Chapter 4

Halophytes as Forages

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Additional information is available at the end of the chapter

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Abstract

It is the chemical composition of the halophyte forages and the digestion process of these forages that matter. As the science gets more advanced and the information about these two points becomes clearer, the view of this information might modify our understanding to these processes. Then, some topics might be dropped, and others might be raised or become more obvious. However, the feeding of halophyte forages as per se has several drawbacks and therefore, they have to be fed in mixed rations, fortifying these rations with energy supplements.

Keywords: halophytes, forages, ruminants, feeding, nutritional values, plant secondary metabolites, protein, energy, rumen function, feed processing

1. Introduction

Halophytes are not a distinct taxonomic group. Halophytes are several species of trees, shrubs, forbs and grasses. They fall into various taxonomic groups, and their life form spectrum exhibits a wide range of variation. When slat tolerant plants are included, the number of halophytes increases significantly. It was estimated [1] that the flowering plants are about to be 350 families of which one-third is halophyte forages. It was found [2] that 50% of the genera belong to 20 of these families. It is concluded, then, that the halophyte forages do not constitute a family per se but they are widely distributed within different families of flowering plants. The fact that the limited number of halophytic species is spread among so many different families indicates that halophytism, even though a trait controlled by several genes, is not such a complex characteristic that only arose once during evolution. The word halophyte, then, does not imply any reference to being a particular taxon or any specific geographic or physiogeographic area [3].

Nature and ecology of halophytes are very complex [4]. They do not necessarily need salinity to grow. Halophytes survive salt concentrations around 200 mM NaCl or more in order to reproduce in environments where they constitute about 1% of the world's flora [5].

It is estimated that 7–10% of the world land area is salt affected [6]. Salt-affected soils happen to occur in all over the world and almost under all climatic conditions. Their distribution, however, is relatively more extensive in the arid and semi-arid regions compared to the humid regions.

The natural resources in Egypt have been diminishing because of increased demands. The increased population and the decline of the arable lands make it inevitable to utilize marginal and long-neglected natural resources and re-assess them in preparation for utilization. Halophyte plants are widely distributed throughout several regions of Egypt due to the presence of numerous saline areas along the Mediterranean Sea and Red Sea shores and inlands (littoral salt marshes and inland salt marshes). The less and unpalatable plant species represent approximately 70% of the total coverage. FAO [7] has estimated that salt-affected soil area in Egypt is about 7360 (ha). The arid climate of Egypt is characterized by high evaporation rates (1500–2400 mm/year), and a little rainfall (5–200 mm/year), which may add up to the existing salt affected soils.

Main causes of salinity development are irrigation with saline water; disturbance of the water balance between rainfall, on the one hand, and streamflow, groundwater level, and evapotranspiration, on the other; overgrazing, and cutting bushes; water percolation through saline materials; and intrusion of seawater [8].

2. Production of green biomass from halophytes

Halophytes can grow naturally or be planted. The biomass production and quality of the natural vegetation of halophytes in such areas vary considerably from season to season and from area to area depending on several factors, mainly environmental ones. In almost any forage populations, of a given species of a browse, there are various degrees of palatability from one plant to the other.

Suppressed growth of field crops is a direct result of the presence of salt in soils and the irrigation with saline waters. Therefore, the yield of these crops is affected dramatically where the expected yield relates to the plant species and salt concentrations either in soil or irrigation water. The studies to estimate the yield potential of halophyte forages were carried out on a laboratory scale. Very few studies were performed in the field. It was found that some halophyte forages like some species of *Atriplex* (e.g., *A. nummularia, A. griffithii* and *A. hortensis*) could tolerate high concentration of salt. It was found [9] that optimal growth of such species would be at 5–10 g/l^{-1} NaCl. The estimated yield value of *A. leucoclada* in the high salinity experimental site was 3735 kg fresh weight and 2058 kg of dry weight [10]. Some species of *Atriplex* yielded 1.26–2.09 kg/m^2 dry matter, 15.5–39.5% crude fiber and 10.2–19.5% crude protein [11].

Kochia indica was found [12] to produce fresh biomass of 8.5 kg per bush from March through August in India. **Table 1** represents some information gathered [13] concerning the yield of

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Plant species	Salt concentration (mM)	Yield (kg m^{-2} $year^{-1}$)
Aster tripolium	40	14.0 (fresh weight basis)
Atriplex lentiformis	500	1.8 (dry weight basis)
Atriplex triangularis	150	21.3 (fresh weight basis)
Batis maritima	500	1.7 (dry weight basis)
Salicornia europaea	500	1.5 (dry weight basis)
Salicornia persica	100	15.0 (fresh weight basis)
Sarcocornia fruticosa	100	28.0 (fresh weight basis)

Table 1. Yields obtained from halophyte crops grown under field conditions [13].

some halophytic forages grown under high salt effects. However, the estimated yield of halophytic forages reaches about 4–5 billion tons [14] resulting from 450 million hectares in the world according to FAO.

3. Feeding and nutritional value of halophytes

3.1. Quality as animal feed components

The quality might be the extent to which a halophytic or salt tolerant plant, as forage, has the potentiality to reach the required animal response. The quality of halophytes as forage varies greatly among and within each crop. In order to determine forage quality, different issues have to be taken into consideration.

The factors that affect forage quality include palatability, nutrient contents (chemical compositions), plant secondary metabolites [15], feeding value (voluntary animal intake, nutrient digestibility), and eventually animal performance.

Analyzing forages for nutrient content (chemical compositions) can be used to determine the quality of forage if it is adequate to meet the animal requirements and to be used for proper ration supplementation. Limitations [16] of halophytic forages as feeds for animals (i.e., accounting for non-protein nitrogen and non-nutritional components) could represent a problem in formulating rations. He also referred to the palatability issues of the halophytic forages as important factors in determining the acceptability of these forages by animals and to which extent they might be consumed. The other factors that assess the quality of these forages (like an assessment of feeding and nutritional values) might be looked upon after the issues of palatability are addressed.

3.2. Palatability and preference

The definition of palatability has been an argument. Regardless of the scientific controversy over this issue, the most agreed upon is that palatability of a feed is the ration between the consumed and offered amounts of feed by any class of herbivores animals on a given time [17, 18]. The palatability and feeding values of individual halophytes or any other types of rangelands vary widely from virtually zero to very high. In almost any forage populations, of a given species of a browse, there are various degrees of palatability from one plant to the other. Palatability depends (among other factors) on the relative abundance of the species on the rangeland. Considering all other conditions being equal, the palatability of a given plant is inversely related to its profusion on the range.

Regardless of the plant internal factors, animal factors also govern the palatability of the halophyte forages. These factors may include, but not limited to, animal species and race, age, physiological state and health status, feeding habits, animal conditions as controlled by nutrition.

Chemical compositions of halophyte forages affect also their palatability. For instance, if the crude fiber percentage is high in forage, it will play an important role in its selection by livestock. Forages with high fiber content are usually better accepted by cattle than by sheep and goats. Mineral content [19, 20] in low rain fall areas compared to high rain ones, the ash percentage (when silica-free minerals are concerned) in halophyte forages could be a critical factor to the palatability, may be because of dilution rate. **Table 2** shows the palatability of halophytic plants for different animal species.

3.3. Chemical compositions

Halophytic plant species vary considerably in their chemical composition, nutritive value, and palatability. The chemical composition of any animal feed is the first indicator if its nutritional value to the animals is considered. Nutritive value is first determined by nutrient concentration through the determination of the feed plant chemical composition. The differences in chemical compositions, and hence nutrient contents, of halophytic forages, may be related to the variations in factors that control plant growth (e.g., soil fertility, soil salinity, environmental factors like rain and temperature, etc.). Therefore, the determination of nutrient contents of these forages is a must to assess their quality as feed components.

3.3.1. Ash contents and mineral compositions

The fact that a high content of ash is a typical characteristic of halophytic forages has resulted in divisive concerns over the bioavailability of mineral contents of these forages. The concerns about this issue are justifiable since the raised questions were to what extent this could affect the nutritional value of these types of forages, how much the mineral contents of halophytic forages could satisfy these requirements and whether they poisonous, in case if they exceed the animal requirements.

However, the mineral profiles of halophytic forages differ from those of traditional ones. These differences may due in part to [19] forage species, stage of growth, seasonality, the degree of soil and water salinity, etc. The concentrations of some mineral contents of halophytic forages are shown in **Table 3**. It appears that these forages could be a source of some minerals to meet ruminant animal requirements. In this context, the concentrations of these minerals may balance the deficiency that may result from in areas depending on grazing ranges (e.g., desert and coastal areas).

Animal species	Plant species
Sheep, goats	*Alhagi maurorum*
Camels	*Arhthrocenemon glaucum*
All species	*Atriplex halimus*
Sheep, goats	*Atriplex leucoclada*
All species	*Atriplex nummularia*
Camels	*Halocnemom strobilaceum*
Nil	*Haloxylon salicornicum*
All species	*Juncus acutus*
All species	*Nitraria retusa*
Camels	*Salicornia fruticosa*
All species	*Salsola tetrandra*
All species	*Suaeda fruticosa*
All species	*Limoniastrum monopetalum*
Goats, camels	*Tamarix aphylla*
All species	*Tamarix mannifera*
Nil	*Zygophyllum album*
Camels	*Zygophyllum simplex*
Camels, goats	*Zygophyllum decumbens*

Table 2. Palatability of some halophytic plants for different animal species [21].

The aspects of ash contents and mineral compositions of halophytes are discussed in detail by [19, 20]. The mineral profiles of some halophytic forages in Australia were examined [23]. The authors found that some ions are present in frequent patterns, especially in certain taxons. Sodium salts (especially chlorides) were found to accumulate in large concentrations in dicotyledons compared with sulfate salts. Chenopodianceae and Caryphyllaceae were found to have normal concentrations of free oxalates. Other dicotyledons found to have moderate salt contents. The ratio of K:Na in these plants was found to be less than one. They also found that the patterns of mineral salts in monocotyledons were in contrast to those of dicotyledons. Low salt concentrations are characteristic monocotyledons like Poaceae and that the K:Na ration is more than one. Similar results, later on, were found [24] in Wales.

All halophyte forage species contain adequate amounts of major and minor minerals (**Table 3**) to apparently meet the mineral requirements of ruminants except for both of phosphorus and sulfur according to [25].

The high levels of mineral contents of halophyte forages do not exceed the normal levels of the requirements of livestock, especially ruminants. However, it is preferred to include supplements of trace and minor mineral in diets in order to correct for any deficiency that may occur.

	Ash (%)	Ca (%)	P (%)	Na (%)	K (%)	Mg (%)	S (%)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
Acacia saligna	8.83	3.75	–	1.15	1.05	6.14	–	140.5	–	–	–
Atriplex nummularia	18.91	2.08	1.17	4.99	2.99	15.63	–	133.5	60.52	–	–
Atriplex halimus	29.20	1.69	0.32	3.91	0.57	0.32	0.17	64	10	503	51
Nitraria retusa	9.99	1.96	0.22	5.35	0.66	0.36	0.14	32	11	567	62
Tamarix mannifera	8.06	3.01	0.01	2.70	0.91	0.46	0.09	45	16	291	52
Suaeda fruticosa	30.2	2.11	0.41	4.06	1.29	0.30	0.20	55	13	674	88
Salsola tetrandra	12.9	3.98	0.16	5.65	1.45	0.59	0.12	44	8.88	664	79
Zygophyllum album	34.84	2.26	0.14	2.89	1.14	0.64	0.09	41	7.78	393	52

Table 3. Overall average values of some mineral composition in halophytic plants (DM basis) grown in Sinai and the North Western coast of Egypt (adapted from [19–22]).

3.3.2. Protein and amino acid contents

It has been long recognized that environmental conditions play a major role in determining the quantity and quality of nutrients produced by halophytes. It is reported that proteins level decreased under salinity is due to low uptake of nitrate ions [26] and due to other factors.

The biochemical processes that take place within halophytic forages for the biosynthesis of different nutrients seem to be affected by the high concentrations of salts [27]. These processes include the protein and amino acid formation [28]. The increases in salt concentrations cause decreases in the protein synthesis and its hydrolysis as well [29]. This process results in the production of amino acids in some halophytic forages. The antagonistic effect of increased salinity on protein synthesis is, then, clear. However, some amino acids like aspartate and glutamate play a critical role in the adaptation of halophytic forages to salt stress. Concentrations of aspartate, glutamate, glycine, histidine, lysine, and arginine amino acids were found to increase as the salinity levels increase [30]. Within the salt-tolerant sorghum types, protein content decreases as the salinity increases leading to the increase of non-protein-nitrogen [31]. It seems, therefore, that with a decrease in soil salinity, the available nitrogen increases significantly.

In general, the nitrogen contents of most of the halophytic forages are reasonable and appear to cover the requirements of grazing animals. As mentioned above, most of the nitrogen contents of halophytic forages are in the form of amino acids (NPN). It was found [32] that almost 42% of nitrogen contents in *Atriplex barclayana* were in the form NPN. This has certain implications in animal nutrition, as an available energy source should be included in the rations of animals feeding on halophytic forages. This inclusion may have its impact on the utilization and efficiency of nitrogen digestion [33].

In evaluating proteins present as a dietary nutrient in halophytes, one should take several issues into consideration. First is the high percent of non-protein nitrogen portion of the crude protein content. Second consideration is that the increased solubility of proteins contents of halophytes arises from their presence as leaf proteins (leaf proteins are usually highly soluble) and because halophytes react in different mechanisms to high salt stress. Halophytes store most of their proteins in the leaves at the beginning and later on (after plant maturation) in the seeds (**Table 4**). The third consideration results from the high solubility of proteins. This characteristic of leaf protein has its implication on their degradability by ruminal microorganisms which tend to be high. The rumen microflora act on dietary soluble proteins once ingested. They degrade them in order to build their body protein. If a readily available energy source is lacking during this process, the degraded protein is, then, wasted and the animal does not get benefit out of it. The literature on halophytes shows that the digestibility of crude fat contents (or ether extract) is low. They also have low contents of soluble carbohydrates. This leads to decreased synthesis of microbial proteins in the rumen of animals. Protein supply to the animal is not, then, sufficient to meet its requirements of proteins even at maintenance level. That is why animals feeding on halophytes alone loss weight. The supplementation of a readily available carbohydrate source is a must in this case in order to increase the synthesis of microbial proteins. The coincidence of the release of both degraded soluble proteins and the highly soluble carbohydrates is a critical process. The non-degraded cereal proteins provide

Halophytic plants	Plant part and/or maturity stage	N (%)	Protein (%)
Acacia saligna	Whole	2.21	13.8
Atriplex halimus	Whole plant	2.11	13.1875
Atriplex nummularia	Whole plant	2.03	12.6875
	Fruits	1.65	10.3125
Salsola tetrandra	Whole plant	1.08	6.75
Suaeda foliosa	Leaves	2.67	16.6875
	Stem	2.69	16.8125
Suaeda fruticosa	Whole plant	1.94	12.125
Tamarix mannifera	Whole plant	1.22	7.625
Zygophyllum album	Whole plant	1.05	6.5625

Table 4. Nitrogen and crude protein contents of different parts of some world halophytes [14].

the animal with a source of protected protein, hence, providing the animal with true proteins. All these together may explain the positive response of animal fed halophytes when supplemented with energy concentrate. It is, then, necessary or may be vital to supplement animals fed on halophytes with cereal grain energy supplement.

3.3.3. Energy contents

The definition of feed gross energy (GE) is the total combustion heat of any feed substance expressed in calories or joules per unit of dry matter. The digestible energy (DE) is the amount of gross energy minus the energy lost in feces, while the metabolizable energy (ME) is the digestible energy minus the amount of energy lost in urine and gasses. The net energy (NE) for maintenance is the metabolizable energy minus that lost as heat. The most common energy form used to express the energy contents of halophytic forages is metabolizable energy.

However, the reported energy content of halophytes is usually estimated in vitro. These values may be unrealistic ones and do not represent real values of in vivo values. However, these *in vitro* values relate to some extent to the *in vivo* ones. **Table 5** was compiled [33] to show the inconsistency of *in vitro* values compared to those produced in vivo.

However, the nutritive value of halophyte species such as metabolizable energy (ME) appears to depend strongly on plant maturity. Energy contents of both traditional forages and halophytic ones (**Table 6**) were found to be similar and had no significant differences. The question is, then, is there a difference in the efficiency by which the energy is utilized in both types of forages? The published values are contradicting. When *A. nummularia* hay was compared with alfalfa hay [34], the ME intake was not different. Coastal grasses like Aeluropus lagopoides and Sporobolus tremulus appeared to have adequate energy contents [35] to meet the maintenance requirements of beef cattle, while those grazing animals on *A. nummularia* need energy supplementation than any other supplementation [36]. It was concluded [37] that the low nutrient digestion and utilization of halophyte forages could be attributable to the low energy contents.

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	In vivo	Pepsin-cellulase	Pepsin-cellulase corrected*	NIRS
Sample 1	58			76
Sample 2	52	77	70	
Sample 3	45	77	71	

* Corrected with non-halophyte calibration.

Table 5. Estimates of *in vitro* and *in vivo* of DOMD values (adapted from [33].

Halophytic forage	ME (Mcal/kg)	conventional forages	ME (Mcal/kg)
Aeluropus lagopoides[1]	2.30	*Medicago sativa*[3]	2.20
Sporobolus tremulus[1]	2.38	*Cynodon dactylon*[3]	2.49
Paspalum paspalodes[1]	2.53	*Sorghum vulgare*[3]	1.75
Paspalidium geminatum[1]	2.33	*Zea mays*[3]	2.97
Atriplex nummularia[2]	2.82	*Trifolium alexandrinum*[3]	1.99
Salsola tragus[2]	2.56	*Lolium multiflorum*[3]	2.50

Table 6. Examples of Digestible Energy (DE) and Metabolizable Energy (ME) values of some halophytes compared to some traditional forages [35, 38, 39].

4. Effect of feeding halophytic forages on rumen function

The microbial population in the rumen and its metabolism is anticipated to be affected by the salt load which increases the osmotic pressure [40–42]. The elevated osmotic pressure within the rumen environment is assumed to be critical to the protozoa growth. This may increase the outflow rate and, hence, decrease the protozoa population [43]. Artificial raises [44] in the osmotic pressure of the rumen up to 400 mOsmol/kg and found that the cellulose digestion was inhibited. The increased flow rate due to the increased salt load in the rumen depressed the protozoal population [37]. On the other hand, Ref. [45] found a significant increase in protozoal count ($\times 10^3$/ml rumen fluid) when camels were fed ration containing *A. nummularia* compared with those fed Acacia saligna and treated rice straw rations. The same increments in the ruminal protozoal population were found when camels were fed on berseem hay compared to those fed traditional rations. It seems that the increased load of salts in the rumen as a result of feeding desert halophytic forages imposes ion burden that needs to be buffered. Therefore, ruminants fed rations containing halophytes are anticipated to release more saliva and may have elevated pH values than those fed grains [46].

5. Limitations of feeding halophytes to ruminants

The low intake of fresh and air-dried halophytic species could be attributed to several factors: (1) high Na, Ca and silica contents, (2) higher levels of ADL and NDF and (3) many shrubs contain higher levels of plant secondary metabolites, (4) low energy contents, (5) low crude protein contents and (6) high percentage of non-protein nitrogen. Nutrient detergent fiber (NDF) is a good indicator for forage intake. The low NDF value (50.2%) for the fresh Potamogeton *crispus* would explain the higher intake by sheep compared to fresh *Tamarix mannifera* and *Glinus iotoides* [47]. The limited halophytic intake and digestion may be attributable to the low crude protein contents (around 6%) and greater levels of NDF, ADF, and ADL. This case is well illustrated in *T. mannifera* and *G. iotoides*. The *P. crispus* showed opposing trend. When *P. crispus* fed to sheep, the TDN and DCP values were high, and the animals were in positive nitrogen balance.

Voluntary feed intake and nutrient digestion/unit of feed are the criteria against which the feeding value of feeds is considered. However, factors like physical and chemical properties of halophytes that are used to defend the plants against predators may considerably limit the feeding values of such forages. Physical factors like the presence of spines and thrones may include the so-called barbed-wire syndrome [48]. Chemical factors may include the higher salinity, silica, and fiber. The presence of lignin and the degree of lignification also affect the nutritive value of halophytes as animal feed components. The secondary plant metabolites that limit the feeding value of halophytes are another example of the chemical defense of halophytes. Salt load present in halophytes affects their palatability and acceptability as well and, therefore, the intake [49, 50].

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Some halophytes are toxic [41]. **Table 7** shows a screening of anti-nutritional factors present in some halophytes. The toxicity results from several secondary metabolites in the plants. However, the rate of toxicity is affected by several factors such as rate of ingestion, type, and rate of microbial transformation of such metabolites in the rumen, rate of gastro-intestinal absorption, liver and kidney enzymatic activity. Alkaloids, saponins, tannins and nitrates are present in most halophytes. High concentrations of alkaloids decrease animal performance and increase diarrhea. Tannins reduce feed intake through reducing palatability resulting from the precipitation that occurs upon reaction of tannins with salivary proteins. Tannins also inhibit digestive enzymes [51].

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Fodder crops	Anti-nutritional factors
Atriplex nummularia	Saponin, alkaloids, tanins, nitrate
Atriplex leucoclada	Saponin, alkaloids, tannins
Atriplex halimus	Saponin, flavonoids, alkaloids, tannins, nitrate
Diplache fusca	Flavonoids, alkaloids
Halocnemum strobilaceum	Saponin, flavonoids, alkaloids, tannins, nitrate
Haloxylon salicornicum	Saponin, flavonoids, alkaloids, tannins
Kochia eriophora	Alkaloids, tannins
Juncus acutus	Flavonoids, alkaloids, tannins, nitrate
J. arabicus	Alkaloids, tannins
J. subulatus	Alkaloids, tannins, flavonoids
Limonium pruinosum	Saponin, alkaloids, tannins
Nitraria retusa	Saponin, tannins
Salsola glauco	Saponin, flavonoids, alkaloids
Suaeda fruticosa	Alkaloids, tanins, nitrate
Tamarix aphylla	Saponin, tanins
Salsola tetrandra	Nitrate
Tamarix mannifera	Saponin, tannins
Zygophyllum album	Saponin, flavonoids, alkaloids, tannins, nitrate
Sesbania sesban	Saponin, alkaloids

Table 7. Examples of plant secondary metabolites in halophytic forages [52].

6. Overcoming constraints of halophytes as animal feed

Natural resources have been diminishing because of increased human pressure. This pressure results from the ever-increasing population of the world. Inevitably, under current and predicted future conditions marginal resources and long-neglected natural resources such as halophytic plants have to be re-assessed in preparation for future utilization. Shortage of animal fodder is one of the main constraints of indigenous animal production on salt affected soils of arid and semi-arid regions and limits its expansion. Animal husbandry, as the main income resource for nomads, is based mostly on the natural vegetation for feeding sheep, goats and other herbivores.

The way in which halophytes are used depends very much on the nature of the community that dominates their ecosystem. Evaluation of the possible contribution of halophytes to the economic well-being of the local nomadic communities depends on the understanding of the economy, agrobiology, and ecology of the forage plants and the knowledge of the carrying capacity of the grazing animals. Halophytic plants have long been ignored and viewed as marginal resources.

The use of halophytes for animal feed has several constraints that must be dealt with, on a rational exploratory and experimental basis. The high content of mineral ash, the presence of plant secondary metabolites and the low nitrogen content are examples of the constraints that face animal nutritionists. Little was done in the exploration of the richness of various halophytic species for the purpose of selection of halophytes of high quality for grazing.

Most of the halophytes contain secondary metabolites (tannins, glucosides, flavonoids, alkaloids, terpenoids, cyanides, coumarin, nitrate, oxalate and organic acids). There are many plants capable of producing toxic metabolites including palatable plants [53]. For example, *Nitraria retusa* one of the most palatable grazed halophytic shrub in Egypt contained different proportions of crude alkaloids, saponins in addition to tannins and sterols [54].

Harmful effects of plant secondary metabolites cause great economic losses to livestock producers. However, ruminants are more tolerant to poisonous plants than non-ruminants. Even among ruminants, there are striking differences in tolerance of plant toxicants. In ruminants, tolerance of poisonous plants may be modified by microbial fermentation of ingesta in the reticulorumen, which can diminish toxicity of some plants compounds and increase the toxicity of other. Some plant compounds may be biotransformed within tissues of the host ruminant yielding products that are more toxic or less toxic than the plant compound ingested [55]. Ruminants may convert a toxic substance to another toxic one (cyanide to thiocyanate, which is goitrogenic) [56]. They also may detoxify some substances with a concurrent loss of some nutrients [57]. Methods of overcoming these constraints may include cooking, germination. The effectiveness of these methods differs from one another. On the other hand, some methods (like steam treatment) may improve the nutritive values of halophytes by increasing the accessibility of nutrients. Steam can break down plant secondary metabolites to some extent and may make fat more available [58].

A summary of the plant secondary metabolites, their impacts on animals and some ways to lessen their effects on animals is present in **Table 8**.

Plant secondary metabolite	Impact on animal	Methods to relief
Phenolic compounds	Affect rumen fermentation	**1.** PEG **2.** Physical treatment **3.** Silage
Glycosides: *1. Saponins*	**1.** Bloat **2.** inhibit microbial fermentation **3.** Formation of calcium salt **4.** Decrease growth rate	**1.** Repeated washing with water **2.** Ensiling or wilting in the field
2. Cyanogens	Animal death due to its harmful on hemoglobin	**1.** Add methionine to animal diet (sulfur combines with cyanide to form thiocyanate (non-toxic) **2.** Sun drying

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Plant secondary metabolite	Impact on animal	Methods to relief
3. Goitergens	**1.** Enlargement of thyroid gland **2.** Rapid decline in serum thyroxine, **3.** Decreased intake **4.** Prolonged feeding has produced hair loss, excessive salivation and esophageal lesions	Broken down in the rumen by rumen bacteria
Alkaloids	**1.** Ataxia **2.** Diarrhea **3.** Decrease animal performance	**1.** Air drying **2.** Ensiling
Nitrates	**1.** inhibition of cellulose digestion **2.** Combines with hemoglobin, thus reducing the oxygen **3.** High nitrates cause abortion in livestock	**1.** Add grains and vitamin A to the diet **2.** Mechanical treatment **3.** Add more soluble CHO to increase microbial nitrogen requirements
Oxalate	**1.** Excess oxalate may result in fatal intoxication with hypocalcaemia, metabolic disturbances and kidney failure **2.** May result in fatal intoxication with hypocalcaemia, metabolic disturbances and kidney failure **3.** Kidney failure due to the accumulation of oxalate crystals	Animal adaptation because rumen bacteria can degrade it
Phytates	Hypomagnesima (low WBC) Milk fever (decreased Ca & P)	**1.** Mineral balance **2.** Vitamin D injection
Tannins	**1.** Reduced voluntary feed intake **2.** Reduced digestibility of protein and carbohydrate through the inhibition of digestive enzymes **3.** May reduce bacterial enzymes **4.** Tannins/protein complex that survives in the ruminal environmental may not be digested in the lower tract	Add PEG

Table 8. Plant secondary metabolites and their impact on animals and how to reduce their effects [59].

7. Processing as animal feeds at farm level

Halophytes and salt tolerant fodders contain some physical and salt materials that limit and constrain its palatability and utilization by animals [14]. The main constraints are high ash content (minerals), high fiber content (in particular the lignin and hemicellulose), low protein and energy contents, high presence of secondary metabolites (anti-nutritional factors) produced by plants, such as tannins, etc. which have a direct impact on the processes of digestion in animals. Halophytes and slightly salt tolerant fodders also contain some physical and chemical materials that limit and constrain its palatability and utilization.

Current methods of processing dry forages include chopping, grinding, shredding, silage, feed cubes, hay or mix components in a TMR [60].

Forages are subject to waste when fed directly to livestock. Waste occurs because of livestock discriminately select specific components of forage (leaves, smaller stems), animal trampling, spoiling (urine and manure deposition) or bedding on excess forage.

Processing halophyte forages (whether cultivated or naturally grown) provides some advantages. Processing can maximize the use of forages to be included in a total mixed ration for livestock diets. Processing also ensures livestock diet consistency in a uniform blend. Processing can decrease waste from animal selection and allow more precise ration formulation. Processing benefits include reduced feed waste and the ability to mix diets more precisely with a wider variety of feedstuffs includes reduced feed waste and the ability to mix diets more precisely with a wider variety of feedstuffs. Processing forages will decrease particle size, reduce opportunity for sorting of forages by animals. Processing also can help producers develop more precise and cost-effective rations.

However, the primary benefits of processing will not improve hay quality; however, it potentially can increase DMI within a blended TMR due to a smaller particle size. These benefits need to be weighed against the processing cost to determine if forage processing is warranted.

The processing of halophytes and salt tolerant plants may increase utilization of natural palatable halophytes or those less palatable with large biomass improve the nutritional value and palatability of forage plants with low nutritional value and palatability, provide balanced nutritional feed all year round.

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