sheep, cattle and goats adds to more than half of the agricultural export and together with the livestock products sector accounts for 80 percent of the total export. During periods of time, importing countries have prohibited the import of Somali livestock due to disease out break. Some countries do not accept animals with bones stained pink by Yeheb and that is what has hampered the export.

AIM

The animals in Somalia get a red/pink skeleton by feeding on Yeheb, that result in a decreased export of meat and livestock, when countries limit the import of these animals. Therefore it is of great importance to understand the background to why the skeleton gets red/pink when livestock feed from the Yeheb bush.

The purpose of this study was to, by a literature review, achieve a basic understanding of the situation in Somalia and the importance of livestock production and export. Yehebs' characteristics and the utilization of the plant are also described. By a feeding-trial of Yeheb, the deposition of cordeauxiaquinone in body tissues of Swedish goats was investigated.

PART 1. LITERATURE REVIEW

BACKGROUND

Somalia

Geography

Somalia is situated in the areas of Northeast Africa and covers 637 660 km^2 (Aquastat, 2005). The country can be divided into five distinct geographic zones differentiated by topography (see picture 1):

- The northern coastal plains.
- The Golis mountain range in the north.
- The central coastal plains. The broad limestone-sandstone plateau covering all of Central and Southern Somalia
- The flood plains of the Jubba and Shabelle rivers in the south, which provide the highest agricultural potential.

Picture 1: Map of Somalia. www.africa.upenn.edu

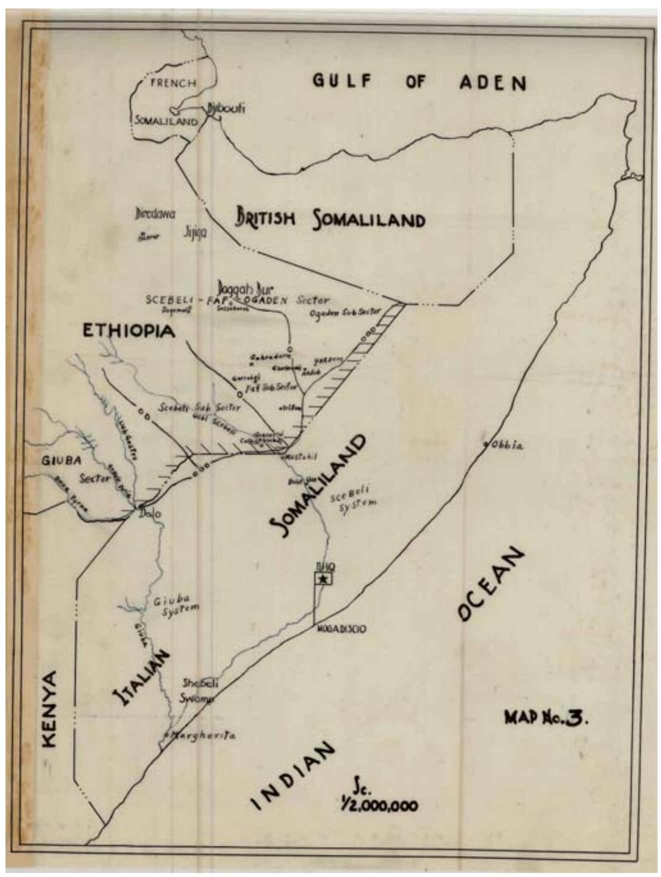
Climate

The climate in Somalia is mainly arid to semi-arid, the average annual daytime temperature is 27º C and the mean annual precipitation is 282 mm (Aquastat, 2005). The precipitation varies between different areas; least rain falls on the northern coast and most in the northern highlands. The large inter-annual variations of rainfall are of importance as this variability has the most pervasive influence on pastoral and agro-pastoral production systems. Moderate drought occur every three to four years and severe drought every seven to nine years.

History

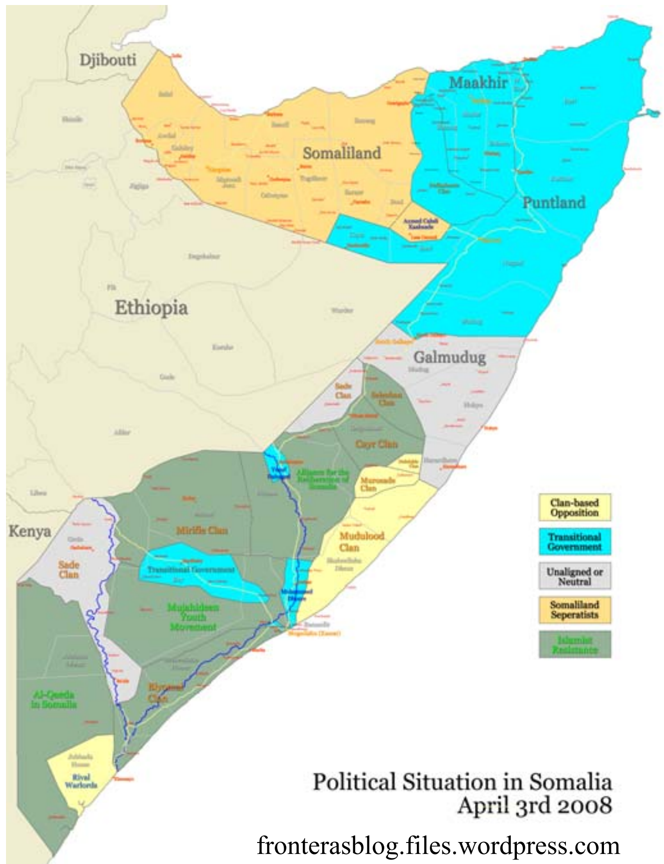
The Egyptians started trading with Somalia 3500 years ago and they brought jewels in exchange for gold, elephant tusks, myrrh, ostrich feathers and spices (AMHS, 2009). The name Somali means “go and milk it” which means that the people were nomadic. Somalia has been a trading point since the 7th century for ships travelling to and from India and mainly Persian and Arab people have visited the coast while the interior of Somalia has been less influenced by visitors (Historyworld, 1999). In 1839 the British started to use the southern coast of Arabia, Aden, as a coaling station and Italy and France established coaling stations in the northern Somali regions. The British, French and Italians got meat and other facilities from the Somali coast. England, France, Italy and Ethiopia were the four countries that competed for Somali territory in the 1880s.

Somalia was divided into French, British and Italian Somaliland during the colonial period (see picture 2). On the map, the area marked as Italian Somaliland belonged to Ethiopia until 1936. In 1960, when the British troops withdrew and the Somali republic was formed, British Somaliland and Italian Somaliland were united again (CIA, 2009). To reunite the Somali people from the three large groups, that had been trapped in French Somaliland, Ogaden and Haud in Ethiopia and in northern Kenya, with the people in the Somali republic, was an unsuccessful political decision (Historyworld, 1999). From 1969 to 1991 the country was ruled by the authoritarian socialist regime led by Mohammed Siad Barre. This regime collapsed and after that turmoil, fractional fighting and anarchism broke out, i.e. the Somali civil war (CIA, 2009; GlobalSecurity, 2009).



Picture 2: Colonial map.

Two self-declared states were formed, the Republic of Somaliland and Puntland. From 1993 to 1996 the United Nations (UN) enforced an UN humanitarian effort and was able to alleviate famine conditions, but also suffered significant casualties and did not manage to restore the order. The Government of Kenya with support from Intergovernmental Authority of Development (IGAD) conducted a two-year peace process concluded in 2004 with the election of Abdullahi Yusuf Ahmed as President of the Transitional Federal Government (TFG) of Somalia and the formation of an interim government, known as the Somalia Transitional Federal Institutions (TFIs). The institutions remains weak but the TFG continued to help building the governance capacity of the TFIs and worked towards the national elections in 2009 (CIA, 2009; GlobalSecurity, 2009), when Sharif Ahmed won the president title.



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Picture 3: Political map of Somalia

In 2006, the Islamic Courts Union (ICU) that had defeated Mogadishu and the Alliance for the Restoration of Peace and Counter-Terrorism (ARPCT), took control of the capital and expanded militarily throughout southern Somalia (see picture 3). In the end of 2006 the ICU collapsed as Ethiopian and TFG forces intervened. Extremist elements, as the al-Shabaab militia, continue to make violent resistance towards the TFG (CIA, 2009; GlobalSecurity, 2009). Since January 2007, hundreds of thousands of people have fled the violence in Mogadishu and aid agencies claim that more than two million Somali rely on food aid. In September 2008 the number of people in need of assistance had increased to nearly 3.2 million people, or 43 percent of the Somali population, an increase by 77 percent since January 2008 (ReliefWeb, 2008). The interim government of today is supported by the UN. In May 2009 the government became attacked by Islamic groups, previously belonging to ICU, as they consider the president too western oriented The attacks forced president Sharif Ahmed to ask for help from abroad and Nato is also leading an anti-piracy operation along the Somali cost.

Economy

In 2008, the Gross Domestic Product (GDP) of Somalia was US$ 2.6 billion or US$ 600 per capita (CIA, 2009). However, the Gross National Product (GNP) is higher due to remittances from Somalis living abroad, totalling US$ 300-400 millions in 2001 (Aquastat, 2005). The agricultural sector contributes to the GDP by 60 percent, while 30 percent comes from the service sector and 10 percent from the industry. The livestock accounts for about 40 percent of the GDP and 65 percent of the export (CIA, 2009) and is the main source of Somali livelihoods (FAO, 2004).

In 2006, the exports amounted to US$ 300 millions; the main commodities were livestock, skins, bananas, hides, fish, charcoal and scrap metals (CIA, 2009). Imports amounted to US$ 798 millions in 2006 and the main commodities were manufactures, petroleum products, foodstuffs, construction materials and qat. During the last years, telecommunications, constructions, money transfer companies and trade have become more important (Aquastat, 2005).

Somalia has been food insecure for the past 20 years and the prevalence of undernourishment by 70 percent is one of the highest in the world. The situation is due to the civil war and natural disasters like flooding, drought and sandstorms (Aquastat, 2005). In 2002, 43 percent of the population was estimated to be on a per capita income of less than US$ 1/day.

The country currently faces issues like famine, use of contaminated water contributing to human health problems, deforestation, overgrazing, soil erosion and desertification (CIA, 2009), uncontrolled urbanization, general insecurity and civil conflicts (Aquastat, 2005).

The Somali people

The population in Somalia is difficult to estimate due to the large number of nomads and refugee movement (CIA, 2009). The estimates vary from 6.8 to 10.3 millions, the lower figures according to the Somalia Watching Brief (2003) and the UN (2004), the higher numbers according to Aquastat (2005). The Somali people are Sunni Muslims and 85 percent are Somali and 15 percent are Bantu or other non-Somali groups (CIA, 2009). The official language is Somali and the literacy rate is 37.8 percent, with more men than women being able to read.

About 65 percent of the population live in rural areas and about half of the population remains nomadic, either pastoralists or agro-pastoralists (Aquastat, 2005). 24 percent of the rural population are crop farmers and one percent is fishermen (FAO, 2004). Of the economically active population, 69 percent are active in the agricultural sector, divided equally between women and men (Aquastat, 2005).

Agro-pastoralist and settled farmers live in villages or small settlements where water resources are reliable, while the nomadic pastoralists move seasonally with their livestock depending on the availability of pasture and water. In 1990 about 55 percent of the Somalis were directly engaged in livestock production and livestock products provide about 55 percent of the calorie intake by the people (FAO, 2004).

Pastoralists

Pastoralists and semi-pastoralists, who are dependent upon livestock for their livelihood, make up a large portion of the population (CIA, 2009). Men are usually in continuous movement with the livestock while the women stay settled with the children (UNDP, 1998). For the pastoralists, clan and sub-clan affiliation plays an important role in social and economic life, and the clan-kinship is strongly maintained across international boundaries.

The nomads move the livestock to the areas with most feed available, depending on season and rainfall (SATG, 2004). The pastoralists usually maximize the herd size in belief that the more animals they have entering a drought period, the more will survive (Prevolotsky, 1986).

The most regular source of cash income for the nomads is the camel milk and they often depend on milk for their livelihoods (Veterinaires, 2006). The milk from camels, goats and cows is also a staple food and a major source of proteins and vitamins for both rural and urban populations. The unequal supply of milk during the year, depending on the access to animal feed, is a major challenge to the people.

Before Saudi Arabia became wealthy in the 1950s and 1960s due to its oil sources, the Somali pastoralists lived mainly on milk, meat and some grain (UNDP, 1998). The market then changed to become livestock export oriented and trade links were established, which resulted in cash earnings and imports of food and commodities.

The pastoralist communities and their welfare are highly dependent on the environment and the natural resources available to the livestock (USAID, 2005). Due to desertification, soil erosion, population growth and the economical and political marginalization, the communities face extreme challenges in meeting the requirements for food and water. The scarcity of resources has led to increased conflict between pastoralist groups as well as between pastoralists and agricultural groups. The communities face challenges like drought and food shortages, severe cold, diseases, lack of feed and water to the livestock, looting and conflicts.

Agriculture

In 2002, the cultivated area in Somalia was 1 071 000 ha (1.7 percent of the total land area), of which 1 045 000 ha was arable land and 26 000 ha permanent crops while permanent pastures covered 43 000 000 ha (69 percent of the total land area) (Aquastat, 2005).

The most important agricultural areas are situated in the south of Somalia. According to Aquastat (2005), the agricultural production system can be divided into:

- Subsistence rain fed farming, often part of agro-pastoral production systems, with a typical farm size of 2-4 ha.
- Small-scale irrigation and oasis farming.
- Commercial farming, which is mainly large-scale and irrigated. The irrigation efficiency is low because of the design of the system.

Traditionally, the Somalis have engaged in rain-fed dry-land farming or dry-land farming complemented by irrigation from the Shabeelle and Jubba rivers or from collected rainwater (Nationsencyclopedia, 2001). Corn, sorghum, beans, rice, vegetables, cotton and sesame are produced in this way while banana farms and some of the newly created Somali cooperatives practice more modern European techniques.

In the early 1970s, a system of state-administered farms grew rapidly. The state took over large areas of irrigable land in the river valleys between 1975 and 1991 when all land was nationalized. In 1993, Italy revitalized the agricultural sector by privatization and assistance, as Italy was the main market for banana exports.

Before the civil war, bananas were the most important export crop. Many of the banana farms were rehabilitated between 1993 and 1996, but the floods in 1997 destroyed 80 percent of them (Aquastat, 2005). Changes in the import regime, particularly to the European countries and Italy, have led to a further collapse of the market. The few remaining banana farms in southern Somalia have attempted to diversify into other crops such as sesame, groundnuts and rice.

The agriculture in Somalia is now essentially subsistence agriculture due to the long-lasting civil war. The opportunities for production for domestic markets are limited and there is virtually no capacity to produce for international markets. Generally fodder has a higher economic value than cereals, particularly in the north of Somalia where livestock export is important.

Due to the exodus as well as migration of people within Somalia, a lot of people leave their traditional life. On the homecoming, returnees realize that other people occupy the land and use resources that they previously had access to (FAO, 2004). Conflicts also arise between nomads and farmers regarding the establishment of enclosures.

Livestock

The grazing livestock population in Somalia (see picture 4) is about 40 million animals: 28 million sheep and goats, six million cattle and six million camels (SATG, 2005). In Somalia, livestock and their products account for 80 percent of the export and the sector accounts for 40 percent of the GDP (Gross Domestic Product) being the main source of Somali livelihood (FAO, 2008). The major production items are camel milk (850 000 tonnes in 2008) (FAO, 2008), indigenous cattle meat (48 000 tonnes) and sheep milk (345 000 tonnes) in 1989-1991 (FAO, 2006). The goats and sheep each comprised 22.4 percent of the agricultural export and the cattle 8.4 percent in 1989-1991. International livestock marketing is mainly a private sector affair through dealers and local markets

(FAO, 2004).

The export goes to several countries in the Arabian Peninsula (SATG, 2005), The Kingdom of Saudi Arabia has traditionally taken up to 95 percent of Somalia´s export (FAO, 2004). Some livestock is exported to Kenya, Djibouti and Ethiopia but the livestock is also an important source of food for the Somali households (SATG, 2005). An important selling point for the Somali livestock to middle-eastern countries is that the animals are raised in an Islamic culture and usually slaughtered according to Islamic rituals.

Importing countries have during periods of time prohibited the import of Somali livestock due to disease outbreak in Somalia (SATG, 2005), like rinderpest, CBPP (Contagious Bovine Pleuropneumonia), PPR (Peste des Petits Ruminants) and Rift Valley fever (FAO, 2004). The Somali Agricultural Technical Group (2005) has learned that some of the Somali livestock importing countries do not accept meat from animals whose bones have been stained pink by Yeheb.

The purchasers believe that the stain is due to a disease or a food colouring agent. In Somalia, the pink colour is regarded as a quality mark, as the meat is considered to have a better taste and the herdsmen are well aware that the stain is due to Yeheb (SATG, 2005).

Picture 4: Pastoralist and livestock in Somalia

Due to the civil war, many people and animals from Somalia have emigrated to eastern Ethiopia and northern Kenya and in the early 1990s there were about two million internally displaced persons (FAO, 2004). During this period people had to sell or eat their livestock in order to survive. Combined with reduced animal growth, reduced reproductive performance, increased morbidity and mortality, the number of livestock decreased. Most animal health services were lost as well as the certification of live animals and products for export, and the spread of livestock diseases became uncontrolled. As a result there was an increased rejection of exports followed by unfavourable prices and the trade shifted from Saudi Arabia to Yemen and elsewhere in the Gulf, where the countries are less demanding.

In 2002 Somalia faced acute shortages of water and fodder, which caused losses of up to 40 percent of the cattle and 10-15 percent of the goats and sheep (Aquastat, 2005). In 2005, FAO estimated the cumulative animal mortality rates during the last four years in Somalia to be 60 percent for goats and sheep and 80 percent for pack camels (USAID, 2005).

The livestock market is facing many challenges, as there are a limited number of markets for major exports and a large competition with other countries (SATG, 2005). There is also a need for development of marketing strategies and establishment of a "brand" both within and outside Somalia. Professionals and research institutions in the livestock industry are needed, as well as veterinary services to control the health status of live animals and carcasses for export. There is a lack of producers' organizations, for example there is a requirement to regulate the seasonality of supply. The livestock exporting companies need to coordinate themselves and are facing difficulties through the banking system. They are not able to open Letters of Credit (L/Cs) and are therefore put in a weak bargaining position. Further challenges are the shortage of animal feed during the dry season and degradation of the rangeland. Water restriction is almost always a problem for livestock and establishment of new water points is necessary (FAO, 2004).

Goats, in contrast with sheep and cattle, tend to increase browsing of shrubs and decrease grazing during the dry season (Migongo-Bake & Hansen, 1987). Therefore they are much better than sheep at selecting an energetically effective diet during this period (Schwartz *et al*., 1984).

Yeheb

Distribution

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,

Picture 5: Yeheb bushes By: Asha Yahya

Yeheb was considered as in danger of extinction within a few years by Allen & Allen (1981). Yeheb is listed as rare 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. Their animals are transported through the Somali inland to the coast and exported from the ports.

Characteristics

Yeheb is multi-stemmed and has a long, massive root system that reaches the deep moisture and makes the bush remain green all year round (NAS, 1979). The taproot, which is up to three meters long, has small secondary rhizomes near the surface (FAO, 1988). These lateral roots develop at 10-40 cm under the soil surface and are up to 2.5 meters long (Brink & Belay, 2006). The taproot makes it difficult to grow Yeheb in a nursery; if it breaks the plant will die, and it is therefore recommended to plant the seed in field directly (FAO, 1988). The stem has conspicuous red glands and there are many red glands on the underside of the leathery leaves (Brink & Belay, 2006). The leaves of Yeheb (see picture 6) have an extremely thick cuticle and mesophyll consisting of palisade cells with lateral walls capable of folding in a concertina-like way. Therefore, the leaves are able to survive during long periods of drought and to quickly store water when available. Two forms are recognised, the smaller Suley (Sulei) from northern Somalia and the taller and more common Moqley (Mogollo) (Brilli & Mulas, 1939). Suley is pale green with large leaflets and stem diameter and the pods contain several smaller seeds while Moqley is dark green and has small leaflets and stem diameter and the pods contain one large seed (Brink & Belay, 2006).

Picture 6: Yeheb bush in greenhouse

Under natural conditions in Somalia there are up to 320 plants per ha (Ali, 1988). The seed yield is 5-8 kg per plant per year and the average forage production is 325-450 kg/ hectare or 1.4-2 kg/ plant (Ali, 1988) or 1-3 ton per hectare of above ground biomass (Kuchar *et al.*, 1985, as cited in FAO, 1988). During favourable conditions the shrub starts to produce pods profusely after four years and the production increases with age (Baumer, 1983) but during dry years the bush might not produce any nuts although the plant can survive up to two years without rainfall (FAO, 1988). During drought the leaves curl and fall off if the conditions are extreme.

Rhizobia are not recorded to have been isolated (Allen & Allen, 1981) and it is not known if Yeheb is able to fix atmospheric nitrogen (Brink & Belay, 2006). Some researchers claim that Yeheb has a limited capability for nitrogen fixation as the seeds protein reserves (12.1-14.2%) are lower than in other pulses (Greenway & Raymond, 1947; Miège & Miège, 1978; N.A.S. 1979; Drechsel & Zech, 1988).

Environmental conditions

Yeheb is very well adapted to (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) and with a minimum distance of 100 km to the Indian Ocean (Roti-Michelozzi, 1957; Drechsel & Zech, 1988). 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).

Picture 7: The Haud is marked as the green area

Growth and development

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).


Picture 8: Blossoming Yeheb

The bushes blossom during the rainy season, once or twice if the rainfall is abundant (Orru, 1938), 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, 1939), 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).

Utilization

Yeheb is one of few species worldwide that is suited for hot and dry environments, why it has the potential to become a 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).

Yeheb nut

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 economical value; a tin [about 400 g (Baumer, 1983)] was sold for 4000

Somali shillings [about 0.25 US $ in 2001 (IPGRI-SAFORGEN, 2004)]. Seeds are exported from Ethiopia to Somalia and Arab countries, but most seeds are consumed locally (Brink & Belay, 2006).

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). Table 1 and 2 shows the composition of nutrients and ash in Yeheb seeds.

Table 1. Chemical composition of Yeheb seeds (%)

Subspecies	Moisture	Protein	Fat	Starch	Reducing sugars	Sucrose	Ash	Fibre
Moqley	16.9	12.6	9.9	34.0	2.3	19.5	2.7	2.1
Suley	16.2	14.4	10.8	31.4	2.2	20.2	2.9	2.0

Table 2. Composition of Yeheb seed ash (mg/100g)

Subspecies	Na	K	Ca	Mg	P	Cl
Moqley	452	625	31	82	221	92
Suley	493	633	33	79	232	94

(El-Zeany & Gutale, 1982).

Shelled seeds have an energy value of 16.66 MJ/ kg (Leung *et al*, 1968). The seeds have a lower protein value than other leguminous seeds and pulses but are rich in sugars and fats (Kazmi, 1979). The amino acid balance of the nuts resembles that of other pulses, containing considerable and well-balanced amounts of essential amino acids, especially lysine (3.9-6.9%) (Protabase, 2006), but they are deficient in tryptophan (Miège & Miège, 1978; El-Zeany & Gutale, 1982), methionine (Miège & Miège, 1978) and isoleucine (El-Zeany & Gutale, 1982).

The seed lipids contain palmitic acid (26-31%), stearic acid (12-13%), oleic acid (31-32%), linoleic acid (25-30%) and traces of linolenic acid (FAO, 1988). The nuts contain trypsin inhibitors (Miège & Miège, 1978), which are inactivated by boiling (Brink & Belay, 2006). The seeds are free from toxic phytohemagglutinins, lectins, alkaloids and glycosides (Miège & Miège, 1978). The seeds contain cordeauxiaquinone but not to the same degree as the leaves (FAO, 1988).

Yeheb leaves

Yeheb leaves contain 54 percent moisture during vegetative growth and 28 percent during the dormant stages (Ali, 1988). The foliar nitrogen is low and the nitrogen and crude protein values are lower than would be expected for a probably nitrogen-fixing plant (Drechsel & Zech, 1988) but the amino acid balance is typical for legumes (Miège

& Miège, 1978; Drechsel & Zech, 1988) and the digestible crude protein is medium to high.

Table 3 to 5 shows the nutritional value of the leaves;

Table 3. Macro minerals (%)

Subspecies	N	P	K	Ca	Mg	S	Si	Cl
Moqley	1.27	0.11	0.65	1.75	0.11	0.14	0.40	0.09
Suley	1.49	0.13	0.71	1.49	0.18	0.17	0.55	0.23

Table 4. Micro minerals (ppm)

Subspecies	Al	Fe	Mn	Cu	Zn	B	Ni	Cr	V	Ti	Sr
Moqley	593	438	39	8	21	48	2.2	2.8	1.1	12.6	81.7
Suley	913	735	46	14	24	18	-	-	-	-	-

Table 5. Nutritional value (%)

Subspecies	Cf	ra	cp	dcp	ev (MJ/kg dm)	Ca/P	Ca/Mg	K/Na
Moqley	27.5	6.87	7.94	3.86	5.59	16	16	-
Suley	25.6	6.23	9.31	5.13	5.86	11	8	-

cf= crude fibre; ra= raw ash; (d) cp= (digestible) crude protein; dm= dry matter;
ev= energy value (Drechsel & Zech, 1988).

The levels of K, Ca, Mg and S are regarded adequate for animal feed as well as Ni, Cr, V and Ti. The foliar Al and Fe are high while P is low. The low P might be because of low P in the soil. The ratios for livestock nutrition of Ca/P and Ca/Mg should be 1-1.7 and 3-4 respectively (Zech 1981; Drechsel & Zech, 1988) compared to 11-16 and 8-16 in Yeheb leaves.

The crude fibre content (26.5-27.5%) is lower than the average value of 30.6 percent for tropical legumes (Minson, 1977; Drechsel & Zech, 1988). The leaves are rich in energy, 5.59-5.86 MJ/kg dry matter, when compared to standard energy content of good quality fodder available in tropical areas (Drechsel & Zech, 1988). The in vitro dry matter digestibility is 27.2-39.8 percent (Ali, 1988) and the tannin content is 2.5-2.7 percent (Brink & Belay, 2006).

Diseases and pests

Seeds analyzed for pests had several well known stored produce pests, but none was crop specific (Wickens & Storey, as cited in FAO, 1988). The bush is free of most insect pests but weevils and moth larvae attack the nuts. After picking, they can be boiled or roasted in order to kill the insects (Ismail 1975, as cited in FAO, 1988; NAS, 1979) and harden the shells for storage (NAS, 1979). Whitefly nymphs feed on the Yeheb bush stems (FAO, 1988).

The effect of Yeheb on livestock

Yeheb is the main feed for camels and goats during the dry season (FAO, 1988) but when available, other plants are preferred by the livestock (Brink & Belay, 2006). Animals that are newly introduced to Yeheb may initially ignore it (Kuchar, 1987). The meat from animals that have eaten Yeheb is considered particularly tasty (FAO, 1988) and the colouration is a sign of good meat quality (Brink & Belay, 2006).

Brilli & Mulas (1939) reported that Yeheb was a poor fodder causing intestinal disorders in goats of which the bones and teeth were stained bright red (FAO, 1988). The animals that have consumed Yeheb are healthy, there have not been any signs of decreased stability of the bone tissue and the fertility is normal (Yahya, 2004).

Researchers at the College of Agricultural & Marine Sciences at Sultan Qaboos University state (Sultan Quaboos University, 2009; Gulf news, 2009; Bartamaha, 2009) that the meat from animals feeding on Yeheb is not harmful to humans. In their study, goats remained healthy on a diet of Yeheb and the meat and organs did not change in flavor, color or odor. The bone tissue and structure of the bones was not damaged and the organs showed no pathological signs. These researchers suggest that cordeauxiaquinone forms a compound with some minerals; the compound is deposited in the bones and stains them pink. Because of the deficiency of some minerals in the soils where Yeheb grows, the amount of magnesium, calcium, barium, potassium and lithium was lower in the bones of animals feeding on Yeheb. The amount of copper and manganese was higher in pink bones while sodium, boron, phosphorus, strontium, sulphur, zinc, iron and aluminum did not show significant difference between treated and control animals.

Presence of cordeauxiaquinone

The molecular formula of cordeauxiaquinone is $C_{14}H_{12}O_7$ (Lister *et al*., 1955). Cordeauxiaquinone is present in Yeheb leafs at 0.7-0.8 % of the weight (Bally, 1966). Lister *et al.* (1955) studied cordeauxiaquinones' structure and extracted and crystallized the pigment from the leaves. From 380 g dry matter, 2.7 g cordeauxiaquinone was obtained. The crystallized form dissolves in chloroform, benzol, and ethanol but not so well in ether or water. Alkaline extracts develop a more intense violet colour than neutral or slightly acid extracts (Brink & Belay, 2006). The quinone forms insoluble dyes with some metals (NAS, 1979).

Medicinal properties

From 1908, medicinal properties have been ascribed to Yeheb seeds (Anon, 1908, as cited in Orru, 1938). Gutale & Ahmed (1984) claimed that pigment deposited in bones might stimulate hemopoietic tissue to produce erythrocytes both directly and indirectly and that cordeauxiaquinone might be useful medicinally to stimulate hemopoesis. Cordeauxiaquinone is said to regulate gastric secretion and to treat burns (Brink & Belay, 2006).

Cultivation and conservation projects

Yeheb has been successfully cultivated on a small scale in Somalia and near Voi in Kenya (Brink & Belay, 2006), where it was introduced in the 1950s. Attempts to establish the plant on an experimental scale have been carried out in Tanzania, Sudan, Yemen, Israel (FAO, 1988; Protabase, 2006) and in the United States (Brink & Belay, 2006), all with poor response. During a trial to establish plants in Israel only one of four sites succeeded, why the climate or the biological factors may have been unsuitable (Nerd *et al*., 1990). Studies on seed germination, viability and storage have been conducted at the Department of Ecology and Crop Production Sciences, SLU, Sweden and nursery and field studies have been performed at Haramaya University, Ethiopia.

The Somali people are aware of Yehebs' usefulness and due to the diminishing number of plants, they have started to grow them and produce tree seedlings (African studies center, 2001). The National Range Agency in Somalia protected 50 ha in the Mudug region in 1975 and 25 ha in Salah Dhadhaad in 1977 but the later became abandoned due to low productivity (Baumer, 1983). In the 1980s many other areas have been protected from grazing and the situation has improved considerably.

In greenhouse experiments at the Swedish University of Agricultural Sciences, conducted within the project *Domestication of Yeheb (Cordeauxia edulis Hemsl.) as a source food and useful chemicals,* Yeheb plants were transplanted after one, four and six weeks of growth into pots with soil collected in Uppsala, Sweden and supplied with fertiliser (manuscript in prep.). These plants, that had cut taproots, were able to reestablish, flower and set fruits within the first year of growth.

Studies to examine the possibilities for an improved field establishment and growth were devised and performed in a field study in Dire Dawa in eastern Ethiopia by Dr Yahya and colleagues including a PhD student working on her thesis with the title *Factors Required for Yeheb (Cordeauxia edulis H.) Establishment and Growth in Eastern Ethiopia* (Mekonnen *et al*., 2009). More than 50 percent of the transplanted seedlings and sown seeds have established but the growth of the field plants is much slower compared to the greenhouse plants.

There is also an ongoing project (2007-2010); *Yeheb,* Cordeauxia edulis — *A multipurpose legume endemic in the Horn of Africa, as a source of useful chemicals and its propagation in eastern Ethiopia for food and feed production* (Ibrahim *et al*., 2008), financed by The Academy of Finland where Dr. Yahya is collaborating with colleagues from Kuopio University, Finland. Two Ethiopian graduate students (Ph.D. and MSc.) from Haramaya University (HU) are working within the project. Yeheb does not become attacked by termites or other insects and is therefore used as building material for houses. The aim of the study is to examine the organic compounds for potential use as organic pesticides.

Quinones

Quinones are lipid-soluble cofactors that are involved in cellular respiration and photosynthesis (Morton, 1965). They are found in the subcellular organelles of animals, plants and microorganisms, in the mitochondria of mammals and in the chloroplast of plants. They are present in the respiratory complex and function as electron transformers, shuttling electrons between other respiratory coenzymes than themselves and may play a direct role in oxidative phosphorylation.

Some bacteria, plants and algae are mixed quinone systems, containing more than one kind of quinone, usually ubiquinone and naphthoquinone. In these cases both types appear to be functional but may participate in different electron transport pathways.

Quinone-depletion results in a loss of electron transport and coupled phosphorylation in mammals and bacteria, and in loss of the Hill reaction and photophosphorylation in plants. Deficiency of vitamin K, one of the quinones, leads to a decreased ability to clot blood in mammals.

Groups;

- **Anthracylclinones** - ca. 30, in bacteria (Thomson, 1971).
- **Anthraquinones** - ca. 170, in lichens, fungi (moulds) and higher plants (heartwood, roots, bark and occasionally in stems, seeds and fruit), bacteria, insects and feather stars.
- **Benzoquinones** - ca. 90, the highest amount is found in flowering plants and fungi but Benzoquinones are also present in all parts of higher plants, fungi, arthropods and echinoids. Ubiquinones, which belong to the group, occur in mammals.
- **Extended quinones** - ca. 15, in fungi and aphids but are rare in higher plants.
- **Miscellaneous quinones** - bacteria and higher plants.
- **Naphthaquinones** - ca. 120, in higher plants (leaves, flowers, wood, bark, roots and fruit), fungi, bacteria, echinoderms and aphids. Cordeauxiaquinone belongs to this group.

The colours of quinones range from yellow to black and are most visible in sea urchins and related marine animals, fungi, lichens or in bark, roots, and animal tissues where they are less visible.

Naphthaquinones

There is a great variety of naphthaquinones in the nature, found in fungi, plants and bacteria (Morton, 1965). To the group belong for example vitamin K_1 (Phylloquinone), K_2 and 6-methyl-1.4-naphthoquinone, of which the last has antibiotic properties. The vitamin K_2 type is found in microorganisms and the vitamin K_1 type in plants. Naphthaquinone analogues, which possess antivitamin K activity, are potent inhibitors of respiratory metabolism.

Cordeauxiaquinone

Cordeauxiaquinone or cordeauxione is a naphthazarin derivative with the formula $C_{14}H_{12}O_7$ and an absorption maximum at 248, 305 and 498 nm, log ε = 4.26, 3.91 and 3.91 (Thomson, 1971). It is the only naphthoquinone found in the leguminosae (Allen & Allen, 1981; Harborne *et al.*, 1971). Very little is known about cordeauxiaquinone and so far its functions have not been described in the literature.

Effects of cordeauxiaquinone in rats

A study was conducted by Gutale & Ahmed (1984) in order to investigate the effects of cordeauxiaquinone on growth and function of kidney, liver and the hemopoietic apparatus. Preliminary results indicated that a small effect on the haemoglobin concentration in the blood was achieved by adding the pigment in the rats' drinking water.

During the study, the rats were divided into four groups; the first got decoction from 5 g of dried leaves in 100 ml water, the second 10 g and the third 15 g, while the fourth was a control group. The treatment lasted for eight weeks. The rats were weighed weekly but no significant difference between the treated groups and the control group was observed.

There were no significant differences when comparing the treated groups with the controls in glutamic oxalacetic transaminases, glutamic pyruvic transaminases, blood urea nitrogen or total and differential leucocyte count. Neither was there any significant difference between the treated groups. However, the pigment significantly increased the hemoglobin levels and hematocrit, the group that received most cordeauxiaquinone having the highest levels.

Similar results were obtained when rats were fed with Yeheb nuts (Gutale, unpublished data, as cited in Gutale & Ahmed, 1984). The bones of the rats that received cordeauxiaquinone in the drinking water were stained red and the authors claim that this indicates that the dye is preferentially deposited in the bones. This location may represent the increased hemoglobin concentration found in the blood. It is suggested by the authors that the pigment might stimulate hemopoetic tissue to produce erythrocytes both directly and indirectly, indirectly through the formation of methemoglobin.

Skeletal tissue

Physiology

Bones consist of an organic part, primarily collagen fibers, and an inorganic part consisting of primarily calcium phosphate crystals (Sjaastad, 2003). Compact bone is situated on the outside of all bones and spongy bone is situated interiorly, allowing space for the bone marrow. The bone marrow in young animals consists of red bone marrow, which contains hemopoetic tissue producing blood cells. The red bone marrow is gradually replaced by yellow bone marrow (adipose tissue) in the long bones when approaching adulthood. In other bones there is red bone marrow throughout life.

Bone formation

Bone formation, or endochondral ossification, in animals starts during the final third of the fetal development and ends after puberty when the bones are fully developed (Sjaastad, 2003). First, cartilage is formed and it is gradually replaced by bone tissue. The fully developed bone tissue remains metabolically active and remodelling occurs throughout life. Osteoblasts produce new bone tissue by synthesizing and secreting collagen and proteoglycans on the internal and external surfaces of bones; this material is called osteoid and crystals of calcium phosphate are deposited here. Osteocytes are formed by osteoblasts when they become embedded in mineralized bone tissue and they have long and thin cytoplasmic extensions that are linked to neighbouring cells by tight junctions.

Bone remodelling and resorption

Osteoclasts change the shape and curvature of the bone and adapt it to altered mechanical stress, a remodelling that continues throughout life (Sjaastad, 2003). Remodelling also heals fractures when callus formation occurs between the two ends. Osteoclasts break down and resorb bone tissue by reducing the pH and by chemical and enzymatic attack in the bone resorption lacuna, at the attachment site of the osteoclast on the bone. The released minerals are transferred to the extracellular fluid and can be utilized for bone formation or for production of e.g. eggs and milk. Young animals have a faster bone turnover than older animals as the calcium in the skeleton is exchanged in one year compared to five years in older animals.

Transport of nutrients

The network of channels formed by the osteocytes is thought to play a role in the transfer of nutrients, metabolites and hormones between the surface and the interior of the bone tissue (Sjaastad, 2003). Osteocytes transport calcium and phosphate from the bone to the extracellular fluid. In spongy bones, the nutrients diffuse from the bone surface through the extracellular fluid in the bone tissue while the diffusion in compact bones is less efficient. The cells deep in the compact bone are supplied with nutrients and oxygen from blood vessels. Minerals, peptides and amino acids are transported into the blood after osteoclast breakdown and hydroxyproline from the collagen is secreted through the kidneys.

Storage of minerals and toxic substances

In addition to calcium, bones contain also other minerals, for example sodium, magnesium and potassium that are bound in the mineral crystals (Sjaastad, 2003). Potentially toxic substances like heavy metals can be stored in the skeletal tissue, e.g. radioactive strontium will become deposited in the bone in young animals during mineralization due to its chemical properties being similar to that of calcium.

PART 2. EXPERIMENTAL STUDY IN GOATS

MATERIAL AND METHOD

Animal housing, feeding and sampling

Place of study and ethical application
The study was conducted at the Department of Anatomy, Physiology and Biochemistry at the Swedish University of Agricultural Sciences. The Uppsala committee for ethical review of animal studies approved the experimental protocol.

Animals and housing
Four goats of Swedish landrace named Becel, Bregott, Halloumi and Lätt, all male castrates and eight months old, were used in the experiment. The animals were kept indoors, in the same animal room as the rest of the goat herd belonging to the department. The goats had a separate enclosure and were put into smaller enclosures during feeding of Yeheb and when blood samples were taken. Two goats were fed with Yeheb for a period of five and nine weeks respectively, and each of the trial-goats had a control-goat that was kept for the same period of time. The experimental period was from the 11th of November to the 7th of January.

Preparation of feed
The goats were fed with dried and ground as well as fresh Yeheb leaves. The ground leaves were mixed with concentrates to increase the palatability and the fresh leaves were fed as twigs. The Yeheb bushes were grown at the Department of Crop Production Ecology, Swedish University of Agricultural Sciences, Uppsala, Sweden and the fresh twigs were collected three times a week.

Feeding and blood sampling regimes
The animals were fed with Yeheb from Monday to Friday weekly and 10 ml of blood was collected from the jugular vein every Monday and Thursday morning. The animals were also weighed at the same occasion to control that the animals had a normal growth rate.

The two goats were accustomed to the dried and fresh Yeheb leaves during the first week of the trial. They did not find Yeheb very palatable, especially not the dried leaves. Therefore, the leaves were ground so that they more easily would mix with concentrates and water. The goats did not like molasses but a more palatable mix with sugar beet pulp, water, crushed pellet concentrates and crushed oat was developed.

Intake of Yeheb
Two kilograms of dried Yeheb leaves had been prepared for the study and the diet

modified according to the supply. During the second week a diet of 15 grams fresh leaves and 50 grams dried leaves was given. The third week the amount of dried and ground leaves was decreased to 25 grams as the feeding period was prolonged and the amount of leaves was limited. It was also difficult to make the goats consume the leaves. In the fifth week the amount of fresh leaves was increased to 30 grams. The amount of fresh leaves was increased when it was realized that there was enough fresh material for the rest of the study. The goats had free access to hay and water.

The goats did not always consume all of the dried leaves and concentrate mix. As it was given in a mixture, the amount of Yeheb leaves left in the container could not be measured but the estimation is that at least 75 percent was consumed all days and most days the whole ration was finished.

Tissue sampling

After the feeding periods of five and nine weeks respectively, the trial goats and the control goats were euthanized. Samples were taken from muscles, bones, parts of the digestive system, liver, kidneys, lymph nodes etc. The blood samples taken twice a week during the trial and at euthanization were centrifuged and the plasma frozen for analyses after the end of the trial. The samples from muscles, bone, the digestive system, rumen liquid etc were also frozen for future analyses. At time of euthanization (day 32 and 60 of the experimental period), blood samples were taken for hematocrit analyses.

Analysis of cordeauxiaquinone

At the beginning of the trial it was planned to develop a method for analysing cordeauxiaquinone in plasma and body tissues. It turned out to be too complicated and time consuming to be a part of this project. Therefore, cordeauxiaquinone was purified and its absorption maximum measured by spectrophotometry for estimation of the presence and the level of cordeauxiaquinone in the rumen liquid and plasma of the goats. Spectrophotometry shows the concentration of a compound, in this case cordeauxiaquinone, by determining the extent of absorption of light at the appropriate wavelength for the compounds absorption maximum.

To purify cordeauxiaquinone, fresh Yeheb leaves were dissolved in ethanol or water and the solution centrifuged in 14 000 revs/min for 15 minutes. The solid fraction was then separated from the ethanol/pigment fraction respectively from the water/pigment fraction.

A Thin Layer Chromatography (TLC) optimization was reached with cordeauxiaquinone solved in water and with a mobile phase of ethylacetate and ethanol 80:20 and 1 volume percent acetic acid. The idea was to get a pure and distinct line with cordeauxiaquinone which could be removed and analysed. It did not work out very well in a larger scale so the TLC plate was instead exposed to iodine which reveals all double bonds in compounds. Only cordeauxiaquinone and one more, and colourless (and therefore not affecting the result), compound was found in the solution, and an absorption maximum could be measured with spectrophotometry for cordeauxiaquinone solved in water and in ethanol.

When estimating the absorbance in the rumen liquid and in the serum of the goats, the sample from the respective control goat was used as a reference to the treated goat's sample. For each sampling-day the spectrophotometer was run with the control and treated goats' samples and the spectrophotometer measured the difference in absorbance between the two goats.

RESULTS

Weight gain

All goats had a similar growth rate, however, one of the control goats had initially a much lower body weight (see figure 1).

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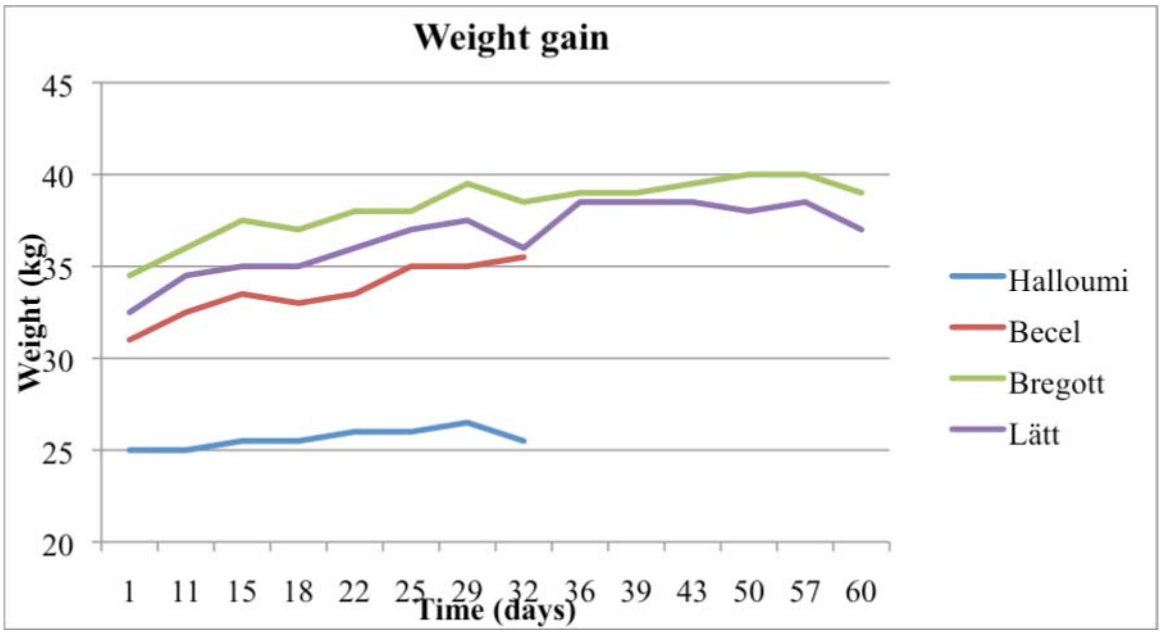

Figure 1. The weight gain of the four goats during the 32 respectively 60 days of the experimental period.

The goats were healthy troughout the trial and no abnormal changes in their body tissues could be seen. They also grew normally. The two goats feeding on Yeheb had a dark purple colour of their urine at some occasions during the feeding period.

Hematocrit

The hematocrit was measured on the last sampling day of each experimental period. The hematocrit was not measured before the start of the experiment.

Table 1. The hematocrit levels on the 11th of December (day 32) and on the 7th of January (day 60).

	11th of December	7th of January
Control five weeks	34	-
Yeheb five weeks	32	-
Control nine weeks	30	34
Yeheb nine weeks	33	36.5

Cordeauxiaquinone

Spectrophotometry was used to measure the absorption maximum. The absorption maximum for cordeauxiaquinone was 494.8, 521.4 and 562.2 in ethanol and 491.2 in water (see figure 2).

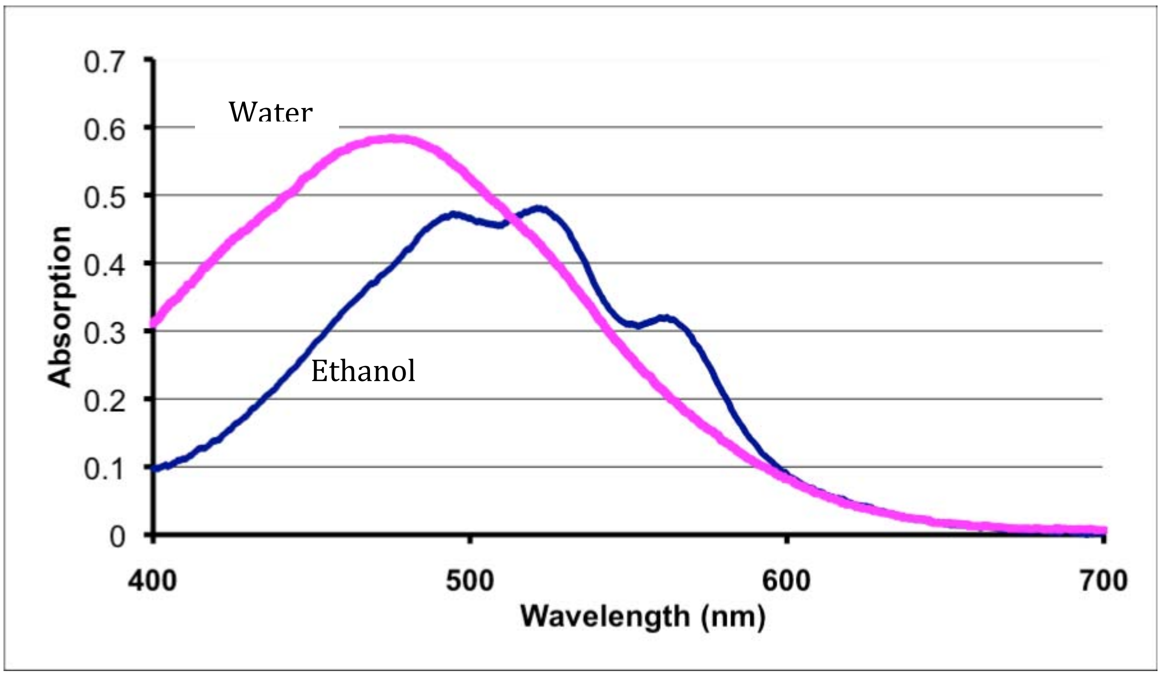

Figure 2. The absorption maximum for cordeauxiquinone in water (pink) and ethanol (blue).

These curves were measured to use as reference curves for the rumen liquid and plasma samples. If the rumen liquid and the plasma showed an increase in absorption at the corresponding wavelenght it meant that cordeauxiaquinone was present in the samples.

Spectrophotometry of rumen liquid

For the five respectively nive week experimental periods, the control-goat’s rumen liquid is used as a reference to the trial-goat’s rumen liquid in the spectrophotometer.

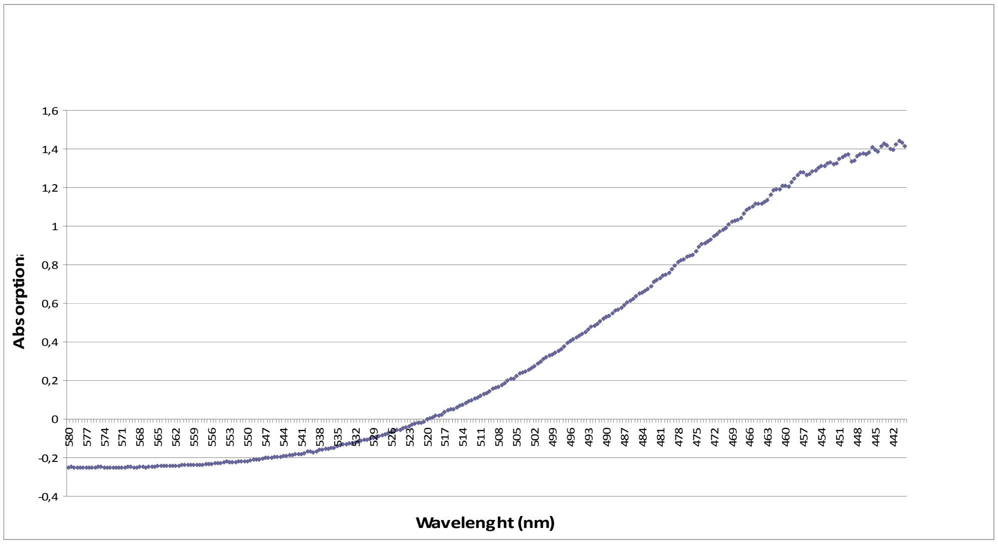

Figure 3: Spectrophotometry of the rumen liquid from the goats of the five week trial. Absorption in the interval 440-580 nm for the five week trial. An increase in absorption is visualised in the interval 440-520 nm.

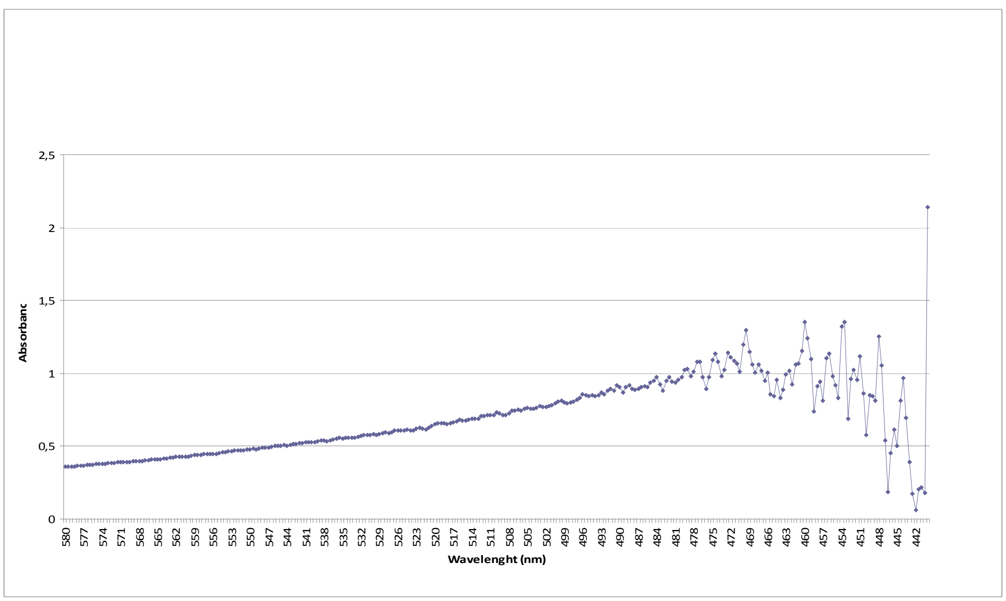

Figure 4: Spectrophotometry of the rumen liquid from the goats of the nine week trial. Absorption in the interval 440-580 nm for the nine week trial. An increase in absorption is visualised in the interval 440-580 nm.

Spectrophotometry of plasma

During the feeding period, the plasma of the treated goats turned red compared to plasma from the control goats. This change was visualised at an early stage of the feeding period (see figure 5).

Figure 5: Plasma from one of the treated goats and one of the the control goats, at the 20th of November, i.e. the tenth day of the feeding period.

The absorption for the November 10th is before the start of the trial, thereafter an increase in concentration of cordeauxiaquinone is found at each sampling day. The absorption presented (Figs. 6 and 7) is the difference between the control goat and the treated goat.

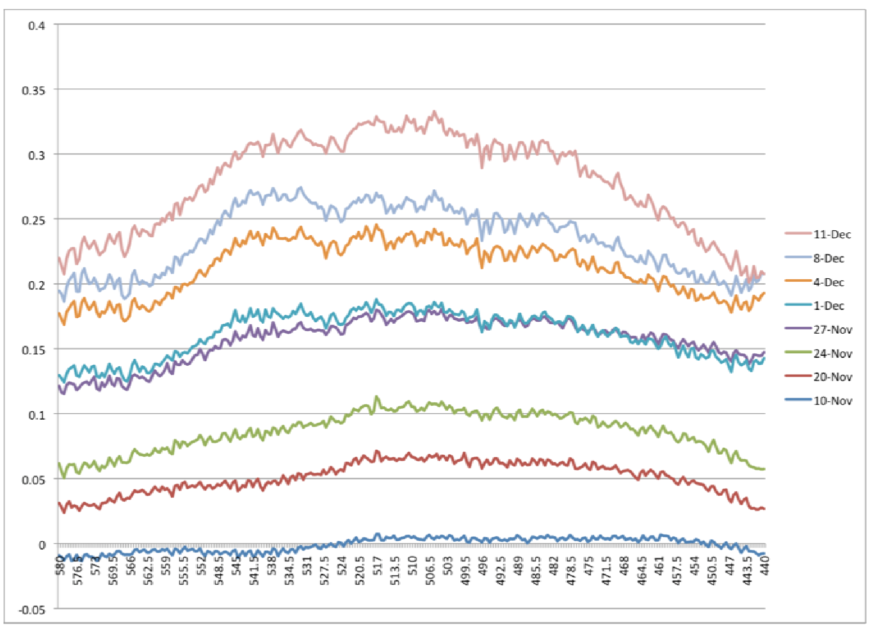

Figure 6. Specrophotometry of the plasma from the goats in the five week trial. Absorption is in the interval 440-580 nm.

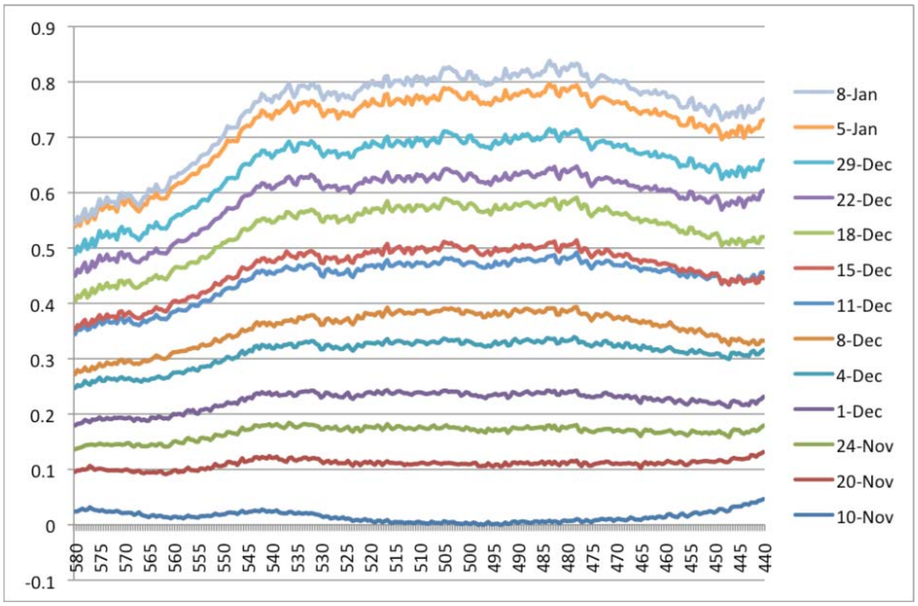

Figure 7. Spectrophotometry of the plasma from the goats in the nine week trial. Absorption in the interval 440-580 nm.

Colouration of the bones

No visible colouration had occurred in the bones of the treated goats (see figure 8 and 9).

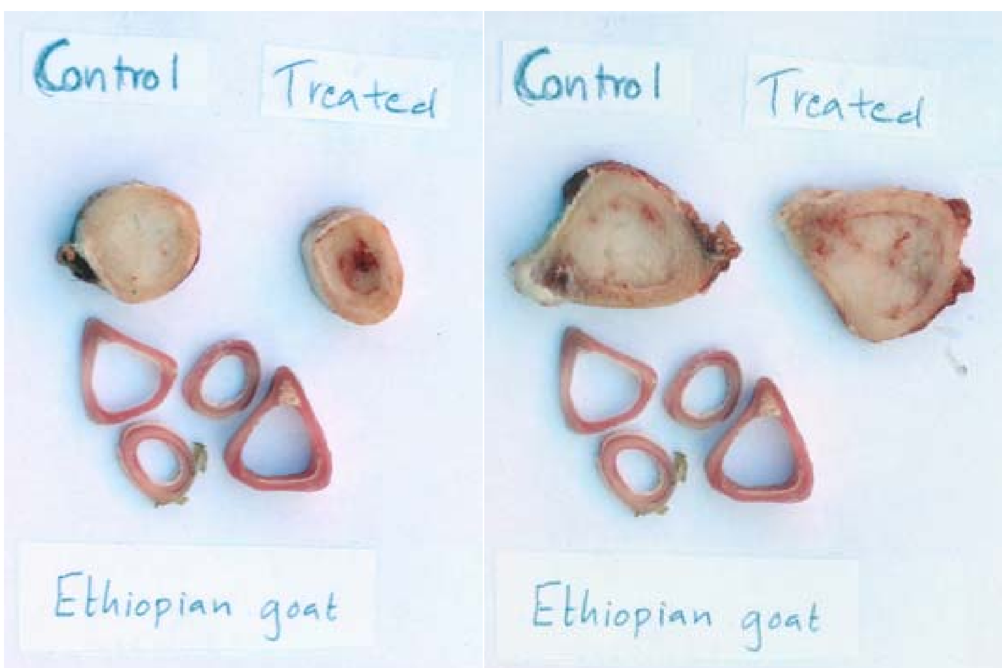

Figure 8 and 9: Pictures of the bones of the treated goats and the control goats in comparison with bones from an Ethiopian goat. Figure 8 (left) is from the five week trial and figure 9 (right) is from the nine week trial.

DISCUSSION

Animal production and export

Somalia is a developing country in great need of food for its own inhabitants and of trade and export for cash income and development of the country. Livestock contributes to 40 percent of Somalia's GDP and up to 80 percent of the export income, including animal products. Therefore Somalia's people and the country's economy would benefit from a sustained or even increased livestock production.

The animal production in Somalia is a very fragile market. The pastoralists are highly dependent on natural resources for availability of feed and water to the animals. In order to develop the sector, the pastoralists need more reliable feed sources but this is difficult to achieve as droughts and other natural disasters are hard to affect. However, if the vegetation cover and the amount of drought tolerant species could be increased, the pastoralists and the animal production would benefit from that.

The pastoralists have traditionally lived on milk, meat and grains. During the 50s and 60s, the export of live animals and animal products started at that time the pastoralists were able to import food and get cash income. Since then, the export has during periods of time been rejected or the prices fluctuating due to disease outbreak in Somalia. In recent years, some countries, due to the red colour of the animals' bones caused by cordeauxiaquinone, have rejected the export-animals from Somalia. The reason is that they believe the colour to come from a food colouring agent or being a sign of disease. Why this has not been a problem previously, might be because of stricter veterinarian controls today or the establishment of trade with new contacts and/or markets. It can also be because of an increased awareness of food colouring agents as it is more debated now than some years ago or that buyers are suspicious towards animals from Somalia as the country has a history of major disease outbreaks.

Yeheb

The warm climate and low precipitation rate in Somalia along with soil erosion, deforestation, overgrazing and desertification contributes directly or indirectly to a lack of both feed to the animals and food to the people. The evergreen Yeheb bush is essential for the livestock production in its growing area, i.e. in central Somalia and eastern Ethiopia, as it constitutes up to 85 percent of the good-quality feed during the dry season. Yeheb is also an important source of food as the nuts are high in energy and fat and they also provide proteins with well-balanced amino acid content.

The number of Yeheb bushes has decreased due to removal of nuts and branches, overgrazing and drought. Widespread land degradation in Yehebs' growing area results in a decreased vegetation cover and a reduction in the diversity of species; furthermore to loss of soil structure and decrease in soil fertility that leads to a reduced biomass yield and a reduced livestock production. The productivity needs to increase on cultivated land and marginal dryland should be exploited to produce food for the increasing population and feed for the animals.

The ongoing or terminated cultivation and conservation projects in Somalia, Sweden and elsewhere have had different rates of success due to climate, soil-type and other factors that may affect the results. At the Swedish University of Agricultural Sciences they have succeeded in re-establishing Yeheb plants with cut taproots (manuscript in prep.), while former trials in other places have not had as good results. Sowing and transplantation of seedlings in eastern Ethiopia has lead to fifty percent established plants (Mekonnen *et al*., 2009). Both experiments show that it is possible to reseed Yeheb bushes in order to increase the total number of plants, the biomass yield of the area and to improve the soil structure and fertility, and decrease the desertification.

Growth and urine colouration of the Swedish goats

The goats grew and developed normally during the trial, as shown by a normal weight gain and no abnormalities in the goats' body tissues. The purple colour of the urine indicates that the Yeheb leaves were metabolized and that the urine secreted some of the cordeauxiaquinone, or its derivatives. The variation in colour of the urine is possibly due to that this course of events is very rapid and therefore the urine quickly recovers its normal colour.

Hematocrit

It is not possible to establish if the hematocrit increased significantly during the trial as no samples were taken before the start of the trial. Samples were taken twice for the goats in the nine week trial, and the hematocrit had increased slightly more for the control goat than for the treated goat. However, no conclusions can be made, as it is not known what the hematocrite was before the start of the trial.

Increase of cordeauxiaquinone in the rumen liquid and in the plasma

The rumen liquid of the goats treated for five and nine weeks respectively had an increased absorption in the same interval as cordeauxiaquinone solved in water or ethanol. The increase in absorbance of the rumen liquid in this interval means that cordeauxiaquinone and/or its derivatives were found in the rumen. In the nine week trial there was an increase in absorbance between 520-580 nm that was not found in the five week trial. One explanation could be that the goat with the longer feeding period developed a microflora more adapted to Yeheb which resulted in different metabolization products. This could also be the explanation of the curve for the nine week trial looking more irregular. The maximum absorbance in the rumen liquid, about 1.4, is the same for both feeding periods. This indicates that cordeauxiaquinone is not accumulated in the rumen liquid and that the goats had consumed the same amount of Yeheb the last days before euthanization.

The plasma of the treated goats turned red during the feeding period and it indicates that the blood transported cordeauxiaquinone and/or its derivatives after metabolization of

Yeheb. The spectrophotometry of the plasma during different times of the trial period shows a consistent increase in absorption in the interval 440 to 580 nm. The wide span of the increased absorption in the plasma might be a result of several different derivatives of cordeuxiaquinone. The increased absorption by time means that the compound or compounds accumulates in the plasma. When comparing the absorption of the goat treated for five weeks with the goat treated for nine weeks it differs at the same dates. For example, on the 11th of December the absorption maximum was about 0.33 for the five week trial and 0.48 for the nine week trial. This indicates that the goat in the nine week trial was consuming more Yeheb than the five week trial goat and/or that there is an individual adaptation in the microflora of goats, affecting the absorption of Yeheb.

Colouration of the bones

The bones did not change colour to red/pink as expected but remained white. Brink & Belay (2006) states that cordeuxiaquinone forms calcium complexes in the skeleton and Kuchar *et al.* (1985) with reference to Ali (1988), claim that the dye is selectively deposited in certain tissues, particularly bone, of livestock feeding on Yeheb. In this study, it is possible that the bones somewhat changed colour but to such a low degree that it could not be detected with the eye. The reason could be that the length of the feeding period was too short or that the amount of Yeheb leaves was too low, or a combination of both. In the area where Yeheb grows, the dry periods are from June to October and from November to March, periods during which Yeheb constitutes 85 percent of the good-quality feed and comprises 16.9 percent of all available feed. It is therefore very likely that the goats in Somalia consume much more Yeheb per day than the goats in this trial, and the period they are feeding on Yeheb in Somalia is also much longer. Another explanation could be that the microflora of the goats' rumen differs between Swedish and Somali goats. The microflora in the Somali goats, which during the dry period feed mainly on Yeheb, will probably differ from the Swedish goats which had hay as the main component in their diet. It is, however, uncertain if this will affect the metabolism and uptake of cordeauxiaquinone. It is also possible that it takes a long time for cordeauxiaquinone to be deposited in the skeleton. The goats were eight months old at the start of the trial and had not stopped growing. It is likely that more cordeauxiaquinone is bound into the tissue matrix during bone formation than during bone remodelling and therefore it is advantageous to use young animals. Maybe the effect of feeding of Yeheb on the colour of the skeleton would have been more pronounced if the goats had been even younger, as bone formation is more extensive during the rapid growth of young animals.

CONCLUSION

Possible enhancement of the animal sector in Somalia

The animal production in Somalia is highly dependent on the supply of feed, and the sector has potential to expand if the access to different feed sources increases. Expansion of the market would favour both the pastoralists and the development of the country. Increased numbers of animals is not enough, the products have to be competitive and it is also necessary to develop the sector in collaboration with researchers and veterinarians. Somalia's reputation as an animal exporting country should be improved, sick animals should not be exported and the reason to the coloured bones established, and the information distributed.

The potential of Yeheb

The Yeheb bush gives feed to the animals even during the dry periods and is also an important source of food to the pastoralists. Due to its drought tolerance and longevity, it is a very valuable bush and it would positively affect both humans and animals directly as well as Somalia's economy and development indirectly if its occurrence could be increased. Furthermore it would decrease the desertification and land degradation. Studies have shown that it is possible to re-establish Yeheb plants but it is also essential to stop the removal of nuts and branches.

Effects of cordeauxiaquinone

Consumption of the Yeheb bush did not show any negative health effects in the goats. Cordeauxiaquinone was metabolized and the quinone and/or its derivatives were absorbed by the blood and present in the plasma samples of the goats. An increased concentration was shown already in the first plasma sample taken. The level of cordeauxiaquinone and/or its derivatives were accumulated in the plasma showing that the concentration increased by exposure time. The level of cordeauxiaquinone in body tissues could not be measured in this study. Cordeauxiaquinone may have other effects on animals than detected up to today, which would be an interesting subject for future studies.

Colouration of the skeleton

The bones did not turn red/pink and it might depend on the length of the feeding period, the amount of Yeheb leaves given, or both. It could also be because of different microflora in the rumen of Somali goats compared to Swedish goats or the age of the animals. It is however possible that some cordeauxiaquinone was bound to the skeleton but not detectable with the eye. To further investigate this and to estimate the level of cordeauxiaquinone in other tissues of the goats, both qualitative and quantitative methods have to be developed. To survey the metabolism and uptake of cordeauxiaquinone in bones and the effect of cordeauxiaquinone on the hemoglobin level, is also of major interest.

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