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Potential Fodder Plants of Cold Arid High Altitude Region for Livestock Feeding in Health and Production: A Review

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Abstract: *The cold arid region of India is usually accompanied by high altitude with little or no rainfall thus making the atmosphere cold and dry. Sixteen percent of the total landmass of the world is under the cold arid zones. Indian cold deserts come under the Trans-Himalayan zone. Major parts are confined to Ladakh in Jammu & Kashmir and Lahaul & Spiti in Himachal Pradesh. In Jammu and Kashmir, the cold desert lies between 32°15′ - 36° N and 75°15′ - 80°15′ E. It covers approximately 68,321sq km. The flora of this region comes under alpine and high alpine zones, followed by few stunted shrubs and bushes. Among these floras, there are several fodder plants which are used by the local people for livestock feeding. Local people rear livestock, particularly cattle, goat, sheep and yak, which play a key role in the development of the socio-economic condition of the inhabitants as they get milk, meat, wool etc. from them besides the manure for improvement of soil fertility. Farmers also earn some cash money by selling them during adverse climatic condition. Therefore, livestock management should be in a scientific way for better production. However, the important in the livestock management is feed which becomes grave during winter months leading to low productivity of the animals. Fodder trees and shrubs, therefore become important as a good source of protein and energy to keep the animals healthy and better milk, meat and wool production which are the critical food and income sources in this region. This review presents a summary of the literature on the important plant bioresources and their bioactive molecules for livestock feeding, better production and health.*

Keywords: *Animal health, Bio-active molecules, Fodder plants, High altitude, Livestock management*

I. Introduction

Ladakh, a cold arid region, comprising of two districts namely Kargil and Leh has the tentative population of 84,362 cattle (native and cross breeds), 4,63,661 goats, and 2,63,473 sheep of various breeds, 2.055 equines, 36,238 yaks and about 200 double humped camels (1). Due to the dry period, it is impossible to the farmers for continual supplementation of food. Fodder trees and shrubs then become a best alternative feed source. Some of the potential fodder trees with their botany and bioactive molecules are listed in the T**able-1** and T**able-2**. Several types of bioactive molecules are found in these plants. These are consumed by livestock as a primary consumer. Animals also consumed dry matter which contains 'energy' (carbohydrates), protein and other substances (like minerals). Even when a cow, goat or sheep is not producing milk, it needs energy to breath, walks and maintains all kinds of body processes, and it needs protein to grow. This basic need of feed which is necessary just to maintain a stable condition of the body. For young animals to grow fast or animals to produce high milk yields, extra energy and protein are needed above the daily maintenance requirements. Increasingly there is the realization that plants may offer non-nutrient performance-enhancing factors that benefit animal production (2). Listed fodder plants have the bioactive molecules which can enhance the animal health and production. This review presents a summary of the literature on the important plant bioresources and their bioactive molecules for livestock feeding, better production and health.

II. Environmental Condition And Agro-Animal Health Scenario At High Altitude Region:

Leh-Ladakh region is located on the rain shadow side of the Himalaya. Here dry monsoon winds reaches after being robbed of their moisture in the plains. This region featured with the combination of both arctic and desert climate condition. Therefore Leh-Ladakh region is often called as "Cold Desert".
The main features of cold desert are:-

- Long photoperiod and seasonal fluctuation in temperature with –40°C in winter and +35°C in summer.
- Precipitation is very low.
- Annual precipitation of 10 cm mainly in the form of snow.
- Range of relative humidity is 6-24%.
- Solar radiation is very high (6-7 Kwh/mm).
- Mainly, in the summer season, dust storms are very common in the afternoon (3).

Average minimum and maximum temperature and humidity data since the year of 2010 to 2015, was showed in the graphical representation (**Fig. 1, Unpublished Data**).

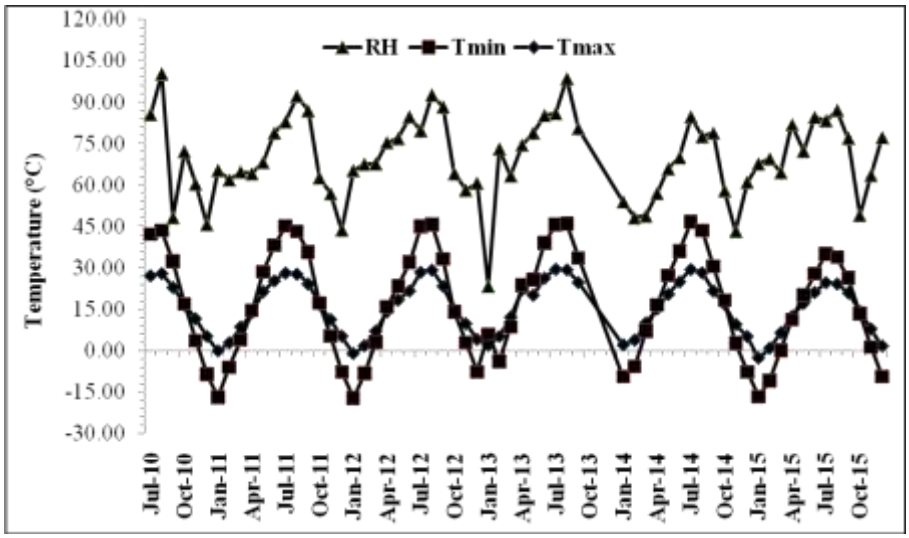

Figure 1. Variation of relative humidity (RH), maximum temperature (Tmax), and minimum temperature (Tmin) of six consecutive years (2010 - 2015) at Leh-Ladakh, Kashmir. (Data Resource: Metorological section of Indian Air Force, Leh-Ladakh, Ministry of Defence, India).

The atmospheric low oxygen partial pressure affects O_2 cascade inducing metabolic adaptations, such as cell oxidative metabolism which ultimately caused the oxidative stress in the cell after producing different types of reactive oxygen species (ROS) and reactive nitrogen species (RNS) (**Table 1**). This is the indicative of an imbalance between oxidants and antioxidants, methods for quantifying oxidative stress mostly include direct or indirect measures of oxidants and antioxidants. Oxidative stress evolved in the animal body due to high altitude exposure is an active field of research in veterinary medicine. It caused several disease processes including sepsis, mastitis, enteritis, pneumonia, respiratory, and joint diseases (4,5).

Table 1: Summary of reactive oxygen and nitrogen species (Source: 6).

Reactive Oxygen Species				**Reactive Nitrogen Species**			
Free Radicals		**Other Substances**		**Free Radicals**		**Other Substances**	
Superoxide anion radical	$O_2^{\bullet -}$	Hydrogen peroxide	H_2O_2	Nitric oxide radical	$NO^{\bullet}$	Peroxynitrite	$ONOO^-$
Hydroxyl radical	$HO^{\bullet}$	Hypochlorous acid	HOCl	Nitric dioxide radical	$NO_2^{\bullet}$	Nitrites	NO_2^-
Alkoxyl radical	$RO^{\bullet}$	Ozone	O_3			Nitrates	NO_3^-
Peroxyl radical	$ROO^{\bullet}$	Singlet oxygen	$^1O_2$			Nitrosyl	NO^+

To sustain in this type of harsh environment, livestock animal has to be provided with good quantities and qualities of feed. At this region, available plant bio-resources with their bio-active molecules have been reviewed for the better livestock health and production.

III. Plant Bio-Resources At Leh-Ladakh For The Livestock Feed

In this trans-Himalayan region, most of the animals graze on the alpine pasture and stall fed during the winter season, since seven months of the year remains covered with the snow. Summer is the only cropping season here, so being one single cropping season farmers grow only cereal crops and fodder crops in limited land. But, to store such quantity for the winter months, this production quantity is not sufficient. Some number of species belonged to the family of Poaceae followed by Leguminosae and Salicaceae, are found in this region. Alfalfa (*Medicago sativa and Medicago falcata) is* the main cultivated fodder plants in Leh-Ladakh. In the winter, animals are give willow leaves, stalks of cereal crops, alfalfa and other plant residues. Among the cultivated crops corn, wheat, millet, barley, buckwheat, sugarcane, oilseeds, cabbage, cauliflower, and potatoes are the main (7).

Important fodder plants have been presented in the Table-2 with their scientific and local nomenclature, plant habitat, characters and their harvesting time (8,9,10).

Table 2. Potential Fodder plants at high altitude with their botanical name, family, botany and uses.

Sl. No.	Family	Species Name	Local Name	Habitat	Plant Characters	Flowering & fruiting	Harvesting Time
01.	Apiaceae	*Heracleum pinnatum*	sPru-ma	3450-4530 m	Perennial herb	June to August	Sept
02.	Brassicaceae	*Lepidium latifolium*	Sauson	3260-3650 m	Perennial herb	July to Sept	Sept
03.		*Sizymbrium loeselii*	-	3105 m	Annual/biennial plant	July to Sept	Sept
04.	Caryophyllaceae	*Stellaria media*	Khalta	3450 m	Annual herb	June to Sept	Sept
05.	Chenopodiaceae	*Kochia indica*	-	2850-3000 m	Annual herb	July to Sept	Sept
06.	Convolvulaceae	*Convolvulus arvensis*	Tiktikma	3540 m	Perennial herb	Mid June to Sept	Oct
07.	Elaeagnaceae	*Hippophae rhamnoides*	Seabuckthorn Tsemang or Sastahulu	3150 m	Perennial shrub	June to Sept	Oct
08.	Ephedraceae	*Ephedra gerardiana*	Chhapat	3960 m	Tufted shrub	June to Sept	Oct
09.	Fabaceae	*Cicer microphyllum*	Seri or Srad-Kar	4230-4870 m	Herb	Mid June to Sept	Oct
10.		*Medicago falcate*	Ole	4250 m	Perennial herb	Mid June to Sept	Sept
11.		*Medicago media*	Ole	4000 m	Perennial herb	Mid June to Sept	Sept
12.		*Medicago sativa*	Ole	4450 m	Perennial herb	Mid June to Sept	Sept
13.		*Melilotus officinalis*	Ole or rGya-spos	4000 m	Biennial hrb	Mid June to Aug	Sept
14.	Iridaceae	*Iris lacteal*	Tesmamentok	3450 m	Perennial herb	June to August	Sept
15.	Plygonaceae	*Fagopyrum esculentum*	Dayat	2780-3890 m	Annual herb	July to Sept	Sept
16.	Poaceae	*Agropyron repens*	Zamak	3320 m	Perennial grass	July to Sept	Sept
17.		*Avena fatua*	Yupo	3075 m	Annual grass	July to Sept	Sept
18.		*Avena sativa*	Yupo	4350 m	Annual /perennial grass	July to Sept	Sept
19.	Salicaceae	*Populus nigra*	Yulat	3700 m	Perennial tree	June to August	August
20.		*Salix alba*	Mulchang	3550 m	Perennial tree	May to Aug	August
21.		*Salix daphnoides*	-	2850-3160 m	Perennial tree	May to Aug	August

IV. Plant Bio-Active Compounds and Their Effects on Livestock Health and Production

IV.I. Ameliorative Effect against oxidative stress

Animal health has challenged by the high altitudinal hypobaric hypoxia. As earlier said, this condition is very suitable for the production of ROS and RNS species which ultimately caused the severe health problem in the animal body. The capability of the defense network of the animal body may be challenged by environmental conditions. Due to oxidative stress, the capability of the defense mechanism has been attenuated, causing oxidative damage to lipids, proteins and to DNA. In this way, high altitude exposure leads to oxidative damage in the body (11). Against the oxidative stress antioxidants has a great pancreatic role in the animal body. It inhibits the initiation and/or further propagation of ROS and RNS production chain (12). Natural antioxidants can protect the biologically important cellular components from oxidative processes. Among the natural antioxidants, it was found that α-tocopherol, ascorbic acid, β-carotene, phenolic compounds, lycopene, quercetin have the great role against the oxidative stress. These have the capability to scavenge the ROS and RNS or other mechanism they help to inhibit the stress inducing mechanism (13-18). Some authors have demonstrated antioxidant activities of essential oils (19-23). Some studies showed that carotenoids possess other bioactivities and are thought to be active agents for the prevention of cancer, cardiovascular diseases, and macular degeneration occurred due to the oxidative stress (24-29).In the Table-3, plants which containing these antioxidant natural products should be helpful for the sustaining of livestock animals in this region.

Table 3: Potential Fodder Plants with their General Chemical Composition and Bio-Active Molecules.

Sl. No.	Species Name	Parts Used	Bio-active Molecules
1.	*Agropyron repens*	Whole plants	Polysaccharides (triticin), mucilage, agropytene. The bark contains several quassinoids including ailanthone derivatives (9).
2.	*Avena fatua*	Whole plants	Dry matter 90.91%, crude protein 6.79%, neutral detergent fiber 38.35%, acid detergent fiber 28.96%, lignin 4.60%, hemi cellulose 9.39%, cellulose 24.34% (8).
3.	*Avena sativa*	Leaves	Proteins, Vitamin-B complex, saponin, carotenes. Silicon dioxide (2%) occurs in the leaves and in the straw in soluble form as esters of silicic acid with polyphenols, monosaccharides and oligosaccharides (9).
4.	*Cicer microphyllum*	Whole plants	Dry matter 91.40%, crude protein 15.30%, neutral detergent fiber 36.38%, acid detergent fibre 32.34%, legnin 5.90%, hemi cellulose 4.04%, and cellulose 26.44% (8).
5.	*Convolvulus arvensis*	Whole plants	Convolvulin, resinous glycoside, tannins. Convolvulin, 1.52-4.0% resinous substances, rhizome contain 4-9% resin. (8) All parts of the plant contain beta- Me-esculetin; aerial parts *n*-alkanes, *n*-alkanols, alpha-amyrin and sterols; roots gave cuscohygrine (9).

6.	*Ephedra gerardiana*	Leaves & Fruits	Dry matter 91.81%, crude protein 9.27%, neutral detergent fiber 45.23%, acid detergent fiber 42.48%, legnin 21.28%, hemi cellulose 2.75%, and cellulose 21.20% (8). Pseudoephidrine, 1-ephidrine, d-pseudoephidrine. Ephedrine (0.3%), pseudoephedrine (8). *Ephedra gerardiana* contains 1.22% total alkaloids and 0.68% ephedrine (9).
7.	*Fagopyrum esculentum*	Whole plants	Dry matter 94.30%, crude protein 25.19%, neutral detergent fiber 7.70%, acid detergent fiber 37.28%, legnin 7.75%, hemi cellulose 13.26%, and cellulose 30.13% (8). Rhamnodiastase and rhamnosidase, enzyme hydrolase, various flavonoides, glycosides (8) It is a potential source of rutin (yield 3-5%). The leaves and blossoms contain most of the rutin (85-90%) (9).
8.	*Heracleum pinnatum*	Leaves	Heraclin, glutamine, essential oils. Contain coumarins which can be converted into Xanthotoxin- a chemical used in preparation of suntan lotions and possess anti-leucodermal molecules (10)
9.	*Hippophae rhamnoides*	Leaves	Dry matter 91.09%, crude protein 23.93%, neutral detergent fiber 22.72%, acid detergent fiber 20.21%, legnin 8.47%, hemi cellulose 2.51%, and cellulose 11.74% (8). Carotenoide, flavonoid, volatile oils, essential oil, saturated and unsaturated oil and fatty acids, tannins, quercitin, provitamine A, Vitamin C, B complex and E (9).
10.	*Iris lactea*	Whole plants	Dry matter 90.37%, crude protein 10.62%, neutral detergent fiber 47.28%, acid detergent fiber 42.35%, legnin 4.01%, hemi cellulose (8).
11.	*Kochia indica*	Whole plants	Resinous alkaloid, isolated from alcoholic extract of the plant. Sitosterol 70.9% (9).
12.	*Lepidium latifolium*	Leaves	Dry matter 91.74%, crude protein 24.62%, and neutral detergent fiber 11.20% (8). The leaves contain cholesterol, stigmasterol and beta-sitosterol (8).
13.	*Medicago falcata*	Whole plants	Crude protein 15.85%, neutral detergent fiber 20.86%, cellulose 25.80% (8).
14.	*Medicago media*	Whole plants	Crude protein 17.50%, neutral detergent fiber 20.58%, cellulose 25.70% (8).
15.	*Medicago sativa*	Whole plants	Crude protein 18.22%, neutral detergent fiber 20.65%, cellulose 25.90% (8). Isoflavones, coumarins, alkaloids, vitamins, porphyrine, stachydrine, 1-homotachydrine. Carotinoides, triterpene, saponins, isoflavonoides, coumarins, triterpenes, spinasterol, stigmasterol, L-canavine betanine, fatty oils, Minerals (sodium, calcium, potassium, iron, manganese, silicon), essential enzymes, Vitamins- A, B_6, B_{12}, D, E and K. (9).
16.	*Melilotus officinalis*	Whole plants	Dry matter 89.95%, crude protein 24.01%, neutral detergent fiber 20.86%, and cellulose 25.80% (8). Flavonoids, coumarins, resin, tannins, volatile oil, dicoumarol. Hydroxycoumarins, Flavonoids, triterpine, saponins. Seeds are nicotinic. Anti-oedemaous properties (9).
17.	*Populus nigra*	Leaves and Barck	The bark of all *Populus* species contains phenolic glycosides, salicin and populin (salicin benzoate) (9).
18.	*Salix alba*	Leaves and Barck	Leaves (flavonoid glycosides, alboside, terniflorin, leuco-anthonidions, iso-rhamnetin-3-O-rutinoside, phenolic compounds- salicin, salicortin, salidroside, fragitin, triandrin. Barck- salicin, triandrin, catechol, gallate, glycosides (9,10).
19.	*Salix daphnoides*	Whole plants	Alkaloids, glycosides, saponins, Phenol glycosides present in the bark are: delphinidin, cyanidin, pipecolic acid, fragilin, picein, alicin, salicortin, salireproside, triandrin and vimalin (8). Tannin content is reported to be 8-13% (9).
20.	*Sisymbrium loeselii*	Whole plants	The seed oil contains erucic acid and larger amounts of etracosenoic acid. The plant contains alkaloids, organic acids, tannins, glycosides, saponins, coumarins and flavonoids (7).
21.	*Stellaria media*	Whole plants	Triterpenoid, saponins, VitamineC, coumarins, flavoineds, linolenic acid, octadecatetraenic acid. The plant also contains saponin glycosides, coumarins, flavonoids (including rutin), and carboxylic acid. The leaves contain vitamin C and carotene (8). The plant also contains mucilage and is rich in potassium and silicon. The aerial parts, in post-flowering period, contain 44 mg mg/100 g of vitamin E (9).

IV.II. Effect on Feed Intake

Several studies showed that essential oil (EO) and tannin has the effective role of livestock feed consumption. Tannin present in the feed above 5 % has the detrimental effects on the ruminants feeding habit. Feed contain higher than 5% tannin considered as the high tannin level. 5-10% level of tannin has the anti-nutritional property. Even it might be toxic. Sequentially, tannin reduced the digestibility if fibre in the rumen as they destroy the microbial population; inhabitant of the rumen (30-33). Plants, in this region, have the low level of tannins and have no capacity of these plants to hamper the digestibility mechanism. On the other hand, EO as the supplement enhances the feed intake of livestock animals. It also helps in the rumen fermentation procedure

(34,35). Most of the plants in this cold arid region are belongs to legumes and cereal crops. So, among the tabulated plants are high in EO and cereal crops which will be helpful for the livestock.

IV.III. Effect on Feed Digestion

The main effects of EO in the rumen have been suggested due to the reduction in protein and starch degradation and an inhibition of amino acid degradation due to selective action on certain rumen microorganisms, specifically some bacteria. The higher concentrations of EO decrease the DM as well as fiber digestibility in the rumen (36-38).

IV.IV. Effect on Wool Growth

Dry matter of plants induced the wool production. Experimentally it was found that in Lamb. Plants like *Lotus corniculatus* have the higher level of dry matter help in increase the level of wool production in lamb. However, experimentally it was also found that reduction in dry matter level of feed consequently reduced the wool production level (39,40). Alkaloids have the great role on wool production, also. It increased the level of amino acid digestion and absorption which will sequentially effective to increase the wool production (41, 42).

IV.V. Effect on Meat Quality

Antioxidant supplementation not only does the defensive act against the oxidative stress but also it did for the better meat quality and stability. Use of vitamin E (α-tocopherol), flavonols such as quercetin and larger polyphenolics as a supplement with feed or direct feeding showed that it has the ability to stabilize the meat colour and enhance the quality. The addition of α-tocopherol after the postmortem stabilized the lipid oxidation in the meat (43-47). Djenane *et al.* (2002) demonstrated that surface application of vitamin C, taurine, rosemary, vitamin E, and combinations of the last three with vitamin C have a positive effect on oxidative stability of beef steaks packaged in a modified atmosphere (48). Supplementation of vitamin-E and Vitamin-C has the capability to stabilise the myoglobin colour (45, 49).

IV.VI. Effect on Milk Production

Essential oil (EO) also has the positive effects on the milk production. Several studies concluded that it increase the milk production after the utilization of nutrient (50). This has not only the ability to increase the milk production but also has the potentiality to enrich the organoleptic and nutritional properties to the milk (51, 52).

IV.VII. Anti-helminthic Properties

Among the 30,000 described species of nematodes, 50% are marine, 15% are animal parasites, 10% are plant parasites and 25% are free living. According to the study of Kuchai *et al.* (2011), four species of nematodes viz; *Trichuris ovis*, *Haemonchus contortus*, *Dictyocaulus filaria* and *Chabertia ovina* are higher among the other nematodes present in sheep. Among these four species, *T. ovis* was most dominant followed by *H. contortus, D. filaria and C. ovina*, respectively (53). EO and lipids application as both can reduce the parasitic load (54). However, tannin also has the antihelminthic properties. In food industry, use of tanic acid increase the life span of food. Epicatechin and catechin, the two tannin components showed the strong anti-microbial activity. So, sometime, use of tannin rich fodder plants will be helpful for the livestock animals at high altitude region (55).

V. Conclusion

This review highlighted that a large reserve of plant species in the local flora are available that could be potentially used for livestock feeding in high altitude area. Therefore, these feed resources, if fully exploited, could assist in increasing the production and improvement of health of the livestock in this region. The manipulation of meat and milk quality, particularly with respect to fatty acid composition, is an active area of research. Hence, feeding or supplementation with different plant materials appears to offer a means to alter the lipid composition in animal products, which may result human health benefits. This is the new field of research where nutritional intervention may help in development of fortified animal product. Therefore, further research may be undertaken and validate their therapeutic importance in livestock species.

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