NUTRIENTS AND NUTRITIONAL VALUE OF NINE *ALOE* SPECIES GROWN ON THE HIGHLANDS OF WESTERN SAUDI ARABIA

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Abstract. The present work compared nine *Aloe* species grown on the highlands of western Saudi Arabia depending on their nutrient contents and nutritive quality. The highest Ca and Na contents were recorded in the tissues of *Aloe hijacensis*, while the highest K and Mg were in *A. vera*, while the highest N and P contents were recorded in *A. armatissima* and *A. brunneodentata*, respectively. The highest nitrogen-free extract, total proteins and lipid contents were recorded in *A. castellorum, A. armatissima* and *A. parvicoma,* respectively, while the highest ash content and crude fibers in *A. sabaea*. The percentage of crude protein in the grazeable parts of all *Aloe* species except *A. parvicoma, A. castellorum* and *A. vera*, lie within the range required for the maintenance of animals, while the crude fiber content was quite low. *A. armatissima* had the highest value of digestible crude protein (DCP), while *A. parvicoma* had the highest value of the total digestible nutrients (TDN). Moreover, *A. castellorum* contributed to the highest values of digestible energy (DE), metabolized energy (ME) and net energy (NE). It seems that the nutritive values of all investigated species lie within the range of nutritive value of goat, dairy cattle, and beef cattle.
Keywords: *Aloes, forage quality, grazeable parts, inorganic elements, organic compounds*

Introduction

The species of *Aloe* L.*,* known as lily of desert, nature's gift, plant of immortality and medicine plants, are perennial, leaf-succulent xerophytes, which are plants that adapted to survive in areas of low or erratic precipitation accompanied with structural and physiological adaptations (Newton, 2001). They are exceptionally heterogeneous, and members of the genus are found in almost every possible habitat, ranging from arid deserts through grasslands and savannas to misty coasts and moist, tropical forests. In these disparate environments, aloes have morphologically become extremely variable and have, for instance, diversified into a wide spectrum of growth forms including geophytes, small rosette plants, shrubs, climbers and small to large trees (Smith and Van Wyk, 1991). Aloe plants grow very well if adequately protected from cold weather; where aloes are injured at 2°C and generally killed at −1°C (Reynolds, 2004).

Almost all *Aloe* species are considered to have medicinal and/or cosmetic value, but a few are poisonous (Klopper and Smith, 2013). They have been used as medicinal plants for centuries to treat both humans and domestic animals (Reynolds, 2004). The topical and internal effects of aloes have been known since ancient times, whereas Nefertite and Cleopatra, two Egyptian queens, used aloes as a beauty aid (Reynolds, 2004). In addition, Dioscorides used aloe as a drug to heal skin ailments and

hemorrhoids, and also Pliny the Elder, Celsus, Galen and other famous physicians used it to treat wounds and gastrointestinal disturbances, but no mention of aloes was made by either Hippocrates or Theophrastus (Shelton, 1991; Hennessee, 1998).

Some other uses are also based on the chemical content, where an insect repellent can be made by dried and burnt aloe leaves and similar preparations are used to protect animals against ticks and stored food against weevils (Newton and Vaughan, 1996). Some *Aloe* species are used to dye cloth and for making ink. The ash of dried *A. ferox* leaves is an ingredient in snuff prepared in some parts of South Africa. Aloes are not regarded as edible due to the bitter compounds in their leaves, but it was reported in South Africa that the leaves of *A. ferox* were used to make jam. However, flowers of various species are eaten in different parts of Africa. Young flowering shoots of *A. kraussii* and *A. minima* are eaten as raw vegetables by Zulus (Reynolds, 1950), who cook the flowers *of A. boylei, A. cooperi* and other species as a vegetable (Watt and Breyer-Brandwijk, 1962). It is reported that the flowers of *A. zebrina* have been used to make cakes (Reynolds, 1950). In West Africa, flowers of *A. macrocarpa* are eaten by various tribes and used as a seasoning herb in cooking (Reynolds, 1966). Moreover, Newton and Vaughan (1996) reported that the dried leaf material may be mixed with tea leaves in South Africa. Furthermore, *A. vera* seems to play an important role in promoting growth in chickens (Bejarand Colapo, 2005) or in their health management (Mwale et al., 2005). As concerns the broiler chickens, the supplementation of their basal diet with 600 mg·kg⁻¹ of Aloe powder, or Aloe water extract or Aloe ethanol extract or an extract mixture of all above, could improve production performance and immune function of male broilers, while the Aloe water extracts had better results than the others (Wang et al., 2007; Christaki and Florou-Paneri, 2010). Because *Aloe* species are often important to local people, there is considerable interest in the relationship among their use. The present work aims to compare between the nine *Aloe* species grown on the highlands of western Saudi Arabia depending on their Nutrients' content, besides their nutritive quality as fodder for animals.

Materials and methods

Species collection

Nine *Aloe* species were collected from different locations in the Kingdom of Saudi Arabia (Taif, Al-Baha, Abha and Jazan) to evaluate their nutrient contents and nutritional values (*Table 1*). These species are: *Aloe parvicoma* Lavranos & Collen., *Aloe x abhaica* Lavranos & Collen., *Aloe brunneodentata* Lavranos & Collen., *Aloe armatissima* Lavranos & Collen., *Aloe vera* var. *officinalis* (Forssk.) Baker, *Aloe sabaea* Schweinf., *Aloe Castellorum* Wood, *Aloe fleurentiniorum* Lavranos Newton and *Aloe hijazensis* Lavranos & Collen. Identification and nomenclature were carried out according to Migahid (1996), Collenette (1999), Chaudhary (2001). Many field visits were carried out to different locations in the kingdom to collect the target species (*Table 1*).

Chemical investigations

Inorganic elements

Three composite samples, from the leaves of each *Aloe* species, were taken from three different individuals, oven-dried at 70°C till constant weight, and then were

homogenized by grinding in a metal-free plastic mill and passed through a sieve of 2 mm mesh size (Ghazi et al., 2019). The total soluble nitrogen (N) was determined by Kjeldahl method, while P by molybdenum blue method using a spectrophotometer (CECIL CE 1021), and K was determined using a flame photometer (CORNING M410). A ground sample of 1 g was digested in 20 ml tri-acid mixture of HNO_3:H_2SO_4:$HClO_4$ (5:1:1, v/v/v) till a transparent color appeared. Plant digests were filtered through filter paper (Whatman no. 1) and diluted to 25 ml with double de-ionized water (Lu, 2000). Calcium, sodium, and potassium were analyzed using a flame photometer (CORNING M410); while magnesium was measured using atomic absorption photometer (Shimadzu AA-6200). All the above-mentioned procedures for plant analysis are outlined by Allen (1989). The instrument setting and operational conditions were done in accordance with the manufacturers' specifications.

Table 1. *Location and collection date of the nine study Aloe species*

Species	Date of collection	Location
Aloe parvicoma Lavranos & Collen.	18-1-2019	Al-Hawiya – Taif
Aloe x abhaica Lavranos & Collen.	18-1-2019	Al-Hawiya – Taif
Aloe brunneodentata Lavranos & Collen.	12/4/2019	Wadi Raidah, Asir
Aloe armatissima Lavranos & Collen.	13-7-2019	Al-Shafa – Taif
Aloe vera var. *officinalis* (Forssk.) Baker	12/12/2018	Taif & Abha
Aloe sabaea Schweinf.	26-6-2018	Jabal Shada - Al Bahah
Aloe castellorum Wood	21-5-2018	Jabal Fayfa, Jazan
Aloe fleurentiniorum Lavranos Newton	16-5-2018	Bani Malik, South Taif
Aloe hijazensis Lavranos & Collen	13-7-2019	Al-Bahah

Organic nutrients

Ash percentage was measured by ignition in muffle furnace by heating a gram of the dried sample at 550°C for 2 h until constant weight. Ether Extract (total lipids) was determined by extracting the plant with ether and crude fiber (CF) were determined by the Soxhlet extraction method (Allen, 1989). Crude protein (CP) was calculated by multiplying the insoluble nitrogen by the factor of 6.25 (Olberg, 1956). Digestible crude protein (DCP) was calculated according to *Equation 1* of Demarquilly and Weiss (1970):

$$DCP \text{ (as \% DM)} = 0.929 \text{ CP (in \%DM)} - 3.52 \qquad \text{(Eq.1)}$$

Carbohydrate content (nitrogen free extract, NFE) was calculated according to *Equation 2* of Le Houérou (1980):

$$NFE \text{ (as \% dry matter)} = 100 - (CP + CF + \text{crude fat} + \text{ash}) \qquad \text{(Eq.2)}$$

where CP = crude protein and CF = crude fiber. In addition, total digestible nutrients (TDNs) were estimated according to *Equation 3* applied by (Naga and El-Shazly, 1971):

$$TDN \text{ (as \% DM)} = 0.62 \ (100 + 1.25 \ EE) - PK \qquad \text{(Eq.3)}$$

where EE is the percentage of ether extract, P is the percentage of crude protein, and K is the coefficient that depends on the protein and fiber contents (0.7). Moreover, digestible energy (DE) was estimated following *Equation 4* (NRC, 1984):

$$DE \ (Mcal \ kg^{-1}) = 0.0504 \ CP \ (\%) + 0.077 \ EE \ (\%) + 0.02 \ CF \ (\%) + 0.000377 \ NFE^2 \ (\%) + 0.011 \ NFE \ (\%) - 0.152 \quad \text{(Eq.4)}$$

Metabolized energy (ME) is 0.82 DE (Garrett, 1980) and net energy (NE) is 1/2 ME. Gross energy (GE) was calculated following this equation (NRC, 1984):

$$GE \ (Kcal \ 100g^{-1}) = 5.72 CP + 9.5 EE + 4.79 \ CF + 4.03 NFE \quad \text{(Eq.5)}$$

Data analysis

The agglomerative clustering techniques, based on Euclidean distance and similarity coefficient (Kruskal, 1964), were applied to ensure that there was variation among the different collected *Aloe* specimens according to their chemical traits.

Statistical analysis

The variation in the chemical characteristics among the different study species were assessed using one-way analysis of variance (ANOVA 1), after testing the data for normality using goodness of fit test according to SPSS software (SPSS, 2006). A post-hoc test was applied according to (Duncan's test) when differences are significant.

Results and discussion

Inorganic nutrients

The statistical data resulted from the application of ANOVA I on the nutrients' content indicated significant variation in all inorganic elements among the nine study species (*Table 2*). It was found that the highest Ca and Na contents (40.35 and 33.15 mg g^{-1}, respectively) were recorded in the tissues of *A. hijacensis*, while the highest K and Mg (40.84 and 14.01 mg g^{-1}) were recorded in *A. vera* var. *officinalis*. Rajendran et al. (2007) and Mahor and Ali (2016) analyzed the inorganic elements in *A. vera*, which showed that concentrations of K, Mg and Na were more than 0.2 mg. They stated that P, K, Na and Ca are macro elements present in high amount in the leaves of *A. vera*. K and Na both are essential, since they play a crucial role in the cellular homeostasis (Pohl et al., 2013), however Ca is main component in bone and helpful for regulating skeletal and cardiac muscles contractions (Toyoshima et al., 2000). In addition, Mg is abundantly present in the human being (Pawar and Kamble, 2015); it plays crucial role in lipid membrane stabilization, replication, and metabolic processes (Yang et al., 2006; Payandeh et al., 2013). Moreover, the highest N content (1.71%) was recorded in *A. armatissima* and the highest P (0.72 and 0.63%) were recorded in *A. brunneodentata* and *A. verra*, respectively with no significant differences. However, the lowest N content (0.56%) was recorded in *A. parvicoma* tissues, and the lowest P (0.12, 0.19 and 0.24%) were recorded in *A. parvicoma, A. fleurentiniourom,* and *A. castellorum* tissues, respectively with no significant differences. On the other side, the lowest Ca, Mg and Na concentrations (12.07, 3.96 and 8.91 mg g^{-1}) were recorded in *A. brunneodentata,* while the lowest K (7.12 and 7.56 mg g^{-1}) was recorded in *A. sabaea* and *A.*

armatissima, respectively with no significant difference. Shah et al. (2016) in *A. vera* recorded lower contents of Ca, K, P, Mg and higher Na than the present study, while Adesuyi et al. (2012) recorded lower K, P, Mg and Na contents. According to Owoade and Adeoye (2016), the presence of these minerals N, P, K, Ca and Mg in Aloe plants shows that they are all important to the plant. Based on the present results, the study *Aloe* species can be considered rich sources of minerals.

According to Boudet and Riviere (1968), the Na, K, Ca, Mg and P contents of the study species meet the level required for the maintenance of animals. In addition, the above-ground tissues had Na, K, Ca and P contents that exceed the maximum tolerable level (NRC, 1984). Moreover, the concentration of inorganic nutrients is lower than that of the mean natural forage in the western Mediterranean coastal rangeland (El-Kady, 2002).

Table 2. *Variations in the inorganic elements (Mean ± SD) in the tissues of the nine Aloe species*

Species	Inorganic element					
	Total N	**Total P**	**K**	**Ca**	**Mg**	**Na**
	%		**mg g^{-1}**			
Aloe hijazensis	1.02 ± 0.02f	0.54 ± 0.1bc	21.39 ± 1.9b	40.35 ± 7.12a	7.12 ± 0.65e	33.15 ± 4.49a
Aloe castellorum	0.95 ± 0.03g	0.24 ± 0.05ef	14.07 ± 2.09c	29.25 ± 2.18c	10.35 ± 0.87c	25.15 ± 2.61b
Aloe fleurentiniorum	1.32 ± 0.1c	0.19 ± 0.03ef	8.21 ± 1.95de	30.39 ± 2.50c	6.54 ± 0.60e	19.14 ± 2.95d
Aloe sabaea	1.15 ± 0.05e	0.33 ± 0.07de	7.12 ± 0.23e	27.18 ± 3.90c	8.28 ± 0.31d	15.26 ± 1.73e
Aloe brunneodentata	1.46 ± 0.04b	0.72 ± 0.12a	19.11 ± 1.06b	12.07 ± 0.80f	3.96 ± 0.25f	8.91 ± 0.25f
Aloe vera var. *officinalis*	0.81 ± 0.02h	0.63 ± 0.08ab	40.84 ± 3.45a	36.41 ± 2.76b	14.01 ± 1.80a	16.22 ± 2.65e
Aloe abhaica	1.24 ± 0.03d	0.29 ± 0.07e	15.05 ± 1.15c	18.22 ± 3.21e	9.41 ± 1.50c	22.47 ± 1.47c
Aloe armatissima	1.71 ± 0.04a	0.47 ± 0.13cd	7.56 ± 0.44de	21.83 ± 1.42d	12.39 ± 1.80b	19.12 ± 1.97d
Aloe parvicoma	0.56 ± 0.03i	0.12 ± 0.04f	10.41 ± 0.54d	13.05 ± 1.65f	7.48 ± 0.43de	21.11 ± 2.29cd
F-value	**301.5***	**17.8***	**132.5***	**73.2***	**75.1***	**76.6***

Means with the same letters in the same column are not significant different (Duncan's test). * *p < 0.05*. Maximum and minimum values are underlined

Based on the inorganic nutrients' constituents of the nine Aloe species (*Fig. 1*), five clusters were produced from the application of the agglomerative clustering technique, which are: A) included A. hijacensis; B) included A. castellorum, A. fleurentiniorum, A. sabaea and A. armatissima; C) comprised A. abhaica and A. parvicoma; D) included A. brunneodentata; and E) comprised A. vera var. officinalis. It is worth to note that, no significant differences in some inorganic elements among A. castellorum, A. fleurentiniorum, A. sabaea, A. armatissima and A. parvicoma (*Table 2*). Moreover, the Wisconsin polar ordination confirmed the segregation of the study species into the same 5 clusters (*Fig. 2*). The statistical analysis represented by the post-hoc test (Duncan's test) revealed that there are significant differences in the inorganic elements among the study species with marked similarity between *A. castellorum, A. fleurentiniorum, A. sabaea* and *A. armatissima.*

### *Organic nutrients*

The statistical data of ANOVA I indicated significant variation in the organic nutrients among the nine Aloe species (*Table 3*). In addition, there are significant differences between the study species according to the post-hoc test. It was observed

that the highest nitrogen-free extract (NFE), total proteins and lipid contents (93.26, 10.71 and 0.73%) were recorded in the tissues of *A. castellorum, A. armatissima* and *A. parvicoma,* respectively. However, the highest ash content and crude fibers (0.41 and 3.22%) were recorded in *A. sabaea*. On the other side, *A. hijacensis, A. sabaea* and *A. armatissima* contributed the lowest values of crude fibers, lipid content and NFE (0.29, 0.03 and 87.98%, respectively), while *A. parvicoma* had the lowest ash content and total proteins (0.08 and 3.52%).
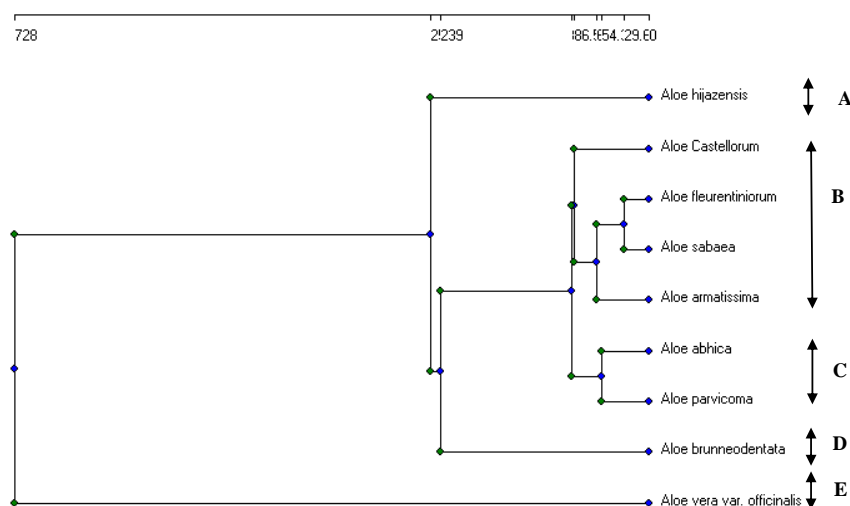
Figure 1. *The dendrogram resulting from the application of the agglomerative clustering technique on the inorganic constituents of the nine study Aloe species*
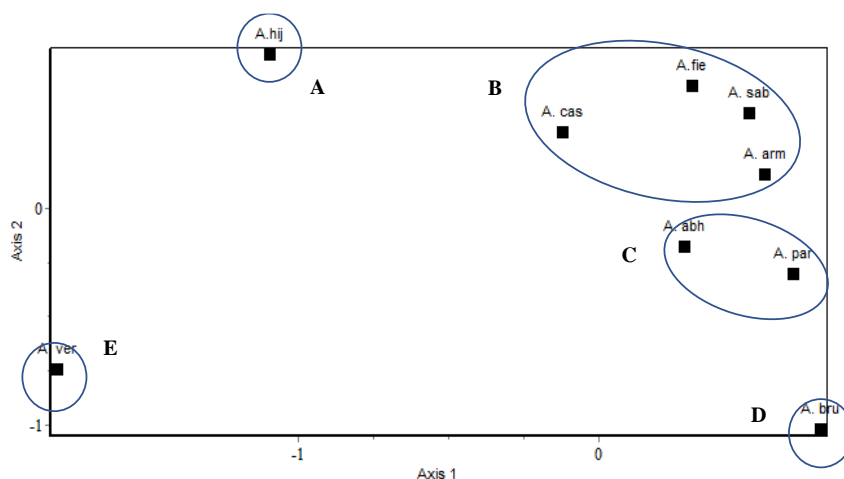
Figure 2. *Similarity ordination resulting from the application of non-metric similarity analysis on the inorganic constituents of the nine study Aloe species*

Añibarro-Ortega et al. (2019) recorded 50.1% dietary fibers and 37.4% carbohydrates, while Femenia et al. (1999) recorded 57.6% fibers in *A. vera* tissues. However, Miranda et al. (2009), Adesuyi et al. (2012), Ahmed and Hussain (2013) and Muñoz et al. (2015) reported 12.9, 7.8, 73.4 and 1.38% crude fibers, 4.2, 0.27, 2.91 and 2.07% fats 15.4-17.6, 2.4, 16.88 and 17.20% ash and 3.7-7.3, 4.7, 6.86 and 6.11%

protein content, respectively in the tissues of *A. vera*. Such compositional variations can be justified by the different geographical and edaphoclimatic conditions, where *Aloe* species were grown (Añibarro-Ortega et al., 2019).

Table 3. *Variations in the organic elements (Mean ± SD) in the tissues of the nine Aloe species*

| Species	Organic nutrient				
	EE	CF	Ash	TP	NFE
	%				
Aloe hijazensis	0.31 ± 0.04e	0.29 ± 0.03i	0.25 ± 0.04b	6.38 ± 0.13f	92.81 ± 11.47b
Aloe castellorum	0.13 ± 0.02g	0.47 ± 0.01h	0.22 ± 0.04b	5.92 ± 0.57g	93.26 ± 13.64a
Aloe fleurentiniorum	0.20 ± 0.01f	1.32 ± 0.03d	0.27 ± 0.06b	8.27 ± 1.26c	89.93 ± 3.75d
Aloe sabaea	0.03 ± 0.01h	3.22 ± 0.10a	0.41 ± 0.07a	7.19 ± 0.31e	89.14 ± 15.93e
Aloe brunneodentata	0.34 ± 0.01d	2.02 ± 0.04c	0.13 ± 0.03c	9.13 ± 0.25b	88.39 ± 3.78f
Aloe vera var. *officinalis*	0.61 ± 0.09b	1.02 ± 0.05e	0.23 ± 0.04b	5.06 ± 0.13h	93.07 ± 12.64ab
Aloe abhaica	0.20 ± 0.03f	0.64 ± 0.01g	0.14 ± 0.03c	7.75 ± 1.87d	91.27 ± 19.73c
Aloe armatissima	0.41 ± 0.06c	0.78 ± 0.01f	0.13 ± 0.04c	10.71 ± 2.60a	87.98 ± 12.58g
Aloe parvicoma	0.73 ± 0.03a	2.48 ± 0.65b	0.08 ± 0.03c	3.52 ± 0.19i	93.19 ± 12.59a
F-value	**176.7***	**205.7***	**15.7***	**301.5***	**328.9***

Means with the same letters in the same column are not significant different (Duncan's test). $* p < 0.05$. Maximum and minimum values are underlined
EE: ether extract, CF: crude fiber, TP: total protein, NFE: nitrogen free extract

Moreover, Adesuyi et al. (2012), Haque et al. (2014) and Muñoz et al. (2015) recorded 73.08, 56.3 and 50.41%, respectively carbohydrate content in *A. vera,* which is lower figure than those recorded in the present study. Carbohydrate is a good source that provide readily accessible fuel for physical performance and regulate nerve tissue (Whimey and Rolfes, 2005). They also recorded 19.5% ash content, which is higher than those recorded in the present study. Ash content reflects the mineral preserved in the sample represents the total mineral content essential for the proper functioning of the tissues and act as second messengers in some biological cascade mechanisms (Antia et al., 2006). Protein, which would be serve as enzymatic catalyst, mediate cell responses, control growth and cell differentiation (Whimey and Rolfes, 2005) was 10.50% in the tissues of *A. vera*, which is higher than that recorded for all investigated *Aloe* species except *A. armatissima* (10.71%). Furthermore, crude fat content was 1.83% (Haque et al., 2014), which is higher and 0.27% (Adesuyi et al., 2012), which is lower than those recorded in the present study. Fats are universally stored forms of energy in living organisms, and they are the major structural elements of biological membranes as phospholipids and sterols (Nelson and Cox, 2008).

As fodder availability and access is becoming limited, the response of farmers has been to keep fewer heads of cattle (Tabuti, 2009; Ghazi et al., 2019). According to Heneidy (2002), crude protein and crude fibers are considered as an indicator of the nutritional value of food for grazing animals. The percentage of crude protein in the grazeable parts of the *Aloe* species (3.52-10.72%), which indicated that all *Aloe* species except *A. parvicoma, A. castellorum* and *A. vera*, lie within the range (6-12% of forage dry matter) required for the maintenance of animals, while the crude fiber content was

quite low. Although the protein content in the tissues of the study species were in the maintenance requirement range, it did not exceed the value of *Trifolium alexandrinum* (16.2% Chauhan et al., 1980).

Based on the organic constituents of the study species, the agglomerative clustering technique produced 5 clusters (*Fig. 3*): A) included *A. castellorum, A. hijacensis* and *A. vera* var. *officinalis;* B) comprised *A. parvicoma*; C) comprised *A. fleurentiniorum* and *A.* abhaica; D) included A. sabaea; and E) included A. armatissima and A. brunneodentata. It is north noting that the statistical analysis confirmed that there are no significant differences among A. castellorum, A. hijacensis and A. vera var. officinalis. Moreover, the Wisconsin polar ordination confirmed the segregation of the study species into the same 5 clusters (*Fig. 4*). The statistical analysis represented by the post-hoc test (Duncan's test) revealed that there are significant differences in the organic nutrients among the study species.
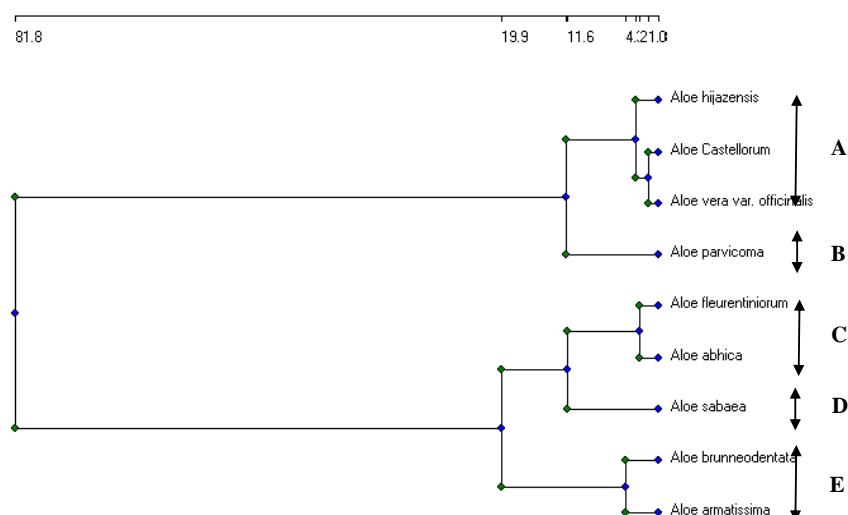
Figure 3. *The dendrogram resulting from the application of the agglomerative clustering technique on the organic constituents of the nine study Aloe species*
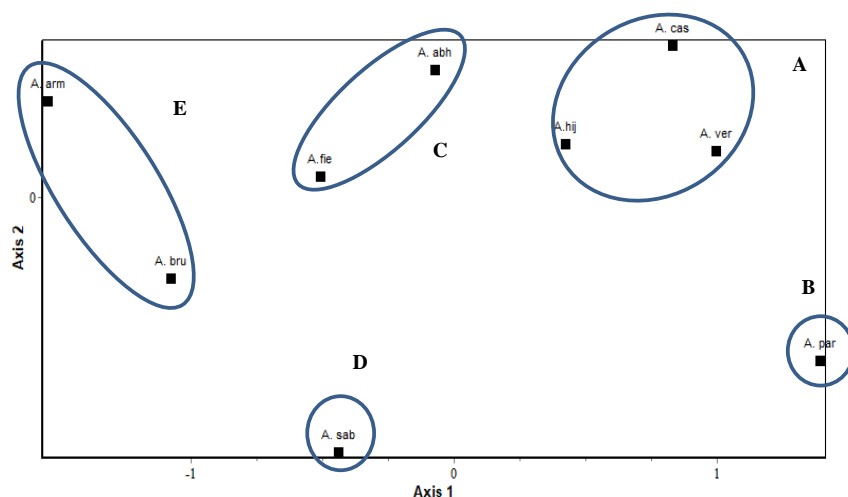
Figure 4. *Similarity ordination resulting from the application of non-metric similarity analysis on the organic constituents of the nine study Aloe species*

Nutritive value

According to the nutrient value of the study *Aloe* species (*Table 4*), it was found that *A. armatissima* had the highest value (6.43%) of digestible crude protein (DCP), while A. parvicoma had the highest value (60.33%) of the total digestible nutrients (TDN). On the other hand, the lowest DCP and TDN values (1.18 and 54.91%) were recorded in A. vera var. officinalis and A. armatissima, respectively. Moreover, A. castellorum contributed to the highest values of digestible energy (DE), metabolized energy (ME) and net energy (NE) (4.47, 3.67 and 1.83 Mcal kg⁻¹, respectively) with significant similar values for A. hijazensis and A. vera, while A. sabaea had the lowest (4.25, 3.49 and 1.74 Mcal kg⁻¹). Furthermore, the highest and lowest values of the gross energy (423.39 and 413.17 Mcal kg⁻¹) were recorded in the tissues of A. armatissima and A. castellorum, respectively. It is worth to note that there were no significant differences in the nutritive values of A. castellorum, A. hijacensis and A. vera var. officinalis. Añibarro-Ortega et al. (2019) recorded a low energy value (269 Mcal kg⁻¹) for A. vera plants.

***Table 4.** Variations in the nutritive value (Mean ± SD) of the nine Aloe species*

Species	Nutritive value					
	DCP	TDN	DE	ME	NE	GE
	%		Mcal kg⁻¹			
Aloe hijazensis	2.40±0.12f	57.95±4.86c	4.42±0.79a	3.62±0.64a	1.81±0.03a	415.28±12.41f
Aloe castellorum	1.98±0.15g	58.14±1.17c	4.47±0.78a	3.67±0.64a	1.83±0.32a	413.17±17.39g
Aloe fleurentiniorum	4.16±0.24c	56.50±1.98f	4.35±0.15d	3.56±0.12d	1.78±0.06d	417.99±5.88c
Aloe sabaea	3.16±0.29e	57.15±2.25d	4.25±0.32g	3.49±0.26g	1.74±0.13g	416.10±7.34e
Aloe brunneodentata	4.96±0.23b	55.99±1.72g	4.29±0.88f	3.52±0.72f	1.76±0.36f	421.29±3.80b
Aloe vera var. *officinalis*	1.18±0.12h	59.13±4.82b	4.46±0.77a	3.66±0.63a	1.83±0.31a	414.73±9.93f
Aloe abhaica	3.68±0.17d	56.88±1.39e	4.41±0.72c	3.62±0.59c	1.81±0.30c	417.13±8.98d
Aloe armatissima	6.43±0.24a	54.91±1.92h	4.32±0.01e	3.54±0.87e	1.77±0.43e	423.39±2.64a
Aloe parvicoma	1.75±0.18g	60.33±1.33a	4.43±0.78b	3.63±0.64b	1.82±0.32b	414.46±4.97f
F-value	**211.4***	**331.8***	**41.1***	**41.1***	**311.6***	**200.1***

Means with the same letters in the same column are not significant different (Duncan's test). * *p < 0.05*. Maximum and minimum values are underlined
DCP: digestible crude protein, TDN: total digestible nutrients, DE: digestible energy, ME: metabolized energy, NE: net energy and GE: gross energy

The total digestible nutrients (TDN) are an appropriate measure of the food energy available to animals only after the digestion losses have been deducted (El-Beheiry, 2009). The mean value of TDN of the above-ground parts of the study species meets the diet requirements of breeding cattle (50.0%; NRC, 1984), but not for sheep (61.7%; NRC, 1975). Moreover, the digestible energy of all species was higher figure than required (2.7 Mcal kg⁻¹) by sheep (NRC, 1985). In addition, the value of metabolized energy of the above-ground shoots was 3.49-3.67 Mcal kg⁻¹, which meet the requirement of sheep and breeding cattle (NRC, 1985, 1984) as well as the previous estimate (2.5 Mcal kg⁻¹) of *Trifolium alexandrinum* (Chauhan et al., 1980). It seems that the nutritive values of all investigated species lie within the range of nutritive value of goat (NRC, 1981), dairy cattle (NRC, 1978) and beef cattle (NRC, 1984).

According to Bachman et al. (2020), the major threats to *Aloe* species are the expansion and intensification of crop farming and livestock farming, but important additional threats include gathering of plants and the unintentional effects of logging and wood harvesting.

Regarding the nutritive values of the study *Aloe* species, the agglomerative clustering technique resulted in the segregation of 6 clusters (*Fig. 5*): A) included *A. hijacensis* and *A. sabaea;* B) included *A. fleurentiniorum* and *A. abhaica;* C) comprised *A. castelloru;* D) included *A. vera* var. *officinalis* and *A. parvicoma;* E) comprised *A. armatissima;* and F) comprised *A. brunneodentata.* Moreover, the Wisconsin polar ordination confirmed the segregation of the study species into the same 6 clusters (*Fig. 6*).
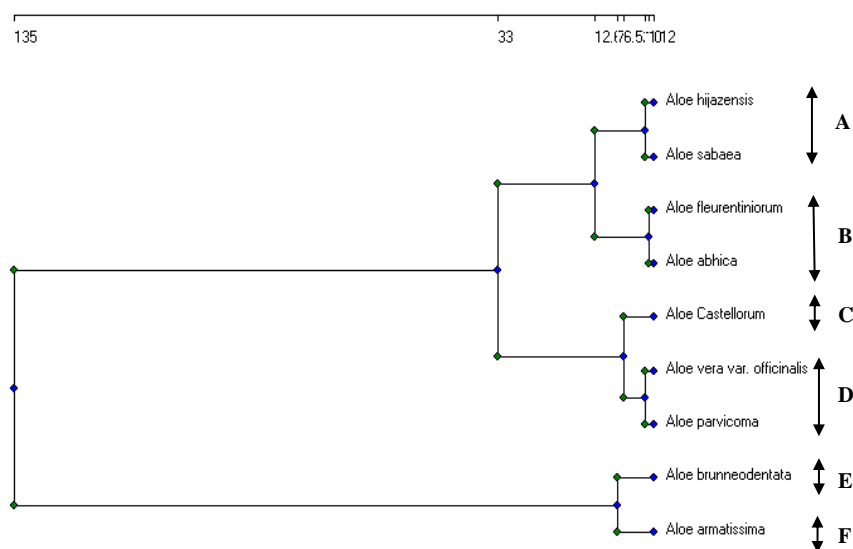
***Figure 5.** The dendrogram resulting from the application of the agglomerative clustering technique on the nutritive value of the nine study Aloe species*
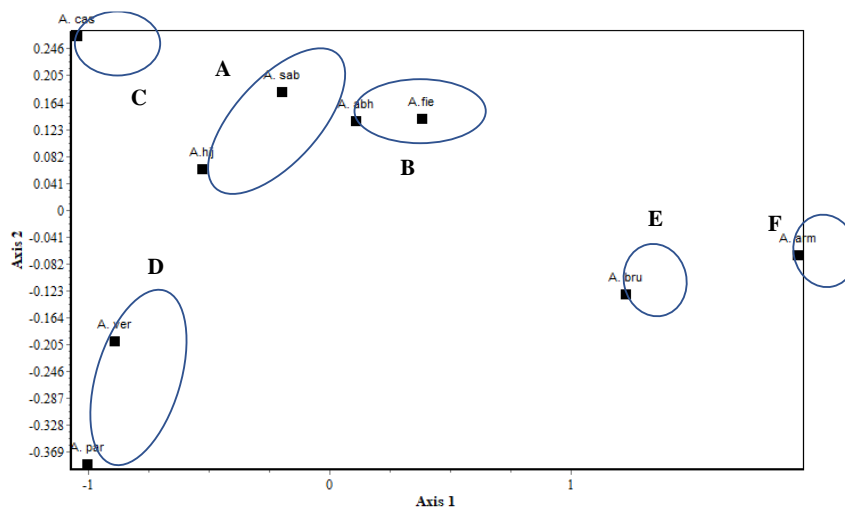
***Figure 6.** Similarity ordination resulting from the application of non-metric similarity analysis on the nutritive value of the nine study Aloe species*

Conclusion

There are significant differences in the inorganic and organic elements among the study species with marked similarity between *A. castellorum, A. fleurentiniorum, A.*

sabaea and *A. armatissima*. The results of proteins and carbohydrates indicated significant variation between the nine study Aloe species. The percentage of crude protein in the grazeable parts of all *Aloe* species except *A. parvicoma, A. castellorum* and *A. vera*, lie within the range required for the maintenance of animals, while the crude fiber content was quite low. The nutritive values of all investigated species lie within the range of nutritive value of goat, dairy cattle, and beef cattle. Under monitoring conditions, all the investigated species except the endemic *A. armatissima* can be daily used since they are available in considerable amounts, and over grazing significantly threat the species diversity.

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