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Potential Nutritional Value of the Macrophyte *Vossia cuspidata* (Roxb.) Griff. (Poaceae) in a River Nile System, Egypt

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AQUATIC plants are of real interest for their nutritive value. The present study aimed at investigating the forage potentiality of the aquatic macrophyte *Vossia cuspidata* (Roxb.) Griff (Poaceae). Two islands in the River Nile system in Greater Cairo, Egypt were selected for sampling the leaf laminae from *V. cuspidata* in eighteen quadrates (0.5x 0.5m each) during February (winter), and August (summer) of 2017. The chemical analyses revealed that there were no significant differences between the contents of summer and winter leaves in their percentages of moisture, dry matter, ash, nitrogen-free extract, neutral detergent fibers, acid detergent fibers, acid detergent lignin, cellulose, and hemicellulose. The leaves were characterized by a high percentage of dry matter (DM, ≈ 92%), low moisture content (7.94-7.27% DM), high crude fibers (24.1-38.2%DM), moderate crude protein (7.2=19.2%), and low lipids content (1.7-2.0% DM). The plant is rich in many important elements (K, Ca, P, Cu, and Zn). The ratio of Ca/P (= 2.43) is within the adequate range for animal forage. The other parameters of the nutritive values of the leaves and their importance to animal feeding were discussed. The leaves of *V. cuspidata* are recommended as good forage for beef cattle and lactating cows.

Keywords: Aquatic plants, Animal forage, Hippo grass, Net energy, Nutritive quality, Total digestible nutrients.

Introduction

In any agricultural country, forage crops constitute an important part of the cultivated land. Moreover, it is well known that any stable agricultural system should include the cultivation of crop(s) for feeding animals either directly in the form of fresh parts, as silage, or dried in the form of hay (Newman, 2006). In arid and semiarid countries, the shortage of feed resources and their year-round supply represent serious problems, which suppress the improvement of livestock productivity (El Shaer, 2006; Olafadehan & Adewumi, 2009). For example, in Egypt, the animal feeding system depends on the cultivation of the key forage crop *Trifolium alexandrinum* (Egyptian clover), which is an annual winter legume (Shaltout et al., 2009; Salama & Zeid, 2016). However, the feed shortage remains by the demand for forage in summer and autumn.

The accurate knowledge of the forage quality-environment relationships could enable us to predict and/or select the best forage and to harvest it at the proper time. For a long time, studies have indicated that alternative feed resources can be obtained from wild plant species, which live in aquatic, saline, and desert environments (Shaltout et al., 2009; Al-Sodany et al., 2012; Galal et al., 2021a). Despite the serious negative environmental implications of the presence of aquatic plants (Shaltout et al., 2009), they have important benefits as animal feed, human food, sources of medicines, soil additives, fuel production, remediation of wastewater, water gardening, aquarium plants, etc. (NRC 2001; Ansari et al., 2020).

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The *V. cuspidata* (Hippo grass), is a C4 perennial emergent aquatic macrophyte, which belongs to Poaceae. It is mostly distributed in the rainforest areas of the world, such as Southeast Asia and Tropical Africa (Boulos, 2009). *V. cuspidata* distribution extends from Mongalla; located at Latitude 5°12ˈN, to Lake No at Latitude 9° 25ˈN). In Egypt, this species is a new invasive plant to the aquatic and riparian habitats and recorded in many sites in Cairo and Nile Delta (Shehata, 1996; Mahmoud et al., 2021a). Shehata (1996) indicates that this species has spread from its original habitats in the south at Sudd Swamps to other northern regions in Egypt within the same continent. The species had not been included in any Egyptian Flora or checklist before Boulos (2009). According to our observation, the species spreads in Lake Burullus, Egypt since 2009.

Despite there is extensive literature on the use of aquatic plants as fodder (e.g., Nafea, 2017), we noticed that there is only one paper that studied the nutritive value of *V. cuspidata* and the forage quality of the aerial shoots (leaf laminae + sheathing leaf bases + stems), and the belowground parts (rhizomes + roots) in polluted and non-polluted water canals in Cairo, Egypt (Galal et al., 2021a). Despite the data obtained in this valuable study, there is still missing information on the forage quality of the laminae of leaves alone. The maximum dry biomass of leaves was obtained in autumn and represents 53.54% of the total aboveground dry biomass of *V. cuspidata* along the River Nile (Farahat et al., 2021). According to our field observations, the stems of this species are not grazed by most field animals due to the presence of dense sharp needle-shaped hairs. Besides, in the study of Gala et al. (2021a), there are either underestimation or overestimation for some of the analyzed elements and parameters in contrast to the well-known facts about the chemical composition of plants as will be discussed in detail in the following sections. Therefore, we expect that the quality of *V. cuspidata* as animal forage would be higher if it consisted of hay made from leaves.

The aims of this study were to (1) Investigate the chemical composition of *V. cuspidata* leaves harvested in winter and summer from the mainstream of River Nile in Egypt, (2) Calculate the nutritive values of the leaves, and (3) Evaluate their suitability for forage production.

Materials and Methods

Study site

The study site lies in two islands in the southern part of the River Nile Delta in Greater Cairo, Egypt: Bin El Bahrain Island and Warraq Island (latitudes between 30^{0}06’43.47” -29^{0}58’45.31”N, longitudes between 31^{0}13’12.41”-31^{0}13’16.30”E). The study site belongs to the River Nile phytogeographical region in Egypt (Mahmoud et al., 2021a). Four microsites (terrace, slope, water edge, and open water) are studied along the riverbank according to Shaltout & El-Sheikh (1993). Terraces are the dry upper part of the riverbank, slopes are the declining part of the ground that extends from terraces to water edges, and water edge is the part of the riverbank, which is in direct contact with the open water. In the study area, the minimum winter air temperature was 6.2ºC in February, while the maximum summer air temperature was 33.3ºC in June. The relative humidity ranged from 63% in January to 59% in July. The sunshine hours ranged from 6.1 in January to 11.8 in July, while the global radiation ranged from 10.2 to 27.3MJ m^{-2} day^{-1} in January and July, respectively (Courtesy of the Egyptian Meteorological Organization 2020).

Plant sampling and analyses

In January and July of 2017, the leaves were sampled from *V. cuspidata* plants, which were growing in the two Nile Islands. On each island, three sites were randomly selected and assigned to represent the microsites where *V. cuspidata* showed the highest plant cover (slope, water edge, and open water) (Mahmoud, 2021a). At each site, samples of fully exposed sun leaves were hand-harvested from the third node on the shoots of *V. cuspidata* plants from three randomly distributed quadrates (0.5x 0.5m). The sampled leaves were mixed in one composite sample. The total number of composite samples obtained from the two islands was six. The samples were placed in plastic bags, stored in an icebox, and rapidly transported within an hour to the laboratory. The leaves of each replicate sample were carefully washed with deionized water, blotted dry, and separated into two groups: Fresh and freeze-dried leaves. Fresh leaves were placed on well-ventilated drying racks and left for air drying under laboratory conditions. The moisture content of the air-dried leaves was calculated and expressed as a percentage of the air-dried mass (to know moisture percentage in the leaves in the case if they were used as air-dried feed before presenting to the animal). The second group of leaves was freeze-dried since this method is excellent at preserving the bioactive compounds in many plant species (Thamkaew et al., 2020). The dry matter (DM) content of the leaves refers to the material remaining after removing water by freeze-drying 100 g of leaves.

Plant chemical analyses

The freeze-dried leaves were ground in a metal-free plastic mill and passed through 2-mm mesh size and finally stored in air-tight labeled plastic containers. For the winter and the summer variations of the chemical analyses of the freeze-dried leaves, 1g of milled samples was digested using sulphuric and perchloric acid mixture (Chapman & Pratt, 1961). The determination of K, Ca, total P, Cu and Zn were carried out in the extracts by using Inductively Coupled Plasma (ICP) Spectrometry (Ultima 2 JY Plasma). The instrumental settings and operational procedures were adjusted according to the manufacture`s user manual. Total K, Ca, P, Cu, and Zn were analyzed, and calculated as concentration percentage of biomass dry matter for each element.

The ash content was estimated by igniting ground leaves in a muffle furnace at 550ºC for 3 hours. Total nitrogen was determined by the Kjeldahl method, according to Chapman & Pratt (1961). The crude protein (CP) was calculated by multiplying the percentage of total nitrogen by the factor of 6.25. Ether extract (EE), which represents the total lipids or fats, was determined by extracting the plant material with diethyl ether in an intermittent Soxhlet extractor (Soxhlet Extractor Gerhardt, Germany) according to Allen (1989). The crude fiber (CF) was gravimetrically determined after chemical digestion and solubilization of other materials present (Allen, 1989). The nitrogen-free extract (NFE), which represents the total carbohydrates, was calculated in the freeze-dried leaves according to Le Houérou (1980) as follows:

NFE (%DM)= 100 – (CP + CF + Fat + Ash)

The digestible crude protein (DCP) was determined according to NRC (2001) as follows:

%Digestible crude protein (%DCP)= 0.85 X – 2.5,

where X= Crude protein % on DM basis.

The cell wall constituents (fiber fractions) are composed of neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined according to Goering & Van Soest (1994) and Van Soest et al. (1991). Meanwhile, hemicellulose and cellulose were calculated by difference as follows:

Hemicellulose= NDF – ADF

Cellulose= ADF – ADL

The gross energy (kcal kg^{-1} DM) was calculated according to Blaxter (1968) where each gram crude protein= 5.65kcal, each gram of fat= 9.40kcal, and each gram of crude fiber and carbohydrate= 4.15kcal.

The animal obtains its energy through feed and loses energy through heat, feces, urine, and gases (McDonald et al., 2011). Gross energy (GE) is the total energy released through the oxidation of the food, while digestible energy (DE) is the difference between GE taken by the animal and the energy of the material excreted in the feces. Moreover, the difference between the DE and the energy lost in the form of urine and the methane gas released by the rumen and the hind-gut microbes of the animal is the metabolizable energy (ME). The net energy (NE) is the ME content minus heat increment (HI) associated with metabolic utilization of ME and the energy cost of chewing, ingestion, digestion, and absorption of nutrients from the gut (Noblet, 2007).

The digestible energy (kcal kg^{-1} DM) was calculated according to NRC (2001) as follows:

Digestible energy (DE)= Gross energy x 0.76.

The metabolizable energy (kcal kg^{-1} DM) was calculated according to NRC (2001) as follows:

Metabolizable energy (ME)= Digestible energy x 0.82.

The net energy (kcal kg^{-1} DM) was calculated according to NRC (2001) as follows:

Net energy (NE)= Metabolizable energy x 0.56.

The caloric values were expressed in Mcal kg^{-1}DM and finally converted to Mj kg^{-1}DM.

Total digestible nutrients (%) was calculated according to NRC (2001):

%Total digestible nutrients (TDN)= Digestible energy/ 44.3.

Data analysis

A one-way ANOVA test was used to test the significant differences between the seasonal nutrient elements in the leaves of *V. cuspidata* according to SPSS software (SPSS, 2012).

Results and Discussion

Chemical analysis of water and sediment

Water analysis shows that it was slightly alkaline, with low concentrations of soluble salts and macro-elements (K, Ca, P). The soil-water extracts of the sediment were slightly alkaline and its average concentrations of total soluble salts and macronutrients (K, Ca, P) were higher than those in water (Table 1). The average pH of the sediment= 7.41± 0.3, EC (ds/m)= 13.4± 2.7 and organic matter (OM%)= 0.29± 0.03 (Table 1). The elements' concentrations of sediment and water were considerably low. The chemical composition of water and sediment of the River Nile is subjected to seasonal variations due to the excess annual or seasonal variations in concentrations of heavy metals in the River Nile's water and sediment. This may be ascribed to several causes, such as excess water discharge into the River Nile during the high flood time, anthropogenic inputs, and living organisms (El-Hady, 2014).

Organic and inorganic nutrients of leaves

The low moisture content of the air-dry leaves of *V. cuspidata* (7.94-7.27% DM) (Table 2), implies that if the green leaves are air-dried to produce hay, the latter would possibly have a long shelf life and would be suitable for feeding animals. The high percentages of the dry matter in summer and winter leaves (92.73 ± 0.03 and 92.06± 0.49, respectively) are about six-folds that of the perennial grass *Pennisetum purpureum* (elephant grass), which contains 15.3% DM (Voltolini et al., 2008), and about 2.5 to 4 folds the dry matter of the forage grasses and legumes as reported by Amiri et al. (2012) (ranged from 19.21 to 32.76% DM). On the contrary, the dry matter content of *V. cuspidata* leaves is lower than that of the nutritious leguminous species *Leucaena esculenta*, L. *diversifolia*, L. *pallida*, and *Calliandra calothysus* (95% DM, Nherera et al., 1999). Mahmoud et al. (2021b) reported that *V. cuspidata* started its growth in winter by forming shoots and reached its maximum growth in autumn. They found that in the different microsites along the River Nile banks, the biomass dry matter production of leaves of the target species is minimum in March while its maximum was obtained in September or October (326.6g DWm^{-2} on slopes, 303.6g DWm^{-2} in water edges and 246.6g DWm^{-2} in open water, respectively).

There was a significant increase in the crude protein (CP) content in *V. cuspidata* leaves from summer to winter (Table 2). The lowest CP content in summer (7.19 % DM), lies within the minimum protein in the animal diet (ranges between 6 to 12%DM) as reported by the Ministry of Agriculture, Fisheries and Food in England (MAFF, 1975). In summer, the low CP of *V. cuspidata* was higher than that reported by Lee (2018) from the grasses *Aristida adscensionis*, *Hyperrhenia hirta*, and *Chloris pycnothrix*; all amounted to 2%. The highest CP content in winter (19.20 %DM) is higher than the values reported in other species of Poaceae, such as *Phragmites australis* (10.20%DM; Kadi et al., 2012), *Echinochloa stagnina, Eichhornia crassipes,* and *Ceratophyllum demersum* (Shaltout et al. 2009) and *Ludwigia stolonifera* (Galal et al., 2021b). Moreover, the CP in winter leaves was comparable with the leguminous fodder crop *T. alexandrinum* (16.2% DM; Chauhan et al., 1980). Lee (2018) indicated that the forage plants grown in hot arid regions have low nutritive value compared to those grown in cooler and wetter regions.

TABLE 1. Sediment and water characteristics of the study area (as mean and standard deviation: SD) of *Vossia cuspidata* along the River Nile in Cairo, Egypt

Sediment	pH	EC (ds/m)	Elements (ppm)						
			N	P	Na	K	Ca	Mg	OM%
Mean	7.41	13.41	113.50	62.30	42.88	17.56	40.79	22.12	0.29
SD	0.30	2.72	49.16	0.26	101.43	59.56	52.46	34.08	0.03

Water	Elements (ppm)								
	pH	EC (dS/m)	NH^+_4	NO^-_3	P	Na	K	Ca	Mg
Mean	7.43	0.39	2.15	8.71	1.07	1.49	0.16	1.23	1.90
SD	0.13	0.04	0.90	2.88	0.28	0.29	0.14	0.13	0.21

TABLE 2. **Organic and inorganic nutrients (mean ± SD) of summer and winter leaves of *Vossia cuspidata* grown in the River Nile, Cairo, Egypt**

Unit	Nutrients	Summer	Winter	F-value	Significance
Dry matter basis (%)	Moisture content	7.27 ± 0.03	7.94 ± 0.49	2.7	ns
	Dry matter	92.73 ± 0.03	92.06 ± 0.49	2.7	ns
	Crude protein	7.19 ± 0.22	19.20 ± 1.73	61.8	*
	Crude fiber	38.24 ± 0.89	24.08 ± 2.27	6.5	ns
	Ether extract	1.67 ± 0.01	2.00 ± 0.39	39.0	*
	Nitrogen free extract	42.44 ± 2.34	40.97 ± 2.36	1.0	ns
	Ash	10.44 ± 2.90	13.73 ± 0.26	124.4	ns
%DM	K	0.82 ± 0.04	0.83 ± 0.06	2.3	ns
	Ca	0.34 ± 0.00	0.43± 0.009	0.0	ns
	P	0.14 ± 0.00	0.23 ± 0.007	0.0	*
mg/kg DM	Cu	3.00± 4.60	9.47 ± 8.01	3.0	*
	Zn	11.35 ± 0.25	10.15 ± 0.25	1.0	ns

ns= Not significant, *= Significant at P< 0.05.

Since *V. cuspidata* populations of this study grow in aquatic and wet banks of the River Nile system, they do not experience drought stress. Accordingly, during summer, the plants are exposed to hot-arid atmospheric conditions, high solar radiation intensity, or their combination. The low content of CP in summer leaves of *V. cuspidata* agrees with McDonald et al. (2011), who state that in mature and young grass, the crude protein contents varied between 30 to 300g kg^{-1}, respectively. In comparison to this study, Galal et al. (2021a) reported much lower CP values in winter (5.6%) in comparison to our study in the same season (19.2%) on the same species. One possible explanation for this conflict is that they have analyzed the protein in the shoots (stems and leaves) of the target species and not in the leaves only as we did in this study. It is well known that the stems of grasses are rich with ground tissue of parenchyma and high content of lignin in the sheaths of fibers surrounding the vascular bundles as well as the fibers in the subepidermal layers of ground tissue. All these structures possibly diluted the content of CP in the study of Galal et al. (2021a). Based on NRC (2000), the content of CP in the shoots of *V. cuspidata* reported by Galal et al. (2021a) is lower than the minimum values required for animals (6-12%).

Considering the crude protein requirements, the winter leaves of *V. cuspidata* tested here were suitable to meet the needs of growing and finishing calves and lactating and dry gestating cows (NRC, 2000). While the summer leaves are nearly adequate to meet the preferred range of 7-9% for dry gestating cows. Accordingly, the air-dried leaves of *V. cuspidata* can be a suitable source of feed protein.

Crude fibre (CF) estimates the insoluble residue of acid hydrolysis, followed by an alkaline one (Wu, 2018). It includes different cell wall fractions, which are resistant to the action of digestive enzymes. In the present study, the CF content in summer leaves of *V. cuspidata* (38.24% DM, Table 2) is higher than that reported in the shoots of some wild species inhabiting the banks of the watercourses in the Nile Delta, such as *P. australis* (29.9% DM) (El-Kady, 2000), *Cynodon dactylon* (20.5% DM), *Panicum repens* (27.3% DM) (Shaltout et al., 2013), and the above-ground shoots and the rhizomes and roots of the aquatic plant *L. stolonifera* (Galal et al., 2021b). Moreover, the range of CF contents in *V. cuspidata* leaves was higher than the mean CF content of temperate grasses (20.0%) and legumes (25.3%) (Norton, 1982). Galal et al. (2021a) reported that in winter, the CF in the shoots of *V. cuspidata* was 60.2%, which is about 2.4 folds of what we analyzed in the leaves in winter (24.08%). This also confirms that the high content of CF in the study of Galal et al. (2021a) was possibly attributed to the presence of fibers in the tissues of the analyzed shoot samples (i.e., stems and leaves).

The lipids (ether extract or EE) are the fraction of fats and fatty acid esters in plant tissues (Cherian, 2020). The percentages of EE in the leaves of *V. cuspidata* (Table 2) are much lower than those in the dry leaves of the grass *Pennisetum purpureum* (14.82% DM) (Okaraonye & Ikewuchi, 2009), but like alfalfa hay, but higher than corn stover (2.2%; Wei et al., 2018) and the shoots of *V. cuspidata* in the study of Galal et al. (2021a).

The nitrogen-free extracts (NFE = total carbohydrates) were not statistically different in the leaves of *V. cuspidata* (Table 2). They were lower than in the shoots of the aquatic species *E. stagnina* and *E. crassipes* (≈54%), and higher than *C. demersum* (33.4%) (Shaltout et al., 2009). To make a high-quality protein in the rumen of a lactating animal, the rumen microbes need to have energy from the carbohydrates and proteins (Wu, 2018). This study revealed that the values of the NFE in *V. cuspidata* are appropriate for a lactating cow (Batajoo & Shaver, 1994).

The ash content of the plant represents the inorganic residue of chemical elements remaining after ignition and/or oxidation of its organic matter. The ash content in summer leaves of the target species (10.44%, Table 2) is higher than that in the grazable shoots of the desert grass *Panicum turgidum* populations growing in the Aqaba gulf area in Sinai (9.1%; Heneidy, 1996) and the Eastern and Western desert of Egypt (7.7 – 8.8%; Heneidy & Halmy, 2009). On the contrary, the ash content in the winter leaves (13.73%) is comparable to the contents in other grasses inhabiting the watercourses of the Nile Delta in Egypt, such as *E. stagnina* (12.9%; Shaltout et al. 2009), *P. australis* (14.3%; Al-Sodany et al., 2012), and *Paspalidium geminatum* (13.6%; Mashaly et al., 2015).

The variations in the concentrations of macronutrient elements (K, Ca, and P) were statistically different only in the case of P (Table 2), which showed a high concentration in winter (0.23% DM) compared to summer (0.14% DM). In winter, the order for the macronutrient concentrations was K (0.83% DM) > Ca (0.43% DM) > P (0.23% DM). The K concentration in the leaves of the target species meets the requirements for growing cattle (0.3-0.4%) and gestating beef cows (0.5-0.7%) (Clanton, 1980).

The concentration of P and Ca in the shoots of the plant reported by Galal et al. (2021a) were more than two folds (4.1g k^{-1} and 10.2g kg^{-1}, respectively) compared with the result of the present study (2.3g k^{-1} and 4.3g kg^{-1}, respectively).

In comparison to the shoots of the grazable desert grass *P. turgidum*, the leaves of the target species showed lower contents of Ca and similar contents of P (Heneidy & Halmy, 2009). The contents of Ca and P in *V. cuspidata* leaves lie within the recommended range (0.12-0.25%) for growing and finishing cattle (NRC 2000). Studies have indicated that improper C/P ratios can lead to disturbance of skeletal health and productivity of the animal (Cherian, 2020). The ratio of Ca/P (= 2.43) in the leaves of *V. cuspidata* is within the adequate range (Ca/P = 2-3) that was proposed by Ayyad & Le Floc'h (1983) for the proper utilization of the animal forage.

There is no significant difference in Zn concentrations between summer and winter, while the concentration of Cu was significantly higher in winter than in summer leaf (Table 2). In winter, the concentration of Cu (9.47mg kg^{-1}) is adequate for the requirements of beef cattle diets, while the summer leaves, which contained 3mg kg^{-1} may meet the requirements of feedlot cattle (NRC, 2000). Since the contents of Zn in summer and winter leaves of *V. cuspidata* are lower than the recommended requirements for beef cattle (30mg kg^{-1}, NRC, 2000), it is evident that Zn supplementation may be needed to compensate for the deficiency in their Zn contents.

Nutritive value of the leaves

Since the acid-alkali extraction of CF results in the solubilization of some non-fiber components such as hemicellulose and acid-soluble lignin (Van Soest, 1994; Hassan et al., 2021), we followed the concepts of Mertens (1997), and Detmann & Filho (2010), who replaced the CF with NDF to express fibers in the feed. The CF, NDF, ADF, and ADL are inversely related to the plant's digestibility, i.e., the lower the CF, NDF, ADF, and ADL, the higher the plant's digestible energy (McDonald et al., 2011). The range of NDF in the leaves of *V. cuspidata* of this study (44.74-54.04% DM) (Table 3) was higher than the minimum values recommended for cows during early (25-29% DM) and late lactation (32-34% DM) (NRC 2001). In the present study, the contents of the NDF and ADF in summer and winter leaves (Table 3) were lower than the values reported by Salama & Zeid (2016) and Wei et al. (2018) for some plants species. Blümmel et al. (2019) reported that in six wheat straw types, the % of NDF and ADF ranges from 75 to 79.2%, and 46.5 to 50.8%, respectively). On the other hand, in winter leaves of *V. cuspidata*, the NDF and ADF contents were comparable to the forage legume trees *Acacia cochliacantha* (36.5%) and *Leucaena lanceolata* (32.1%) (Martínez-Martínez et al., 2012) and *T. alexandrinum* (Kholif et al., 2015).

The contents of cellulose in the leaves of *V. cuspidata* (25.79-36.31 %DM) were similar to the values recorded in other members of Poaceae, such as *Andropogon gayanus* (30%) (Odedire & Babayemi, 2008) and *Panicum maximum* (36.5%) (Das et al., 2016). It is known that the higher the lignin contents, the stronger it holds hemicellulose and cellulose. Van Soest (1994) indicated that a lignin content above 60g kg^{-1}DM (= 6% DM) would negatively affect the forage digestibility. It is concluded that the relatively low value of ADL in the winter leaves of *V. cuspidata* (5.6 %DM, Table 3) would not affect the digestibility of hemicellulose and cellulose. The hemicellulose contents in the leaves of *V. cuspidata* were lower than the values reported by Odedire & Babayemi (2008) for *P. maximum* (22%) and *A. gayanus* (21%).

The information on the palatability of *V. cuspidata* is based on Skerman & Riveros (1989) who indicated that the plant shoots provide a favorite fresh and dry pasture for the herbivorous animals in its native habitat in the African flood plains. Besides, the data on the digestibility included the digestible crude protein (DCP), total digestible nutrients (TDN), and caloric value, which is evaluated by various indices such as digestible energy (DE), metabolizable energy (ME), and net energy (NE) (NRC, 2001). DCP is the fraction of protein ingested and absorbed by the animal and not excreted in feces (Cherian, 2020). In the present study, the DCP varied from 3.61 to 13.82% DM in summer and winter leaves, respectively (Table 3). The lowest value was similar to the DCP in the shoots of the aquatic grass *E. stagnina* in winter (2.8%) and in the free-floating plant *E. crassipes* (3.7%) in summer (Shaltout et al., 2009). The value of DCP in the winter leaves of *V. cuspidata* (13.82%) is higher than that in the shoots of Egyptian clover (9%) (Shoukry, 1992).

The phrase "total digestible nutrients" (TDN) refers to the energy content of feeds available to animals (especially the ruminants) after the digestion losses have been deducted (Wu 2018). The calculated TDN values of *V. cuspidata* of this study (67.12 - 68.16%, Table 3) are higher than the values in the shoots of the two aquatic plants *E. crassipes* (54.2%) and *C. demersum* (48.6%) (Shaltout et al., 2009), the leaves of *P. australis* (41.58%, Al-Sodany et al., 2012), and the shoots (51.5%) of *L. stolonifera* (Galal et al., 2021b). This study reveals that the TDN of *V. cuspidata* has suitable contents for sheep (61.7% TDN, NRC 2000) and a mature dry gestating beef cow, which requires 55-60% TDN (Gill & Omokanye, 2016).

TABLE 3. Nutritive value (Mean ± SD) of summer and winter leaves of *Vossia cuspidata*

Unit	Nutritive value	Summer	Winter	F-value	Significance
% DM	NDF	54.04 ± 0.59	44.74 ± 1.49	6.4	ns
	ADF	44.31 ± 0.81	31.39 ± 2.07	6.5	ns
	ADL	8.00 ± 0.15	5.60 ± 0.38	6.4	ns
	Hemicellulose	9.73 ± 0.22	13.35 ± 0.58	6.9	ns
	Cellulose	36.31 ± 0.66	25.79 ± 1.69	6.6	ns
%	TDN	67.12 ± 2.02	68.18 ± 0.90	5.0	ns
	DCP	3.61 ± 0.19	13.82 ± 1.47	61.5	*
MJ kg^{-1}DM	Gross energy	16.37 ± 0.74	16.63 ± 0.22	11.3	ns
	Digestible energy	12.44 ± 0.37	12.64 ± 0.17	4.7	ns
	Metabolized energy	10.21 ± 0.31	10.38 ± 0.13	5.7	ns
	Net energy	5.71 ± 0.17	5.80 ± 0.08	4.5	ns

NDF: neutral detergent fibers, ADF: acid detergent fibers, ADL: acid detergent lignin, TDN: total digestible nutrients, DCP: digestible crude protein, TDN: total digestible nutrients, DE: digestible energy, ME: metabolized energy, NE: net energy and GE: gross energy. ns= not significant, *= significant at $p < 0.05$.

The values of GE of the summer and winter leaves of *V. cuspidata* (16.37 and 16.63MJ kg^{-1} DM, Table 3) are similar to those in the grazable shoots of 23 plant species in the Matruh area in the western part of the coastal Mediterranean region (16.69MJ kg^{-1} DM= 3.99Mcal kg^{-1} DM; Heneidy, 2002), and to the living shoots of the perennial grasses *C. dactylon* and *P. repens* (16.28 to 16.65MJ kg^{-1} DM= 3.89 to 3.98Mcal kg^{-1} DM; Shaltout et al., 2013).

Both DE and ME, as well as NE of *V. cuspidata* leaves, are higher than those in the leaves of *P. australis* inhabiting the northern Lake Burullus, Egypt (Al-Sodany et al., 2012), and the roots and shoots of the aquatic plant *L. stolonifera* (Galal et al., 2021b). The values of DE and ME in summer and winter leaves were higher than in the hay of alfalfa (*Medicago sativa*; DE and ME were 11.09 and 9.08MJ kg^{-1} DM, respectively (i.e., 2.65, and 2.17Mcal kg^{-1} DM, respectively) and red clover (*Trifolium pratense*; DE= 10.17, i.e., 2.43Mcal kg^{-1} DM, and ME= 10.17 i.e., 1.99Mcal kg^{-1} DM, respectively) (NRC, 2000).

Conclusions

Based on the comparisons of the chemical analyses and the caloric values of *V. cuspidata* leaves with several fodder species, the target species has an excellent feed value for beef cattle and lactating cows. The leaves of the species displayed high nutritive values and low contents of lignin and fibers. Besides, the digestible and metabolizable energies of the leaves revealed that they are comparable to those in the hay of the forage crops alfalfa and red clover, *P. australis*, and *P. turgidum*. The concentrations of copper in the leaves are not toxic for cattle since it is below the minimum tolerable values. We recommend adding zinc supplementation to the leaves of the *V. cuspidata* to compensate for the deficiency in their Zn contents

Conflict of interest: The authors have no conflicts of interest to declare.

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القيمة الغذائية المحتملة لنبات أم الصوف في نظام نـهر النيل، مصر

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تتميز النباتات المائيه بقيم غذائيه مرتفعه نظراً لقيمتها الغذائية. تهدف الدراسة الحالية إلى التحقق من الإمكانات العلفية لنبات أم الصوف (العائلة النجيلية) . تم اختيار جزيرتين في نظام نهر النيل في القاهرة الكبرى، مصر لأخذ عينات من أوراق نبات أم الصوف في ثمانية عشر مربعاً (0.5 × 0.5 م لكل منهما) خلال شهر فبراير (الشتاء) وأغسطس (صيف) 2017. كشفت التحليلات الكيميائية عدم وجود فروق معنوية بين محتويات أوراق الصيف والشتاء في نسب الرطوبة والمادة الجافة والرماد والمستخلص الخالي من النيتروجين وألياف المنظفات المتعادلة وألياف المنظفات الحمضية واللجنين الحمضي والسليلوز والهيميسليلوز. تميزت الأوراق بنسبة عالية من المادة الجافة (92٪ وزن جاف)، محتوى رطوبة منخفض (7.27-7.94٪ وزن جاف)، ألياف خام عالية (24.1-38.2٪ وزن جاف) ، بروتين خام معتدل (7.2-19.2٪) و محتوى منخفض من الدهون (1.7-2.0٪ وزن جاف). النبات غني بالعديد من العناصر المهمة (بوتاسيوم، كالسيوم، فسفور، نحاس وزنك). وجد أن نسبة الكالسيوم/ الفوسفور (= 2.43) تقع ضمن النطاق المناسب للأعلاف الحيوانية. تمت مناقشة المتغيرات الأخرى للقيم الغذائية للأوراق وأهميتها لتغذية الحيوانات. يوصى باستخدام أوراق أم الصوف كعلف جيد لأبقار اللحم والأبقار المرضعة.