

## NUTRITIONAL VALUE OF COMMONLY CONSUMED DESERT DATE TREE PRODUCTS

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### ABSTRACT

The desert date (*Balanites aegyptiaca*, Del. L.) is one of the neglected staple crops of growing importance in the drought and famine-prone areas of Uganda. Unfortunately, information on its nutritional composition is still lacking, thus limiting their wider use and promotion. This study was designed to determine the nutritional composition of various parts of *B. aegyptiaca* eaten by Ugandans. Samples were collected from Katakwi, Adjumani and Moroto districts in Uganda. Dry matter content of the leaves, flowers and fruit pulp ranged from 95% in fruit pulp, to 98% in leaves and flowers. Ash content of the leaves and flowers was 8.07%; while that of the fruit pulp was 6.97%. Fat content of the leaves (2.29%) was significantly higher than that in fruit pulp (0.37%). Similarly, crude protein content was greater in the leaves and flowers (16.95%) than in the fruit pulp (5.4%). The leaves and flowers were generally richer in macronutrients than in fruit pulp in the order of K>Na>Mg with mean values of 19.54, 3.32 and 1.26 mg g<sup>-1</sup>. Iron was the most abundant micronutrient in all *Balanites* parts. This was followed by Mn, Zn and Cu with mean values of 452.21, 60.65, 35.69 and 25.49 µg g<sup>-1</sup>, respectively. A similar trend was found in fruit pulp. There is a need to determine the level of anti-nutritional factors in *Balanites* products and the effect of different leaf preparation methods on nutrient availability to further guide their wide usage.

**Key Words:** *Balanites aegyptiaca*, crude fat, crude protein, Uganda

### RÉSUMÉ

Le dattier du désert (*Balanites aegyptiaca*, Del. L.) est une culture de base négligée qui croît dans les milieux à sécheresse et sujets aux famines en Ouganda. Malheureusement, l'information sur sa composition nutritionnelle est encore manquante, ainsi limitant son utilisation et sa promotion. Cette étude a été conduite pour déterminer la composition de *B. aegyptiaca* dans différentes parties consommées par les ougandais. Des échantillons étaient collectés dans les districts de Katakwi, Adjumani et Moroto en Ouganda. Le contenu en matière sèche des feuilles, des fleurs et des pulpes de fruits variait de 95% dans les pulpes de fruits, à 98% dans les feuilles et fleurs. Le contenu en cendre des feuilles et fleurs était 8.07% et 6.97% dans les pulpes de fruits. Le contenu en matières grasses dans les feuilles (2.29%) était significativement plus élevée que celui des pulpes de fruits (0.37%). De façon similaire, le contenu en protéine brute des fleurs était plus élevé dans les feuilles et fleurs (16.95%) que dans la pulpe de fruits (5.4%). Les feuilles et les fleurs étaient généralement plus riches en macronutriments que dans la pulpe de fruits dans l'ordre de K>Na>Mg avec de valeurs moyennes de 19.54, 3.32 et 1.26 mg g<sup>-1</sup>. Le fer était le micronutriments plus abondant dans toutes les parties de *balanites*. Ceci était suivi de Mn, Zn et Cu avec pour

valeurs moyennes 452.21, 60.65, 35.69 et 25.49  $\mu\text{g g}^{-1}$ , respectivement. Une tendance similaire était observée dans la pulpe de fruits. Le besoin s'impose de déterminer le niveau des facteurs anti-nutritionnels dans les produits de *Balanites* et l'effet de différentes méthodes de préparation des feuilles sur la disponibilité de nutriments pour guider leur vaste usage.

*Mots Clés:* *Balanites aegyptiaca*, matière grasse brute, Protéine brute, Ouganda

## INTRODUCTION

*Balanites* leaves, flowers, fruits and oil have been utilised for many generations by both rural and peri-urban communities across the *Balanites* range in dryland Africa (Hall and Walker, 1991). In Uganda, the young succulent leaves are eaten as dry season vegetable by the Iteso ethnic group, while the fruits and oil are popular among the Madi, Lugbra and Karamojong (Katende *et al.*, 1999; Teklehaimanot, 2008). These products are also traded in both local and urban markets in Karamoja, Teso and West Nile sub-regions of Uganda (Katende *et al.*, 1999), thus providing an income and a source of livelihood to many rural households.

Because of its hidden potential, *B. aegyptiaca* has been described as one of the underutilised and neglected indigenous species in the drylands of eastern Africa (Chikamai *et al.*, 2005; Teklehaimanot, 2008). A report by the National Research Council of US, ranked *B. aegyptiaca* among the 24 priority lost "crops" of Africa and called for a concerted effort to develop its true potential using modern capabilities (NRC, 2008). The report indicates that although *B. aegyptiaca* produces the necessities of life in one of the world's most difficult zones of existence (drylands), its full potential has not been explored.

Barminas *et al.* (1998) noted that in many developing countries, frequent food shortages and high cost of cultivated green leafy vegetables results in frequent consumption of wild leafy vegetables especially in the rural communities. The vegetables supply calories and nutrients during dry season when there is shortage of cultivated green vegetables and other food resources. According to Baumer (1995), knowledge of nutritional composition of such wild foods could improve their utilisation prospect. Kubmarawa *et al.* (2008) observed that *B. aegyptiaca* falls in the category of such plants yet it is popular among certain communities

throughout its range in Africa. Understanding their nutritional and anti-nutritional composition permits better assessment of their importance to the well-being of communities that consume them.

Understanding the nutritional value of *Balanites* leaves, fruits and oil that are commonly consumed and traded will contribute to unlocking its hidden potential. This is essential in the current emerging efforts to promote increased use and commercialisation of *B. aegyptiaca* and other wild food resources for poverty alleviation. If adequately exploited, *Balanites* products offer great opportunity to reduce malnutrition, contribute to food security and reduce poverty among dryland communities. This will also help in understanding its nutritional value among households that are dependent on the products for up to five months every year.

According to the National Research Council of US, *B. aegyptiaca* products could provide raw materials for small and medium-scale enterprises otherwise inconceivable in the dry areas where it grows (NRC, 2008). In a study of the nutritional composition of wild food plants (including *B. aegyptiaca*) in West Africa, Cook *et al.* (1998) noted that nutritional information could widen the food choices for populations inhabiting the Sahel and other dryland regions of the world. They also reported that knowledge of the comparative nutrient values of wild edible plants could serve as a basis for creating awareness among governmental and non-governmental organisations about which plants to conserve and propagate for times of food shortage. Such information could be disseminated to increase knowledge of the nutritional worthiness of certain plants to households in rural areas where the health benefits would be most beneficial (Cook *et al.*, 1998). The objective of this study was to determine the nutritional composition of *B. aegyptiaca* edible parts in Uganda so as to promote their wider utilisation.

## MATERIALS AND METHODS

**Study area.** This study was conducted in the eastern and northern parts of Uganda, specifically in the districts of Katakwi (Iteso ethnic group), Moroto (Karamojong ethnic group) and Adjumani (Madi ethnic group), during 2008-2010 period. This region is located within the country's dry belt and *B. aegyptiaca* is of nutritional significance. People from Teso and Karamoja consume leaves and fruits. On the other hand, the Adjumani communities consume Balanites fruits and oil extracted from seed kernels. Different communities preserve and utilise the plant parts differently (Okia *et al.* (2011).

**Sample collection.** In consultation with the district forestry officials and community leaders, samples were collected based on their accessibility and availability. Leaf samples were only collected from Katakwi district where they are eaten as a leafy vegetable. Locally processed Balanites oil was collected from Adjumani district where it was available at the time of the study. Fruit samples were collected from all the three study sub-regions.

The local people, knowledgeable in superior quality leaf yielding trees, guided the identification of trees for leaf sample collection. About 2 kg of fresh leaves were collected from each of the three randomly selected trees. Leaf samples from each tree were sub-divided into two equal portions: one portion (1 kg) was boiled in an earth pot with leaves fully submerged in water for three hours, the remaining water decanted and the boiled leaves left to cool, while the other portion was kept fresh. The leaves were boiled in an earth pot to mimic the farmer practice. One of the trees selected for leaf sampling was heavily flowered and as such, flowers that were found on the harvested twigs were collected as one of the samples. The reasons for failed flowering in some Balanites trees have not been well documented. Boiled (pre-cooked) leaf samples sold in a local market in Katakwi district were collected from three randomly selected traders on a market day. In each locality, ripe fruits were collected from 10 randomly selected healthy trees after natural fruit fall. These were mixed and a

sub-sample of about 3 kg was obtained and double tagged.

**Sample preparation.** Fresh weight of the leaf samples was taken before drying. The fruit epicarp was removed by hand and the mesocarp separated by peeling with a knife. Leaf and flower samples were then chopped, put on trays and dried in a forced draught oven (LEEC type Model FXC1) at 60°C for three days; while the fruit pulp and nuts were dried at the same temperature for seven days. Dry leaf and flower samples were ground in a blender, while the pulp was ground using a mortar and pestle due to its oily nature. Ground samples were kept in airtight containers prior to laboratory analysis.

**Analysis of samples.** Moisture content, dry Matter, total ash and crude fat were determined using methods described by AOAC (1990). Crude protein was determined using the micro-Kjeldhal method as described by FAO/WHO (1994). Calcium, sodium and potassium were determined using a flame photometer (Jenway, UK) while magnesium, iron, copper and zinc were determined using atomic absorption spectrophotometer as described by (AOAC, 1990).

**Data analysis.** A one-way analysis of variance (ANOVA) in SPSS Version 16 was used during data analysis. Where the null hypothesis was rejected in favour of the alternative, Scheffe's test (due to unequal sample size) was used to identify homogeneous subsets of means (Kleinbaum and Kupper, 1978).

## RESULTS

**Composition of *B. aegyptiaca* leaves, flowers and fruit pulp.** Results of the proximate analyses of *B. aegyptiaca* leaves, flowers and fruit pulp are presented in Table 1. The moisture content of leaves and flowers was lower (1.39 – 2.20%) than that of the fruit pulp (4.72 – 5.35%). Dry matter for all the samples was generally above 94%, varying from 94.7% in fruit pulp to 98.6% in leaves. The ash content in leaves, flowers and fruit pulp varied between 5.7 and 9.0% while the

TABLE 1. Proximate composition of *B. aegyptiaca* leaves, flowers and fruit pulp

Site/sample	N	Mean $\pm$ SE				
		MC (%)	Dry matter (%)	Ash (%)	Fat (%)	Crude protein (%)
<b>Leaves &amp; flowers*</b>						
Fresh leaves	6	1.76 $\pm$ 0.05 <sup>a</sup>	98.24 $\pm$ 0.05 <sup>b</sup>	8.69 $\pm$ 0.17 <sup>b</sup>	2.02 $\pm$ 0.05 <sup>b</sup>	14.24 $\pm$ 0.78 <sup>b</sup>
Boiled leaves	6	1.39 $\pm$ 0.14 <sup>a</sup>	98.61 $\pm$ 0.14 <sup>b</sup>	6.39 $\pm$ 0.14 <sup>ab</sup>	2.41 $\pm$ 0.18 <sup>bc</sup>	17.25 $\pm$ 0.39 <sup>bc</sup>
Market leaves	6	2.20 $\pm$ 0.28 <sup>a</sup>	97.80 $\pm$ 0.28 <sup>b</sup>	9.02 $\pm$ 0.84 <sup>b</sup>	2.00 $\pm$ 0.11 <sup>b</sup>	16.36 $\pm$ 0.77 <sup>bc</sup>
Fresh flowers	2	2.18 $\pm$ 0.12 <sup>a</sup>	97.82 $\pm$ 0.12 <sup>b</sup>	8.18 $\pm$ 0.01 <sup>ab</sup>	2.74 $\pm$ 0.15 <sup>c</sup>	19.96 $\pm$ 0.23 <sup>c</sup>
Mean		1.88	98.12	8.07	2.29	16.95
<b>Fruit pulp</b>						
Katakwi	4	5.35 $\pm$ 0.13 <sup>b</sup>	94.65 $\pm$ 0.13 <sup>a</sup>	7.26 $\pm$ 0.30 <sup>ab</sup>	0.43 $\pm$ 0.08 <sup>a</sup>	4.54 $\pm$ 0.16 <sup>a</sup>
Adjumani	4	5.10 $\pm$ 0.41 <sup>b</sup>	94.90 $\pm$ 0.41 <sup>a</sup>	7.90 $\pm$ 0.09 <sup>ab</sup>	0.30 $\pm$ 0.02 <sup>a</sup>	6.01 $\pm$ 0.30 <sup>a</sup>
Moroto	4	4.72 $\pm$ 0.95 <sup>b</sup>	95.28 $\pm$ 0.95 <sup>a</sup>	5.74 $\pm$ 0.08 <sup>a</sup>	0.37 $\pm$ 0.01 <sup>a</sup>	5.64 $\pm$ 0.68 <sup>a</sup>
Mean		5.055	94.94	6.97	0.37	5.40

Means for groups in homogeneous subsets are shown with similar letter (Scheffe's method,  $\alpha = 0.05$ )

SE = Standard error of the mean

\* Leaves and flowers were only collected from Katakwi district

fat content in leaves and flowers was higher (2.0 – 2.7%) than in fruit pulp (0.37%). Fat content was highest in flowers (2.7%) and crude protein was highest in flowers (19.96%) followed by leaves (14.2 – 17.3%) and lowest in fruit pulp (5.4%).

There were significant ( $P < 0.05$ ) differences between plant part samples in all the parameters observed. Comparison of means using Scheffe's method at  $\alpha = 0.05$  (Table 2) revealed that dry matter, moisture content, fat and crude protein varied significantly ( $P < 0.05$ ) between the leaves, flowers and the fruit pulp. There were no differences in means between fresh and boiled and/or market leaves. The flowers however, had significantly ( $P < 0.05$ ) higher fat and crude protein than fresh leaves. There was no difference in the fruit pulp contents across all the study sites.

**Mineral composition of leaves and fruit pulp.** The micro mineral composition, in different parts of *B. aegyptiaca*, is given in Table 2. The amount of K in fresh leaves (24.59 mg g<sup>-1</sup>) and flowers (28.67 mg g<sup>-1</sup>) was higher than in boiled and marketed leaves, 12.78 and 12.10 mg g<sup>-1</sup>, respectively. The amount of K in the fruit pulp was high and comparable to that in the fresh leaves and flowers, ranging between 24.78 -29.84 mg g<sup>-1</sup>. The Na content in leaves, flowers and fruit pulp ranged between 1.62 – 4.02 mg g<sup>-1</sup> while the magnesium content was  $< 1.0$  mg g<sup>-1</sup> in fruit pulp and ranged between 1.15 – 1.35 mg g<sup>-1</sup> in the leaves and flowers.

Iron was the most abundant among the micronutrients followed by manganese, zinc and copper in that order (Table 2). The iron content was less variable in the leaves, flowers and fruit pulp (427.05 – 493.92 mg g<sup>-1</sup>). Manganese was highest in the leaves (61.50 – 72.58  $\mu$ g g<sup>-1</sup>) followed by flowers (45.30  $\mu$ g g<sup>-1</sup>) and lowest in fruit pulp (27.78 – 35.73  $\mu$ g g<sup>-1</sup>). The amount of zinc was highest in the leaves (39.73 – 50.13  $\mu$ g g<sup>-1</sup>) followed by fruit pulp (28.48  $\mu$ g g<sup>-1</sup>) and lowest in flowers (10.75  $\mu$ g g<sup>-1</sup>). Copper was higher in the leaves and flowers (23.25 – 28.97  $\mu$ g g<sup>-1</sup>) than in fruit pulp (18.92  $\mu$ g g<sup>-1</sup>). The amount of Cu in fruit pulp varied across the three study sites from 13.78  $\mu$ g g<sup>-1</sup> in Adjumani district, 17.78  $\mu$ g g<sup>-1</sup> in Moroto district to 25.20  $\mu$ g g<sup>-1</sup> in Katakwi district.

There were significant ( $P < 0.05$ ) differences between plant part samples in all the parameters assessed except iron. Separation of means (Scheffe's method) showed that, among the macronutrients (K, Na and Mg), there was a significant ( $P < 0.05$ ) difference in the amount of magnesium in the leaves and fruit pulp. The amount of potassium in the flowers and fresh leaves was significantly ( $P < 0.05$ ) higher than that in boiled and market leaves. The flowers had significantly ( $P < 0.05$ ) lower amount of magnesium than all the leaf samples.

The amount of Mn was significantly ( $P < 0.05$ ) higher in leaves than in the fruit pulp (Table 2). Fruit pulp from Katakwi district had significantly ( $P < 0.05$ ) higher amount of Cu than that from Moroto and Adjumani districts. Magnesium was also significantly ( $P < 0.05$ ) higher in fresh leaves than in fresh flowers. The Zn content of all types of leaves was significantly ( $P < 0.05$ ) higher than that of the flowers.

## DISCUSSION

**Proximate composition of *B. aegyptiaca* leaves, flowers and fruit pulp.** Although *B. aegyptiaca* fruit pulp had significantly higher moisture content (5.06%) than the leaves and flowers (1.88%), all of them can be considered to have lower moisture content when compared with other fruits and vegetables (Lockett *et al.*, 2000). The dry matter content of leaves, flowers and fruit pulp was generally high, ranging from 95% in fruit pulp to 98% in leaves and flowers. Dietary study in northern Nigeria by Lockett *et al.* (2000) revealed equally high dry matter content in *B. aegyptiaca* fruits (90.9%). High dry matter content has also been reported in some of the commonly consumed vegetables in rural areas (Dhello *et al.*, 2006).

The low moisture content and high dry matter in Balanites products is not surprising given the hardy nature of the Balanites tree. The low moisture content suggests that all the three Balanites products could have a long shelf life, implying that products could be dried under ordinary conditions and kept for longer periods by households. This however, was not observed in the study areas since the scarcity of vegetables during the dry season means that all leaves

TABLE 2. Mineral compositions of *B. aegyptiaca* leaves, flowers and fruit pulp

Sample	Mean $\pm$ SE							
	K (mg g <sup>-1</sup> )	Na (mg g <sup>-1</sup> )	Mg (mg g <sup>-1</sup> )	Cu ( $\mu$ g g <sup>-1</sup> )	Mn ( $\mu$ g g <sup>-1</sup> )	Zn ( $\mu$ g g <sup>-1</sup> )	Fe ( $\mu$ g g <sup>-1</sup> )	
<b>*Leaves and flowers</b>								
Fresh leaves (n=6)	24.59 $\pm$ 0.99 <sup>b</sup>	3.26 $\pm$ 0.25 <sup>a</sup>	1.35 $\pm$ 0.03 <sup>d</sup>	24.82 $\pm$ 0.58 <sup>a</sup>	72.58 $\pm$ 6.55 <sup>c</sup>	39.73 $\pm$ 5.27 <sup>bc</sup>	436.58 $\pm$ 10.97 <sup>a</sup>	
Boiled leaves (n=6)	12.78 $\pm$ 0.89 <sup>a</sup>	4.02 $\pm$ 0.39 <sup>a</sup>	1.23 $\pm$ 0.02 <sup>cd</sup>	24.92 $\pm$ 0.44 <sup>a</sup>	61.50 $\pm$ 6.04 <sup>bc</sup>	42.15 $\pm$ 2.79 <sup>bc</sup>	427.05 $\pm$ 29.74 <sup>a</sup>	
Market leaves (n=6)	12.10 $\pm$ 1.34 <sup>a</sup>	3.66 $\pm$ 0.57 <sup>a</sup>	1.32 $\pm$ 0.04 <sup>d</sup>	28.97 $\pm$ 5.47 <sup>a</sup>	63.23 $\pm$ 4.17 <sup>bc</sup>	50.13 $\pm$ 3.97 <sup>d</sup>	473.05 $\pm$ 61.10 <sup>a</sup>	
Fresh flowers (n=2)	28.67 $\pm$ 0.94 <sup>b</sup>	2.35 $\pm$ 0.31 <sup>a</sup>	1.15 $\pm$ 0.05 <sup>bc</sup>	23.25 $\pm$ 0.95 <sup>a</sup>	45.30 $\pm$ 3.30 <sup>ab</sup>	10.75 $\pm$ 0.45 <sup>a</sup>	472.15 $\pm$ 07.85 <sup>a</sup>	
Mean	19.54	3.32	1.26	25.49	60.65	35.69	452.21	
<b>Fruit pulp</b>								
Katakwi (n=4)	27.11 $\pm$ 0.99 <sup>b</sup>	1.62 $\pm$ 0.50 <sup>a</sup>	0.93 $\pm$ 0.09 <sup>bc</sup>	25.20 $\pm$ 1.40 <sup>a</sup>	27.78 $\pm$ 2.68 <sup>a</sup>	28.55 $\pm$ 4.14 <sup>ab</sup>	433.40 $\pm$ 26.21 <sup>a</sup>	
Adjumani (n=4)	29.84 $\pm$ 1.16 <sup>b</sup>	3.20 $\pm$ 0.43 <sup>a</sup>	0.83 $\pm$ 0.11 <sup>ab</sup>	13.78 $\pm$ 0.58 <sup>b</sup>	35.73 $\pm$ 2.09 <sup>a</sup>	27.48 $\pm$ 1.26 <sup>ab</sup>	493.92 $\pm$ 49.29 <sup>a</sup>	
Moroto (n=4)	24.78 $\pm$ 1.77 <sup>b</sup>	2.19 $\pm$ 0.18 <sup>a</sup>	0.73 $\pm$ 0.08 <sup>a</sup>	17.78 $\pm$ 2.18 <sup>b</sup>	30.28 $\pm$ 1.95 <sup>a</sup>	29.40 $\pm$ 2.46 <sup>ab</sup>	475.70 $\pm$ 50.16 <sup>a</sup>	
Mean	27.24	2.34	0.83	18.92	31.26	28.48	467.67	

\*Leave and flower samples were only collected from Katakwi, where they are widely used and traded. Significantly different means within columns are shown with different letters in superscript (Scheffe's method,  $\alpha = 0.05$ )

harvested were consumed thus leaving no extra for storage. The high dry matter contents make these products appropriate foods for dry season or famine time in areas where they are found. The quantity of *Balanites* leaves was not greatly reduced by cooking. During severe famine, *Balanites* leaves are eaten as a major sauce and such high dry matter content reduces the length of starvation.

The ash content of *Balanites* leaves and flowers was 8.07% while that of the fruit pulp was 6.97%. Kubmarawa *et al.* (2008) reported ash content of 9.26% in leaves while Lockett *et al.* (2000) found higher ash content in leaves (12.27%) and a closely similar amount (7.42%) in fruit pulp. Hall and Walker (1991), citing several sources, reported an ash content of 2.4 – 6.9 % in fruit pulp of *Balanites*. This is closer to the ash content reported in other locally consumed leafy vegetables such as 4 – 5% in *Amaranthus hybridus* (Dhello *et al.*, 2006) although these are leaves of herbs and not trees. Since most fruits and vegetables tend to have an alkaline ash, the consumption of *Balanites* leaves, flowers and fruits can contribute to healthier diets by neutralising the effect of other acidic foods. Snyderhealth (2003) recommended that a diet should consist of at least 70 to 80% basic foods and with no more than 20 to 30% acidifying foods in order to maintain a balanced pH in the blood and tissues.

The fat content of *Balanites* leaves (2.29%) was significantly higher than that in fruit pulp (0.37%). Lockett *et al.* (2000) reported slightly higher values in Adamawa State, Nigeria, namely 3.34 and 1.34% for the leaves and fruits, respectively. Kubmarawa *et al.* (2008) also reported a similar fat content (2.9%) in *B. aegyptiaca* leaves collected from Adamawa State, Nigeria. In contrast, Cook *et al.* (1998) reported a much higher fat content in fruit pulp (14%) in Niger. Dougal *et al.* (1964) also reported a slightly higher fat content (6.6%) in Kenya while most of the earlier literature including, Abu-Al-Futuh (1983), Backer (1983) and Nour *et al.* (1985) reported the fat content of 0.1 – 0.7% in *Balanites* fruit pulp which are consistent with the findings of the present study. Dougal *et al.* (1964) and Backer (1983) reported a higher content of fat in the young shoots and leaves (1.5 – 4.2%) than in

the fruit pulp, further supporting the results of the present study. Omujal (2008) found fat content of 1.5 – 3.5% in shea pulp which compares well with that found in *Balanites* leaves and both of them are dryland fruit trees. This indicates that *Balanites* leaves and flowers are better sources of fats than fruit pulp.

Importance of lipids in human nutrition and health has been long known. Fats are a major source of energy for the body and aid in vitamin absorption and tissue development. They also play an important role as antioxidants (Anhwange *et al.*, 2004; NAS, 2005). In order for a body to meet its daily nutritional needs while minimising risk of chronic diseases, NAS (2005) recommended that adults should obtain 20 – 35% of their calories/energy from fat. Though the quantity of fat in *Balanites* leaves, flowers and fruits are somehow low (0.3 – 2.7%), this could still be vital as energy supplements during the dry season when alternatives are few. Moreover, their consumption could have a substantial cumulative effect thus sustaining rural diets. It is also important to remember that *Balanites* fruits are mainly consumed by the nutritionally vulnerable members of the community (children, women and elderly) whose health could be more compromised in their absence.

Similarly, crude protein content was significantly higher in *Balanites* leaves and flowers (16.95%) than in the fruit pulp (5.4%). The crude protein value in the leaves reported in this study is close to that reported by Kubmarawa *et al.* (2008) who found 15.86% in Niger but higher than that reported by Lockett *et al.* (2000) (7.88%) in Nigeria. However, Dougal *et al.* (1964) reported much higher protein content (20.8 – 27.5%) in Kenya. The protein content in the fruit pulp reported in the present study (5.4%) is generally within the range reported by Hall and Walker (1991), Cook *et al.* (1998) and Lockett *et al.* (2000) (3.2 – 8.5%). These levels of crude protein in both *Balanites* leaves and fruits are within the range reported for most tropical vegetables and fruits (Saka and Monthi, 1994; Omujal, 2008; Kubmarawa *et al.*, 2008). Thus, *Balanites* leaves, flowers and fruits are generally good sources of protein that compare well with other tropical leafy vegetables.

Proteins play an important role in nutrition and diet since they are the major structural components of all body cells. They function as enzymes, membrane carriers, hormones and provide energy. According to NAS (2005), the recommended daily allowance (RDA) for proteins is 0.8 g kg<sup>-1</sup> of body weight for adults and an increased value of 1.1 g kg<sup>-1</sup> of body weight for pregnant and breast feeding women. WHO (2007) recommended a slightly higher protein value of 0.83 g kg<sup>-1</sup> of body weight which translates to about 33 - 66 g day<sup>-1</sup> for adults and about 16.2 - 59.9 g day<sup>-1</sup> for boys and girls aged between 4 - 18 years. Christian and Ukhun (2006) noted that protein quality and quantity are major concerns in human diets. Protein deficiency causes growth retardation, muscles wasting, oedema, kwashiorkor and abnormal collection of fluids in the body (Anhwange *et al.*, 2004). According to WHO (2004), there is inadequate protein consumption in many developing countries, including Uganda. Wide-spread consumption of *Balanites* leaves during the dry season in Uganda supplements other protein sources such as beans, peas and groundnuts that are rare at such times.

**Mineral composition of *B. aegyptiaca* leaves, flowers and fruit pulp.** The level of macronutrients was generally higher in the leaves and flowers than in fruit pulp in the order of K>Na>Mg with mean values of 19.54, 3.32 and 1.26 mg g<sup>-1</sup> in leaves and flowers; respectively. The corresponding mean values in fruit pulp were 27.24, 2.34 and 0.83 mg g<sup>-1</sup>, respectively. Amounts of Mg reported here are close to those reported by Lockett *et al.* (2000) as 2.96 and 0.81 mg g<sup>-1</sup> in leaves and fruit pulp; respectively. Reports on other minerals are rare in literature. In the present study, pre-boiling of leaves appeared to reduce the amount of potassium while Na and Mg remained the same. At the same time, the amount of potassium in fresh leaves and flowers was significantly higher. Origin/sub-region of fruit pulp did not significantly affect the macronutrient contents found in *Balanites* fruit pulp.

Macronutrients are important in human diet because of their various functions in the body. For instance, sodium is vital for maintaining fluid volume, osmotic equilibrium and acid-base balance. Its deficiency during hot weather is

attributed to heavy work in hot climate (Christian and Ukhun, 2006). Magnesium functions as a cofactor of many enzymes involved in energy metabolism, protein synthesis, RNA and DNA synthesis and maintenance of electrical potential of nervous tissues and cell membranes (Al-Ghamdi *et al.*, 1994). Potassium is very important in the human body where, along with sodium, it regulates the water balance and the acid-base balance in the blood and tissues. In the nerve cells, sodium-potassium flux generates the electrical potential that aids the nerve impulses. A low Na/K ratio is recommended in a diet. In the drylands of Uganda, this can be achieved through consumption of *Balanites* leaves and pulp since potassium level is significantly higher than sodium.

Iron was the most abundant micronutrient in the *Balanites* leaves, flowers and pulp. Micronutrients in leaves and flowers were in the order Fe>Mn>Zn>Cu with mean values of 452.21, 60.65, 35.69 and 25.49 µg g<sup>-1</sup>, respectively. A similar trend was found in fruit pulp with mean values of 467.67, 31.26, 28.48 and 18.92 µg g<sup>-1</sup> for Fe, Mn, Zn and Cu, respectively. Lockett *et al.* (2000) also reported a higher level of Fe (579.3 µg g<sup>-1</sup>) in *Balanites* leaves but with lower levels of other trace elements than reported in this study. The levels of Zn and Cu were as low as 22.7 and 11.0 µg g<sup>-1</sup> respectively. Furthermore, the two studies by Lockett *et al.* (2000) and Kubmarawa *et al.* (2008) reported much lower levels of Mn, Zn and Cu than found in this study. More notable, is the great variability in the level of Fe, 58.0 - 120 µg g<sup>-1</sup> in fruit pulp compared to 579.3 µg g<sup>-1</sup> in leaves. In the present study, the level of Fe in pulp (467.67 µg g<sup>-1</sup>) was closely similar to that in leaves and flowers (452.21 µg g<sup>-1</sup>). A much higher content of copper was found in *Balanites* pulp (18.92 µg g<sup>-1</sup>) than that reported by Cook *et al.* (1998) [2.4 µg g<sup>-1</sup>].

The role of trace elements, including those reported above, in human nutrition and disease control cannot be over-emphasized. Even though they form a small proportion of the nutrients required by the body and do not contribute to the energy value of food, they are of great physiological importance particularly in body metabolism (Schwart, 1975; Saura-Calixto and Canellas, 1982; WHO, 2004; NAS, 2005). Iron is a

constituent of hemoglobin, myoglobin and a number of enzymes, which catalyse oxidation and reduction processes in body cells and its deficiency causes anaemia (Dallman, 1986; Christian and Ukhun, 2006). Availability of a significant amount of iron in *Balanites* leaves, flowers and pulp is therefore of nutritional and health benefit to dryland communities since their consumption during the dry season helps in reducing incidences of anaemia or need for iron supplementation among pregnant women. Zinc is an essential component of many enzymes participating in the synthesis and degradation of carbohydrates, lipids, proteins and nucleic acids as well as metabolism of other micronutrients. Zinc also plays a central role in the immune system by modulating increased susceptibility to infection (Aggarwal *et al.*, 2007; Prasad *et al.*, 2007). Due to this important role, Cook *et al.* (1998) commended the consumption of *Balanites* fruits in Niger for provision of zinc and other nutrients. They further observed that for people who live in the Sahel and other dry areas, especially children who are at risk of many microbial and parasitic infections, consumption of *Balanites* fruits could provide useful amounts of this critical micronutrient (Zn) to maintain their immune systems and reduce vulnerability to diseases.

The findings of the present study indicated that *Balanites* leaves commonly consumed by the rural populace of Katakwi district and other areas are not inferior to the conventional Ugandan vegetables. Although Kubmarawa *et al.* (2008) observed nutrient loss during blanching and cooking of vegetables, the present findings showed that pre-boiling of *Balanites* leaves before selling or direct household consumption had no effect on the amounts of both macro and micronutrients, except potassium. It is possible that the level of vitamins, not determined in this study, could be significantly reduced during the pre-boiling and washing of leaves. The effect of pre-boiling and squeezing of *Balanites* leaves on vitamin availability needs to be investigated in order to provide a basis for minimising losses.

Potassium was the most abundant macronutrient in the leaves, flowers and pulp. This is nutritionally significant because potassium plays a key role in neuro-muscular

function. The high quantity of potassium, sodium, magnesium, iron, manganese, zinc and copper make *Balanites* leaves, flowers and fruit excellent sources of macro and micronutrients. *Balanites* leaves should constitute diets of individuals with low levels of these minerals.

### CONCLUSION AND RECOMMENDATIONS

The results of this study revealed that *Balanites* leaves, flowers and fruit pulp are good sources of proteins, Fe, K, Mn, Zn and Cu thus contributing substantial amounts of macro and micronutrients to human diet. However, leaves and flowers were nutritionally superior to fruit pulp.

Nutritional information on *Balanites* leaves, flowers and fruit pulp reported here should prove useful to nutritionists, policy makers, development agencies and the general public in Uganda and elsewhere where nutrition and health benefits would be most beneficial in the following ways: (1) provide communities living in the drylands where *Balanites* is found with a basis to continue and/or increase consumption of *Balanites* products (2) be used to disseminate information on the nutritional worthiness of *Balanites* products (3) assist in eliminating negative perceptions about consumption of *Balanites* products so that they become part of the normal diet rather than being considered as 'famine' or 'poor people's food; (4) serve to educate government agencies and NGOs concerned with natural resources as well as dryland communities about the need to conserve indigenous plants such as *B. aegyptiaca* for multiple products and services.

Improved processing of the *Balanites* leaves for use outside the producing areas and exploring other uses of fruit pulp, for instance for making wine or other beverages could provide more income to dryland communities. There is also need to understand the level of anti-nutritional factors and the bioavailability of nutrients in these products so as to guide their wider use and possible commercialisation. The effect of storage and processing on the nutritional value of *Balanites* products also requires detailed investigation.

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