Chemical Composition and *In vitro* Digestibility of Cactus
(*Opuntia ficus indica* var. *inermis*)

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Date: August/2017.
Chemical Composition and In vitro Digestibility of Cactus

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Date of Examination: 12 /August/2017.
DEDICATION

This piece of work is dedicated to all my beloved families, to my mother, father, all my brothers and my sisters, my friends and all my teachers.

Thowiba
Acknowledgement

First and foremost, I would like to provide thanks for my God for giving me health and ability to complete this research, also for the blessing and supplying strength, believes, love, hope, patience and protection to me and my families throughout my study.

I wish to express my deep gratitude and appreciation to my main research advisor Dr. Manar Omer Ibrahim for her sustained guidance, encouragement and constructive comments at all stages of the thesis work and without her encouragement, insight and professional expertise the completion of this work would not have been possible.

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Big thanks for my brothers (Alharith and Hafiz) for their excellent cooperation in collecting of fresh cactus

Sincere thanks are to University of Gezira, Department of Animal Science.
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**Abstract**

The continuous increase in livestock population in Sudan increases the demands for feeds. The main constrains of arid and semi-arid zones are the increasing degradation of rangeland and the consequent decline in feed supply. Cacti (*Opuntia ficus indica* var. *inermis*) are some of the best plants in arid and semi-arid areas; they can play an important role in these regions. This study aimed to evaluate and introduce cacti as a non-conventional Feedstuff in Sudan. Three samples of cacti were collected from three locations in Gezira State namely: Wadalshafie (natural pasture), Alhasaheisa (nursery), and Barakat (water courses) to evaluate the nutritive value of Cacti. The samples were chemically analyzed to determine DM, Ash, EE, CF, CP, sugar; mineral content (Na, CL, K, P, Ca), ADF, NDF, HC and finally NFE and ME were calculated. In addition, alkaloids, tannins and total carotenoids were assessed. Rumen liquor collected from calf grazed freely in natural range was used to estimate the *in vitro* digestibility (DM and OM). The results showed significant differences (*P*≤0.05) in DM, ash and NFE, CP, CF ranged between 10.5-15.1, 7.0 - 15.4, 70.6 - 76.7, 3.7 - 5.0, and 3.8 - 4.7%, respectively. ADF, NDF, HC were not significantly different (*P*≤0.05). Calcium showed the highest value (2.3 - 2.8%) and P had the lowest value (0.1 - 0.2%). Metabolizable energy ranged between (12.6-13.7MJ/KgDM). Moreover, dry matter and organic matter digestibilities were not significantly different (*P*≤0.05), about 99 and 94%, respectively. It could be concluded that cacti are valuable source of energy and characterized by high digestibility for both DM and OM. So it can be recommended as a supplementary source of energy.
التحليل الكيميائي للتين الشوكي و الهضمية العملية

ثويبة علي موسى علي

ملخص الدراسة

أدت الزيادة المستمرة في تعداد الثروة الحيوانية في السودان إلى زيادة الطلب للأعلاف. من المعوقات الرئيسية في المناطق الجافة وشبه الجافة تدهور المراعي والانخفاض المستمر في كمية الاعلاف المتاحة. التين الشوكي من أفضل النباتات في المناطق الجافة وشبه الجافة، ويلعب دور هام في تلك المناطق. تهدف هذه الدراسة إلى تقييم وادخال التين الشوكي لتغذية الحيوان. جمعت ثلاث عينات من التين الشوكي من ثلاث مناطق في ولاية الجزيرة ود الشافعي (مرعي طبيعي)، الحصاحيصا (مشتل)، بركات (مزيج) لتقييم القيمة الغذائية للتين الشوكي. تم تقدير المادة الجافة، الرماد، مستخلص الألياف الخام، البروتين الخام، السكر ومحتوى المعادن (الصوديوم، البوتاسيوم، الكالسيوم، الفوسفور والكليور) والهيموسيليلوز ثم حساب المستخلص الخالي من النتروجين والطاقة القابلة للتمثيل بالإضافة إلى الألكلولات والكربوهيدرات والكوارتوني. تم تجميع سائل الكرش من عجل يرعى نباتات طبيعية واستخدم لقياس هضمية المادة الجافة والمواد العضوية. أظهرت النتائج وجود فروقات معنوية في نسبة النيتروجين، البروتين الخام، السكر والمواد الحيوية بين العينات. بينما لا يوجد فروقات معنوية في مستخلص الألياف، من النتائج أن الكليور يمثل أعلى قيمة (2.3-2.8%)، بينما الصوديوم يمثل أقل قيمة (0.1-0.2%). كما وجدت فروقات معنوية في نسبة الطاقة القابلة للتمثيل والتي تراوح بين 12.6-13.7 ميجا جول/كم مادة جافة. لا يوجد فروقات معنوية بين هضمية المادة الجافة والمادة العضوية. خلصت الدراسة إلى أن التين الشوكي مصدر جيد للطاقة ويعتبر بهسميًا عالية ويوصي بان يستخدم كمصدر بديل للطاقة.
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CHAPTER ONE
INTRODUCTION

1.1 Background

Sudan is located in northeastern Africa between latitudes 8° 45’ and 23°8’ north and longitudes 38°34’ and 21°49’ east with an area of 1.88 million square kilometers. It is bordered by Egypt to the north, the Red Sea to the northeast, Eritrea and Ethiopia to the east, South Sudan to the south, the Central African Republic to the southwest, and Chad to the west and Libya to the northwest. Sudan is the third largest country in Africa, after Algeria and DR Congo. It had been the largest country on the continent until the 2011 separation of South Sudan. It has a human population of 33.41 million. The country is traversed by the River Nile and its tributaries which have varying degrees of influence on irrigated agriculture and livestock production systems. There are also a large number of seasonal rivers and watercourses. The grazing lands constitute 40.04% from total Sudan area. The pastoralists of Sudan own 90% of the national herd of livestock. Arable area for agriculture is 200 million acre, utilized area 20%, irrigated area 11 million acre, irrigated area by rains 29 million acre, forest area 11.6% of country area.

The country is characterized by variable soil types, which reflect the broad climatic zonation of the country (Harrison and Jackson, 1958). The climatic zones were:

**Desert zone:** irrigated agriculture is practiced along the banks of the River Nile and Atbara River and on the neighboring lands. Rangelands form an immense natural resource and the major source of feed for the national herd. The various types of grazing land vary from open grasslands to seasonal water courses, river banks and associated islands, woodlands, hills and mountain slopes. The following description is based on the work of (Harrison and Jackson, 1958), it is covered by ephemeral herbs and grasses confined to water courses and flat low lying areas that receive runoff.

**Semi-desert Zone:** This zone has rainfall <300 mm/annum hence rain-fed cultivation is limited to traditional farming on the ‘Qoz’ sand (mainly millet) and areas with higher clay content where runoff harvesting is practiced.

**Low Rainfall Savanna Zone:** hosts irrigated agriculture as the large scale schemes such as Gezira extend south into these Zones.
Mountains: Jabel Marra is the area utilized for agricultural production on a reasonable scale; important for horticultural production and field crops (Harrison and Jackson, 1958).

Livestock (cattle, sheep, goat, camel, birds and wild animals) represent an important part of natural resources, provided official estimates of the size of Sudan's livestock population currently are 106 million heads of which: 40.2 million sheep, 31.2 million goats, 30.4 million cattle and 4.8 million camels (MARF, 2015). Livestock play a very crucial role in poverty alleviation, food and nutritional security for the country (Ngongoni et al., 2006, 2009 and Odongo et al., 2010). However, fluctuations in both quality and quantity of feed make the sector unreliable and susceptible to high livestock mortality and low productivity (Vasta et al., 2008; Ngongoni et al., 2009).

Animal production in Sudan is one of the most important components of the agricultural sectors in spite of the traditional way of husbandry. Rapid and continuous increase in population led to increasing demand for livestock products. In general, in arid and semi-arid zones animal feed resources are fluctuating and insufficient. Safe guarding food security will depend on better utilization of conventional as well as non-conventional feeds. Feed, fodder and industrial by-products are important sources of feedstuffs in the developing regions in Africa and Asia having low rainfall and limited irrigation resources. These conventional feeds are used in limited amount, because they are scarce and expensive (Nefzaoui et al., 1993). Moreover, the main constrains of arid and semi-arid zones are the increasing degradation of rangeland and the consequent decline in feed supply, the continuous increase in the number of ruminants and lack of right to graze animal on rangeland. The importance of browse trees and shrubs, especially in arid and semi-arid zones, is increasingly acknowledged throughout the world, they provide protein, vitamins and frequently mineral elements which are lacking in grassland pasture during dry and/or cold seasons (Ponce, 1989 and Teferi et al., 2008). Cacti are an important resource in these regions, fruits and stems are consumed directly as food or as forage and are used for making marmalade drinks and syrup (Dominguez, 1985 and Saenz, 2006).
Unfortunately there is scarcity in information about the chemical and nutritive value of cacti in Sudan in spite of their potential to play an important role in animal feeding. All these facts initiate the necessity of this study.

1.2 General objective

To identify and introduce a new source of animal feed mainly cacti.

1.3 Specific objectives

The specific objectives are, to:

1. Determine the dry matter productivity, chemical composition and energy value of cacti.
2. Determine total carotenoids value.
3. Assess some anti-nutritional factors, mainly alkaloids and tannins, in cacti.
4. Assess the in vitro digestibility of cacti.
CHAPTER TWO
LITERATURE REVIEW

2.1 Livestock population

Sudan is the second largest livestock owning country in Africa and ranks first among the Arab countries. The provided official estimates of the size of Sudan's livestock population currently are 106 million: 40.2, 31.2, 30.4 and 4.8 million heads of sheep, goats, cattle and camels, respectively (MARF. 2015). Traditional natural rangelands are the main source of feed in Sudan.

2.2 Systems of Livestock Production in the Sudan

Livestock systems play an important role in the livelihoods in many rural communities in the Sudan they are raised mainly under harsh dry land farming conditions for meat production. Livestock are particularly important for increasing the resilience of vulnerable poor people (Elhag, 2011). Currently, three systems of livestock production prevail in the Sudan; these are: Production under natural range systems, production in the irrigated schemes and riverine farms and production under commercial systems.

Animal performance, regardless of whether it is expressed as yield (meat or milk), growth rate or disease resistance, is dependent on the quality of nutrition. Nutrition is often the most limiting factor of productivity in ruminants and non-ruminants (Corson et al., 1999). With the increase in size and wealth of the population, and the subsequent increase in demand for animal products raise the importance of increasing feed quantity (Babić and Perić, 2011). Feed costs typically represent the highest cost item in smallholder production systems, implying that both quantity and quality of feed have a significant effect in determining profitability (Muller et al., 2007 and Roy et al., 2004). Furthermore, when concentrates are fed, it is provided in small quantities, and therefore low returns are achieved from their inputs (Biwott et al., 1998). The effect of feeding concentrate supplementation on animal performance is relatively well known and has been documented by several authors. In addition, other research has shown that milk yield increases at higher levels of concentrate feeding (Biwott et al., 1998 and Muller et al., 2007).
Supplementation with nutrient rich feeds is especially important in smallholder systems in East Africa because animal diets mainly consist of fibrous crop residues and low quality hay and pastures, which are low in protein and energy. Increasing protein supply through supplementation helps to build the microbial population to better digestion and extract the nutrients in poor quality feedstuffs (Tolera et al., 2000). Furthermore, supplementation is important to compensate for low availability and nutritional value of forage during dry periods (Bosing et al., 2014). With an increasing human population, land holdings are decreasing whilst animal numbers are increasing (Githinji et al., 2009). However, due to several constraints such as high stocking rates and a growing human population, these communal pastures typically have a low nutritional value, especially during the dry season (Mwilawa et al., 2008). In reversing this trend, more efficient feeding can alleviate land pressure due to reduced stocking rates, without compromising total animal mass output per unit area of land (Bosing et al., 2014). However, the efficiency of supplementation will depend on the quality of the supplement highlighting the importance of feed manufacturers in alleviating such pressures.

2.3 Nutrient requirements in animal feeding

There are several underlying principles in animal feeding which must be given due attention when determining the nutrient requirements such as energy, protein, minerals and vitamins (Parr, 1988). The traditional sources (conventional feeds) of energy, oilseed such as soya been, cotton seed and sunflower (McDonald et al., 2011), cereal by products, tubers roots, sugars; molasses (starch and sugars) and crude fiber consists of cellulose, hemi-cellulose, lignin are found in the fibrous parts of plant material (Parr, 1988). CF is essential for rumen functions and for the production of good quality milk .the main sources of CF are cereal by-products, maize, Stover and straw. The main sources of protein are oilseed by-products, fish meal and Blood meal (Parr, 1988),Mineral components should be considered individually during feed formulation, the main sources are Bone meal (P, Ca), Cereal grain (P), fish meal (Ca), lime stone (Ca) and Dicalcium phosphate (Ca, P). The natural dietary supply of vitamins by the raw materials must be considered before supplementing. Although vitamins are required in relatively small quantities they are very important in maintaining good animal Health,
sources of vitamins are cereal, oilseed by-products and Manufactured P-mixes (McDonald et al., 2011).

2.4 Feed resources

The main feed resources of livestock are: natural grazing and browses, crop residues, improved pasture, forage crops and agro-industrial byproducts (Alemayehu, 2005). In addition, non-conventional feed is terms referred to unusual feed. There are several sources of non-conventional feeds which include perennial crops, multipurpose trees and shrubs and agro-industrial byproduct (AIBPs).

The increasing human demand for several types of food led to a considerable increase of lands occupied by crops, consequently, huge amounts of by-products are available and still not fully utilized in livestock feeding. In addition, processing of human foods, mainly from agricultural products, produces considerable amounts of agro-industrial by-products. The most important by-products are oilseed cake, brans, and brewers…etc. which are known to be rich in protein, energy or both.

Moreover, fodder trees and shrubs have high potential values as a source of feed for domestic livestock and wildlife. They can be successfully integrated into production systems to provide additional feed source, fuel and mulch, to control erosion when planted as wind breaks and to maintain or rehabilitate degraded areas of rangelands (Ben Salem et al., 2004). Low quality roughages which form the basal feeds in Sub-Saharan Africa are deficient in nitrogen, energy, vitamins, and minerals. These nutrients deficiencies affect microbial growth and fermentation in the rumen resulting in an overall low animal productivity. Moreover, mineral blocks are equally expensive. Thus, leguminous trees, can improve the utilization of low quality roughages, they are being used more extensively throughout the world in various production systems. These trees are capable of enhancing both crop production through soil fertility maintenance and livestock production through increased availability of high quality feed. In addition; they produce forage for livestock during the dry season when feed shortage is critical. Like other supplements they provide critical nutrients lacking in the basal diet (Bonsi et al., 1995).
Browse trees and shrubs have an advantage over grasses to improve diets based on low quality grasses and straws (Petit, 2003). Also they improve the productivity and the ability of animals to resist the harmful effects of parasites during dry season. Waller (1999) and Hoste et al. (2006) cited that using of browse leaves have positive effect on productivity and stocking rate of livestock in the tropics (Leng, 1997 and Van, 2006). The use of tree leaves in complete feeds for bucks resulted in higher voluntary intake and digestibility of nutrients (Bakshi and Wadhwa, 2007). The foliage are particularly had high quality and low protein feed for livestock. Some browses contain anti-nutritional factors. Browse foliage used as nitrogen supplement to low quality feeds for livestock (Eyog-Matig et al., 2002 and Arbonnier, 2004).

Mostly cactus spread in degraded areas in which few grasses were grown. Cactus species fit with most of the requirements of a drought resistant fodder crop (Amar et al., 2009).

2.5 Cactus
2.5.1 Background

Opuntia is a large genus of succulent shrubs, now widely grown in the warmer parts of the world. It belongs to family Cactaceae genus Opuntia (Evans, 2005 and Reyes Aguero et al., 2005). They are commonly known as Prickly pears, because of their edible fruits. In India, as well as in other countries, they spread rapidly monopolizing, in large areas of forest and cultivated lands (The Wealth of India, 2001). Opuntias are the first cultivated plants in Mexico. They used by human in Mexico in pre-Hispanic times, where it played a major role in the agricultural economy of the Aztec empire; with maize (Zea mays) and agave (Agave spp.). Opuntias are now part of the natural landscape and the agricultural systems of many regions of the world. Typically, there are three main production systems: wild cactus communities; family orchards; and intensive commercial plantations. Opuntias are adapted perfectly to arid zones characterized by droughty conditions, erratic rainfall and poor soils subject to erosion. There is increasing interest in O. ficus indica in particular and has an important role in sustainable agricultural systems in arid and semi-arid zones. Thus Opuntias have become an endless source of products and functions, initially as a wild plant and later as a crop for both subsistence and market-
oriented agriculture, contributing to the food security of populations in agriculturally marginalized areas. Cactus plant originated from Mexico was introduced into North Africa in the 16th century (Griffiths, 2004). About 1500 species of cactus are in the genus Opuntia they are distributed in Europe, the Mediterranean countries, Morocco, India, Africa, the southwest U.S., northern Mexico and other areas (Hegwood, 1990). Many species of Opuntia produce edible fruit and very fragrant (Enigbokan et al., 1996). Cactus pear grows wild in arid and semiarid regions, where the production of more succulent food plants is severely limited. Low water exigency and a high water-use efficiency ratio favor the extension of cactus production, as underlined FAO (2009).

2.5 2 Uses of cactus

The plant is bitter, hot used as: laxative, stomachic, carminative, diuretic, antipyretic, urinary complaints, tumors, ascites, loss of consciousness, piles, and used to treat: inflammations, vesicular calculi, anemia, ulcers, cures bronch it is of children, ophthalmia, liver complaints lumbago and enlargement of the spleen and other diseases. The cladodes are very tasty, stomachic; cure inflammations, ascites, tumors, pains. The hot cladode applied to boils hastens suppuration. In South Africa and in Australia a decoction of the stem has been used as a diabetes remedy. The flowers cure bronchitis and asthma. The fruit is considered a refrigerant, and is said to be useful in gonorrhea, whooping cough, increase the secretion of bile, and control spasmodic cough and expectoration (Kirtikar and Basu, 1999 and The Wealth of India, 2001). Prostate problems, rheumatism, nosebleed, kidney problems and measles (Galt and Galt, 1978). Stem joints are fed to livestock on occasion because of their high water content (Barbera et al., 1992). Generally, these species are used as live fences to protect agricultural fields from human and animal encroachments with few exceptions (Gurbach and Singh, 2003). Although traditionally appreciated for its pharmacological properties by the Native Americans, cactus pear is still hardly recognized because of insufficient scientific information (Feugang et al., 2006). Prickly pears can be a good alternative forage crop on land that is presently deemed marginal for other crops (Mondragon-Jacobo and Perez-Gonzalez, 2001). Though cactus leaves are characterized by high palatability and digestibility, (Nefzaoui and Ben Salem, 2002), they can serve as a very good source of
roughages, especially in rain fed and severe drought prone areas. *Nopale acochenillifera* (*Opuntia cochenillifera*) is the species widely used in semi-arid regions as a forage crop. The material not sold in the vegetable market is being used as dairy cattle fodder with an increased milk yield. It imparts better flavor and quality to the milk and also enhances the colour of the butter (Oliveira *et al*., 2007). In Texas the primary use of cactus has been in times of drought when the spines have been burned off the cactus to feed cattle. Therefore excellent live weight gain, reproduction, and lactation from nursing cattle (Maltsberger, 1991). The fruits of two columnar cacti, cardondato (*Stenocereus griseus*) and cardonlefaria (*Cereus repandus*) have good potential as food and feed in arid zones (Emaldi *et al*., 2004).

2.5.3 Nutritive value of cactus

Generally cacti are highly palatable for livestock therefore is expected to have higher intakes. Livestock fed on straw were able to consume up to 560 g DM of spineless cactus. Animals received diet containing up to 500 g of spineless cactus didn’t show any digestive disturbance (Nefzaoui and Ben Salem, 2005). Animals during summer and drought periods in tropical countries have a real problem in utilizing a lot of energy to reach water points, therefore fed on cactus pads to solve this problem in dry areas. They clearly observed that water intake by an animal is not recorded when cactus intake is about 300 g of DM (Nefzaoui and Ben Salem, 2005). In other findings, volume of water consumed daily by animals decreased from 2.4 liters for the control diet to 0.1 liters when the level of spineless cactus is above 300 g DM.

The nutritive value of cactus cladodes depends on plant species, varieties, cladode age and growing season and management (Nefzoui, 2010). The effect of cladode age on nutrient content is quite interesting (Nefzoui and Ben Salem, 2001). Young cladodes have high protein content than the mature ones (Firew *et al*., 2006), crude protein content decreases (3 to 5% DM) and crude fiber increases (9 to 20% dry matter) with cladode age (1 to 5 years). This trend is similar to other fodder sources where valuable nutrients decrease with plant age (Nefzoui and Ben Salem, 2001). Cactus contains moisture, ash, Ether extract, crude fiber, crude protein and metabolizable energy ranged between 85 -
90%, 12 - 15%, 6.7 - 7%, 8 - 9%, 3 - 5%, and 8MJ/Kg DM, respectively (Feugang et al., 2006 and Nefzouï, 2010).

Nutrition is one of the factors that affect live weight gain. Poor nutrition results in low rates of growth (Alemu, 2008). But, the degree of response varies with breed type. The rate of growth of an animal is controlled by its nutrient intake, supplementation of roughages with high energy and protein sources. The objective to develop feeding strategy that will fill the gap in seasonal feed availability (McDonald et al., 2002), as Kassahun (2000) reported in tropical and sub-tropical regions. The growth rate of animals fluctuates because of seasonal availability of forage where extensive grazing system is practiced. Supplementation of livestock had brought a significant change in the growth rate/body weight gain (McDonald et al., 2002), A rapid rate of growth is desirable because it minimizes the overhead cost of maintenance per unit of meat produced (McDonald et al., 2002). The nutrient requirements for growth are dependent on growth rate. A supply of 0.035 MJ ME/day is required per gram of growth (Alemu, 2008). For instance, Simret (2005) and Mulu (2005) reported that significantly higher daily live weight gains were recorded in supplemented groups than non-supplemented ones. Similarly maximum average daily weight gain of 52.8 g was reported by Tikabo (2004) for livestock fed straw and supplemented with different levels of cactus and 60 g noug seed cake. Cactus is also a good supplement to ammonia or urea-treated straw, since it provides the necessary soluble carbohydrates for the efficient use of the non-protein nitrogen in the rumen. Using spineless cactus as livestock feed can improve meat and milk production. It is notable that cactus pads may reduce the use of concentrate feed and therefore the feeding cost (Ben Salem et al., 2002a). Cactus can prevent livestock deaths during periods of drought and increased daily body weight gain when lambs were fed cactus.
CHAPTER THREE
MATERIALS and METHODS

3.1 Study area
This study was conducted in Central part of Gezira State covering three locations, namely: Wadalshafie, Alhasheisa and Barakat.

3.2 Samples collection and preparation
Three samples of cactus were collected from three different locations in Gezira State namely: Wadalshafie, Alhasheisa and Barakat the samples were washed, their thorns were removed and the pulps were chopped and dried at 105°C. Then the samples were ground by using laboratory mill, sieved by using a sieve (2mm in diameter) and stored in glass jars.

3.3 Chemical analysis
The chemical analysis was done in laboratory of agricultural research cooperation and in vitro digestibility was estimated in laboratory of Food Engineering and Technology at Alnisheishiba campus, University of Gezira.

3.3.1 Proximate analysis
Moisture content, crude protein (CP), ether extractives (EE), ash and crude fiber (CF) were analyzed according to AOAC (1990), NFE and ME were calculated by using the following equations according to Rostock (1979).

\[
\text{ME (MJ/Kg DM)} = 0.012 \times \text{CP} + 0.031 \times \text{EE} + 0.005 \times \text{CF} + 0.014 \times \text{NFE}
\]

Minerals, Na, Cl, P, Ca and K were determined according to AOAC (1990).

3.3.2 Acid detergent fiber, neutral detergent fiber and Hemicellulose evaluation
Acid detergent fiber (ADF), neutral detergent fiber (NDF) and hemicelluloses (HC) were determined according to Van Soest et al., (1991). The relationship between the levels of total plant cell walls based on the crude fiber (CF) was determined according to INRA (2007).
NDF=0.575*CF+32  
ADF=0.579*CF+14.7  
HC=NDF−ADF

3.3.3 *In vitro* digestibility

*In vitro* digestibility was estimated according to Tilley and Terry (1963) and Terry *et al.* (1978).

3.4 Phytochemical analysis

3.4.1 Preparation of sample extract

Fifty gm. dried powdered samples were used to prepare the extract, 300 ml of ethanol were added and the mixture was reflux for one hour. The extract was filtered by using whatman filter paper. Finally filtrate was used for phytochemical screening to determine the alkaloids, tannins and total carotenoids.

3.4.2 Assessment of tannins

Tannins content determined according to E.Trease *et al.* (1987): In a test tube, 1 ml of ethanolic solution was added to 2ml of distilled water and 2-3 drops of diluted solution of FeCl₃ and subjected to observe a green, a blue black or a blue green coloration, to detect the presence of tannins.

3.4.3 Assessment of alkaloids

The presence of alkaloid was determined according to Memelink *et al.* (2001) by using two methods: 1) 20ml of extract was added to 5ml of HCL (10%). A volume of NH₄OH (10%) was added to this acidic medium to obtain a medium of PH=9 and boiled in a water bath then extracted with diethyl ether and concentrated with a rotary evaporator.5ml of HCL (2%) were added to the residue which later divided into two equal parts, the first was treated with a few drops of Mayer’s reagent and the second with Wagner’s reagent to observe occurrence of turbidity or precipitation. 2) Alkaloid by TLC: 10g of plant. Powder were wetted with 15 ml of NH₄OH (25%, m/m) at room temperature, then 300 ml of ethyl acetate were added and extracted for 72 h. The extract
was filtered and the solvent was evaporated in rotary evaporator under reduced pressure (40), the residue dissolved in distilled water and acidified with H$_2$SO$_4$ to pH 3-4 and extracted with petroleum ether and diethyl ether to remove lipophilic, acidic and natural materials. After basifying the aqueous solution to pH 9-10 with NH$_4$OH (25% m/m), it was extracted with chlorophorm, the extract washed with distilled water to neutral pH, dried with Na$_2$SO$_4$ and concentrated to dryness under reduce pressure to obtain crude alkaloids (Bruneton, 1999).

Already made plates were activated by heating in hot air oven at 120°C for 30 min; the plate was allowed to cool at room temperature and marked about 2 cm from the bottom as the origin. The working extracts were loaded on plates, and then development of chromatogram was run in saturated tank with benzene/methanol 1-80:20.

### 3.4.4 Determination of total carotenoids

Total carotenoids content were determined according to Jaeger et al. (2012). For carotenoids extraction, successive additions of 25 ml of acetone were made to obtain a paste of plant powder, which was transferred into a sintered funnel (5 micro ml) coupled to 250 ml Buchner flask and filtered under vacuum, this procedure was repeated three times or until the sample became colorless. The extract obtained was transferred to a 500 ml reparator funnel then 40 ml of petroleum ether were added. The acetone was removed through the slow addition of ultra-pure water to prevent emulsion formation. The aqueous phase was discarded. This procedure was repeated four times until no residual solvent remained. Then, the extract was transferred through a funnel to a 50 ml volumetric flask containing 15 g of anhydrous sodium sulfate. The volume was made up by petroleum ether; the total amount of carotenoids was determined using a spectrophotometer, at 450 nm. The total carotenoid content was calculated using the following formula:

$$\text{Carotenoids content(µg/g)} = \frac{A \times V(\text{ml}) \times 10^4}{A_{1%cm} \times P(\text{g})}$$

Where A= absorbance=total extract volume; P=sample weight; A$_{1%}$cm=2592(β-carotene Extinction coefficient in petroleum ether)
3.5 Statistical analysis

The Statistical analysis was carried out using Analysis of variance (ANOVA). Duncan’s Multiple Range Test (DMRT) was used to separate the means.
CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Chemical composition of cactus (*Opuntia ficus indica* var. *inerms*)

Table 4.1 shows the chemical composition and metabolizable energy of cactus cladodes grown in Wadalshafie, Alhasheisa and Barakat area. From the results it was obvious that there were significant differences (P≤0.05) in DM content in cactus cladodes in different sites, sample collected from Alhasheisa and Barakat were similar in DM content (10.5%). In general, Wadalshafie had the highest value (15.1%). These results were higher than that reported by Hadj-Sadok *et al.* (2008). But were nearly similar to those reported by Lopez *et al.*, (2001) and Gebremariam *et al.* (2006). The difference in DM content maybe refereed to differences in soil type and climate. Generally, moisture content of cactus was inline with those reported by Firew *et al.* (2006), Gebremariam *et al.* (2006), Feugang *et al.* (2006) and Alary *et al.* (2007). A significant difference (P≤0.05) was observed in ash content in cactus cladodes; it ranged between 7 and 15.4%. Cactus grown in Alhasheisa had the highest ash content but those collected from Barakat showed the lowest value. The results showed that ash content of cactus agreed with those reported by Hernandez-Urbiola *et al.* (2010), however, it is lower than that reported by Nefzaoui and Ben Salem (2001 and 2002). Ether extract content of cactus ranged between 6.8 and 8.1%, it was significantly different (P≤0.05) in cactus cladodes in different sites, sample collected from Wadalsafie had the highest EE content, on the other hand, Alhasheisa and Barakat samples were similar in EE content. The results showed that ether extract of cactus was higher than that reported by Zeeman (2005). Cactus cladodes grown in Wadalshafie, Alhasheisa and Barakat areas were significantly different (P≤0.05) in CF content. However, CF content in Wadalshafie and Alhasheisa samples were nearly similar, cactus cladodes grown in Barakat had the highest value. CF content ranged between 3.8 and 4.7%, these results were in contrast to those reported by Feugang *et al.* (2006). Crude protein content ranged between 3.7 and 5%, showed significant differences (P≤0.05). In general, Barakat cladodes had the highest CP content, while Alhasheisa and Wadalshafie samples showed the lowest values. These results were in line with that reported by Nefzaoui and Ben Salem (2001), Tegegne (2001). Ben
Salem et al. (2002a) Batista et al. (2003) and Nefzou (2010), Cactus cladodes grown in Wadalshafie, Alhasaheisa and Barakat, showed significant differences (P≤0.05) in their NFE content. It ranged between 70.6% and 76.7%. Barakat sample had the highest value. Alhasaheisa and Wadalshafie cladodes were nearly similar in NFE content. On the other hand All Cactus cladodes were not significantly different (P≤0.05) in their sugar content, it ranged from 0.04 to 0.1 %. It could be observed that sugar content of cactus cladodes were nearly similar to the findings of Salim et al. (2009) and lower than that reported by El-Samahy et al. (2006). In general, differences in chemical composition of cactus cladodes grown in Wadalshafie, Alhasaheisa and Barakat may be due to the differences in soil type, climate and availability of water.

Cactus cladodes from different sites had similar ADF (14.7%) and NDF (32%) and HC (17.3%); they were not significantly different (P≤0.05). Moreover, ADF contents in cactus cladodes were lower than those reported by Tegegne (2001), Mengistu (2001), Nefzaouei and Ben Salem (2001) and Tikabo (2004). While NDF content of cactus cladodes was higher than that reported by Mengistu (2001) and Tikabo (2004), Table 4.1b.

With respect to metabolizable energy (ME) content, all cactus cladodes grown in different sites showed significant differences (P≤0.05) in ME content. The highest values were obtained from Barakat (13.7%) and Wadalshafie cladodes (13.1%) which were nearly similar. Alhasaheisa had lower value (12.6%). These findings were in contrast with Moreno-Álvarez et al. (2007) who found it higher than those.
Table (4.1a): Chemical composition (%) and energy content (ME, MJ/kg DM) of cactus (*Opuntia ficus indica* var. *inermis*) Wadalshafie, Alhasaheisa, and Barakat (mean± SD).

<table>
<thead>
<tr>
<th>Source of cactus</th>
<th>DM</th>
<th>Ash</th>
<th>EE</th>
<th>CF</th>
<th>CP</th>
<th>NFE</th>
<th>ME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wadalshafie</td>
<td>15.1±0.6</td>
<td>13.0±0.1</td>
<td>8.1±2.1</td>
<td>3.9±0.2</td>
<td>3.8±0.1</td>
<td>71.3±0.6</td>
<td>13.1±0.2</td>
</tr>
<tr>
<td>Alhasaheisa</td>
<td>10.5±0.2</td>
<td>15.4±0.3</td>
<td>6.8±0.5</td>
<td>3.8±0.2</td>
<td>3.7±0.3</td>
<td>70.6±0.6</td>
<td>12.6±0.4</td>
</tr>
<tr>
<td>Barakat</td>
<td>10.5±0.2</td>
<td>7.0±0.5</td>
<td>6.8±0.4</td>
<td>4.7±0.6</td>
<td>5.0±0.2</td>
<td>76.7±0.2</td>
<td>13.7±0.3</td>
</tr>
</tbody>
</table>

Means with different letters in the same column were significantly different (P≤0.05).

Table (4.1b): Sugar, Acid detergent fiber (ADF), neutral detergent fiber (NDF) and Hemicellulose of cactus (*Opuntia ficus indica* var. *inermis*) Wadalshafie, Alhasaheisa, and Barakat (mean± SD).

<table>
<thead>
<tr>
<th>Source of cactus</th>
<th>Sugar</th>
<th>ADF</th>
<th>NDF</th>
<th>HC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wadalshafie</td>
<td>0.4±0.5</td>
<td>14.7±0.0</td>
<td>32.0±0.0</td>
<td>17.3±0.0</td>
</tr>
<tr>
<td>Alhasaheisa</td>
<td>0.1±0.02</td>
<td>14.7±0.0</td>
<td>32.0±0.0</td>
<td>17.3±0.0</td>
</tr>
<tr>
<td>Barakat</td>
<td>0.04±0.01</td>
<td>14.7±0.0</td>
<td>32.0±0.0</td>
<td>17.3±0.0</td>
</tr>
<tr>
<td>Level of significant</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

4.2 Mineral composition (%) of Cactus (*Opuntia ficus indica* var. *inerms*)

Table 4.2 presents mineral composition of cactus cladodes grown in Wadalshafie, Alhasaheisa and Barakat area. Mineral content showed significant differences (P≤0.05) in cactus cladodes grown in Wadalshafie, Alhasaheisa and Barakat area, these differences maybe referred to differences in soil type and climate. Mondragon-Jacoboand Perez-Gonzalez, (2001) stated that soil and climate affect mineral content in cactus. Ca content of cactus cladodes grown in Wadalshafie, Alhasaheisa and Barakat area ranged from 2.3 to 2.8%, and they were not significantly different (P≤0.05) it could be observed that
cactus cladodes. Grown in Alhasaheisa and Barakat had similar values. These findings agreed with those reported by Nefzaoui and Ben Salem (2002) and Medina et al., (2007). On the other hand, P content had no significant differences in different sites. It ranged between 0.1% and 0.2%, these values agreed with Tegegne (2001), Nefzaoui and Ben Salem (2002) and Nefzoui (2010). Na content of cactus cladodes grown in Wadalshafie, Alhasaheisa and Barakat area, were approximately similar, it ranged between 1.2 and 1.4%. These values were lower than those cited by Nefzaoui and Ben Salem (2002).

From these results it was obvious that K contents of cactus cladodes grown in Wadalshafie, Alhasaheisa and Barakat area were significantly different (P≤0.05). Alhasaheisa sample showed the highest value (4%). With respect to Cl content in cactus cladodes in different sites, significant differences (P≤0.05) were found, Wadalshafie showed the highest value (17.5%). While Barakat had the lowest value (14.4%).

Table (4.2): Mineral composition (%) of cactus (Opuntia ficus indica var. inerms) Wadalshafie, Alhasaheisa, and Barakat (Mean ± SD).

<table>
<thead>
<tr>
<th>Source of cactus</th>
<th>Ca</th>
<th>P</th>
<th>K</th>
<th>Na</th>
<th>Cl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wadalshafie</td>
<td>2.8±0.3</td>
<td>0.1±0.01</td>
<td>3.6±0.06</td>
<td>1.2±0.01</td>
<td>17.5±1.2</td>
</tr>
<tr>
<td>Alhasaheisa</td>
<td>2.4±0.2</td>
<td>0.2±0.05</td>
<td>4.0±0.4</td>
<td>1.3±0.2</td>
<td>15.3±1.1</td>
</tr>
<tr>
<td>Barakat</td>
<td>2.3±0.3</td>
<td>0.1±0.01</td>
<td>3.3±0.2</td>
<td>1.4±0.2</td>
<td>14.4±1.1</td>
</tr>
</tbody>
</table>

Means with different letters in the same column were significantly different (P≤0.05).

Table (4.3) presents the anti-nutritional factors detected in cactus cladodes grown in Wadalshafie, Alhasaheisa and Barakat area. From the results it was obvious that there were no significant differences in Alkaloids content in cactus cladodes in different areas. In general, the contents of alkaloids were trace. These findings were similar to those reported by Negessea et al. (2009). Tannins were not detected in cactus cladodes which are grown in Wadalshafie, Alhasaheisa and Barakat area. The results were in contrast with those reported by González–Gómez et al. (2006), on the other hand, similar to Dib et al (2013) findings.

Moreover, total carotenoids value of cactus grown in Wadalshafie, Alhasaheisa and Barakat area ranged from 0.001 to 0.002%. The results revealed that no significant
differences in carotenoids values were found in different sites. The detected values were lower than that reported by Moreno-Álvarez et al. (2003). In general, Negessea et al. (2009) stated that young and mature cacti have low levels of secondary compounds.

Table (4.3): Anti-nutritional factors of cactus (Opuntia ficus indica var. inerms) Wadalshafie, Alhasheisa and Barakat (mean ±SD)

<table>
<thead>
<tr>
<th>Source of cactus</th>
<th>Alkaloids</th>
<th>Tannins</th>
<th>Total carotenoids(µg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wadalshfie</td>
<td>+</td>
<td>-</td>
<td>0.002±0.0</td>
</tr>
<tr>
<td>Alhasheisa</td>
<td>+</td>
<td>-</td>
<td>0.00±0.0</td>
</tr>
<tr>
<td>Barakat</td>
<td>+</td>
<td>-</td>
<td>0.001±0.0</td>
</tr>
<tr>
<td>Level of significant</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Table (4.4) presents the in vitro digestibility of DM and OM of cactus cladodes grown in the three different areas. The results revealed that the IVDMD and IVOMD were similar in all cactus cladodes. In general cactus cladodes were highly digestible in both ruminants and monogastric animals. The results of IVDMD were similar to those reported by Batista et al. (2003). While IVOMD of the cactus cladodes were higher than those reported by Nefzaoui and Ben Salem (2002), Ben Salem et al. (2002b), McMillan et al. (2002), Batista et al. (2003) and Zeeman (2005).

Table (4.4): In vitro DM and OM digestibility (%) of cactus (Opuntia ficus indica var. inerms) in ruminants and monogastric animals (mean ±SD).

<table>
<thead>
<tr>
<th>Source of cactus</th>
<th>In vitro digestibility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ruminants</td>
</tr>
<tr>
<td></td>
<td>DM</td>
</tr>
<tr>
<td>Wadalshfie</td>
<td>99±0.0</td>
</tr>
<tr>
<td>Alhasaheisa and Barakat</td>
<td>99±0.0</td>
</tr>
<tr>
<td>Level of significant</td>
<td>NS</td>
</tr>
</tbody>
</table>
CONCLUSIONS AND RECOMMENDATIONS

Conclusions
1. Cacti are rich in moisture, carbohydrates, low in protein content and free of anti-nutritional factors.
2. Cacti are valuable source of energy and highly digestible.

Recommendations
1. From these results, it is recommended to use cactus with low quality feeds to improve their nutritive value.
2. Further research must be done to assess the effect on cactus on animal performance.
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The Wealth of India. (2001). A Dictionary of Indian Raw Material & Industrial products, raw material, National Institute of Science Communication, CSIR, New Delhi, India, VIII, 100-104.


APPENDICES

Appendix (1): Cactus (*Opuntia ficus indica* var. *inerms*)
Appendix (2): Cactus (*Opuntia ficus indica* var. inerms) collection and preparation