Plant Secondary Metabolites in some Medicinal Plants of Mongolia Used for Enhancing Animal Health and Production

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Summary

The levels and activities of a number of plant secondary metabolites (PSMs) are known to increase in response to increase in stress. The Mongolian plants considered to possess medicinal properties may contain novel compounds since they are exposed to severe conditions; such plants could become good candidates for modern drug discovery programmes. Information on distribution, palatability to livestock and opinion of local people on their nutritive and medicinal values was compiled for 15 plant materials from 14 plant species considered important for medicinal purposes. These plants were evaluated for nutritive value and PSMs: tannins, saponins, lectins, alkaloids and cyanogens. High levels of tannins were found in roots of Bergenia crassifolia *and in leaves of* B. crassifolia*,* Vaccinium vitisidaea *and* Rheum undulatum*. High lectin activity (haemagglutination) was present in B. crassifolia roots, and leaves of* R. undulatum, Iris lacteal *and* Thymus gobicus *contained weak lectin activity.* Tanacetum vulgare*,* Serratula centauroids*,* Taraxacum officinale *and* Delphinum elatum *leaves contained saponin activity (haemolysis). Alkaloids and cyanogens were not present in any of the samples. The paper discusses the known medicinal uses of these plants in light of the PSMs levels, and identifies plant samples for future applications in human and livestock health, welfare and safety.*

Résumé

Métabolites secondaires végétaux de quelques plantes médicinales de la Mongolie utilisées pour améliorer la santé et la production animale

Les niveaux et activités d'un certain nombre de métabolites secondaires végétaux (plant secondary metabolites, PSMs) sont connus pour augmenter à la suite de stress croissant. Les plantes mongoles, censées avoir des propriétés médicinales, pourraient contenir de nouveaux composés puisqu'elles sont exposées aux conditions environnementales rudes. De telles plantes seraient de bons candidats pour des programmes modernes de découverte de drogue. Des informations sur la distribution, la sapidité pour le bétail et l'opinion de la population locale concernant les valeurs nutritives et médicinales ont été rassemblées pour 15 matières végétales provenant de 14 espèces de plantes considérées importantes dans des applications médicinales. Ces plantes on été évaluées concernant leur valeur nutritive et les PSMs: tannins, saponines, lectines, alcaloïdes et cyanogènes. Des niveaux élevés en tannins ont été trouvés dans les racines de Bergenia crassifolia *ainsi que dans les feuilles de* B. crassifolia*,* Vaccinium vitisidaea *et* Rheum undulatum*. Une activité élevée de lectin (hémagglutination) était présente dans des racines de* B. crassifolia*, tandis que des feuilles de* R. undulatum, Iris lacteal *et* Thymus gobicus *démontraient une faible activité de lectin. Les feuilles de* Tanacetum vulgare*,* Serratula centauroids*,* Taraxacum officinale *et* Delphinum elatum *démontraient une activité de saponines (hémolyse). Des alcaloïdes et cyanogènes n'étaient pas présents dans ces échantillons. Cette publication discute des applications médicinales connues de ces plantes devant de niveaux PSMs, et identifie des échantillons de plante pour de futures applications au service de la santé des êtres humains et du bétail, leur bien-être et sécurité.*

Introduction

The use of various herbs and medicinal plants has a long history. They have been used since ancient times, especially in oriental countries. However, the advent of antibiotics in early 20th century led to decline in their usage and waned interest in providing scientific bases to their effects. The adverse effects of using

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antibiotics and other synthetic compounds on human and animal health and on product quality and safety have regenerated interest in the fields of 'phyto-chemistry, phyto-pharmacology, phyto-medicine and phyto-therapy' during the last decade. The ban on the use of antibiotics and other chemicals in livestock feeds since 2006 by the EU, because of the risk to humans of chemical residues in food and of antibiotic resistance being passed on to human pathogens, has further provided momentum to the research efforts on exploiting plants, plant extracts or natural plant compounds as potential natural alternatives for enhancing livestock productivity. The plant kingdom might provide a useful source of new medicines, pharmaceutical entities and bioactive compounds that may be used for not only treating human diseases but also for enhancing animal production and health; and food safety and quality, whilst conserving environment (13).

Plants have long been and continue to be the basis of many traditional medicines worldwide. Asian traditional medicinal systems such as traditional Chinese medicine (TCM), Korean Chinese medicine, Japanese Chinese medicine (kampo), Ayurveda from India, Jamu from Indonesia are well known. Mongolian traditional medicine, not much known to the world, is an amalgam of traditional Tibetan medicine, Ayurveda and Chinese medicine. Integrative medicine – the combination of traditional medicine with conventional or Western medicine could provide novel medicines for treatment of both animals and human disease. Bioactive compounds from plants could also be used as feed additives for enhancing livestock productivity and reducing environment pollutants such as methane in the exhaled gas and nitrogen and phosphorus in urine (13). The bioactivities in the plants are generally ascribed to the presence of plant secondary metabolites (PSMs) which could have beneficial or adverse effects (13, 17). In recent times, there has been change in the perception and several studies have been conducted on exploiting the beneficial effects of these phytochemicals.

To form the basis for rational exploitation of medicinal plants of Mongolia, we characterised some of the medicinal plants for PSMs and chemical composition, and the data are presented and discussed in this paper.

Material and methods

The samples were sun dried and brought to Germany for analyses. For analysis of crude protein and fibre fractions, the samples were ground to pass through 1 mm sieves; for the analysis of PSMs the samples were ground to fine powder using a ball mill (Retsch MM200, Haan, Germany). Crude protein (Kjeldahl method; N x 6.25) and ether extract were determined using AOAC (1). Neutral and acid detergent fibre analyses were conducted according to Van Soest's fiber analysis (18). Sodium sulphite and α-amylase were not used for the determination of fibre.

Extractable total phenols, total tannins and condensed tannins were determined in aqueous acetone (70:30, acetone:distilled water) extracts as described by Makkar (11). Total phenols were determined with Folin-Ciocalteu reagent using tannic acid as a standard. Total tannins were measured as the difference between total phenols before and after tannin removal by adsorption on insoluble polyvinylpyrrolidone (Sigma, Darmstadt, Germany). Both total phenols and total tannins were expressed as tannic acid equivalent. Condensed tannins (CT) were measured using the butanol-HCl-iron reagent (14) and expressed as leucocyanidin equivalent. The biological activity of tannins was determined in a bioassay developed in our laboratory. In this bioassay, samples are incubated with and without polyethylene glycol, PEG (MW 4000 or 6000) in syringes containing buffered rumen liquor. The polyethylene glycol binds to tannins making them inert, which leads to higher gas production; the higher the increase in gas production, the higher the biological activity of tannins (14).

Analysis of the lectin content was conducted by haemagglutination assay in round-bottomed wells of microtitre plates using 1% (v/v) trypsinised cattle blood erythrocytes suspension in saline phosphate buffer, pH 7.0 (12). The haemagglutination activity was expressed as the minimum amount of the material (in mg per ml of the assay medium) which produced agglutination. The minimum amount was the material per ml of the assay medium in the highest dilution that was positive for agglutination.

Saponin activity was determined as haemolytic activity. The sample was extracted in phosphate buffer saline (PBS). An aliquot (50 µl) of the PBS extract was diluted two-fold with PBS in separate wells of a microtiter plate and was mixed with 50 µl of 3% red blood cell suspension (from cattle blood) in each well and incubated at room temperature for 2 h. A clear concentric circle around the red blood cells indicated a non-haemolytic well, and the spread of red colour in the well and absence of a clear zone around red blood cells showed haemolysis. The haemolytic activity was expressed as the inverse of the minimum amount of saponin extract per ml of the assay medium in the highest dilution that started producing haemolysis (14).

The presence of alkaloids was assessed by extracting the finely ground materials in chloroform and application on thin layer chromatography (TLC) plates (Silica gel G). Dragendorff reagent was used for detection of alkaloids (6).

The determination of cyanogens was based on evolution of hydrocyanic acid from the sample and reduction of sodium picrate on a filter paper to a red-coloured compound, in proportion to its amount evolved and measurement of absorption at 510 nm using a spectrophotometer (5).

Results and discussion

Plants are good sources for the discovery of pharmaceutical compounds and medicines. Natural products could be potential drugs for humans or livestock species, and also these products and their analogues can act as intermediates for synthesis of useful drugs. Bioassay directed isolation and synthesis of analogues have long been appreciated as the effective approach for development of new plant derived compounds.

Levels of secondary metabolites are both environmentally induced as well as genetically controlled. The secondary metabolites are also called as plant defensive compounds since these have been evolved to deter pathogens or herbivores such as insects and mammals. The plants growing on low nutrient soil or in harsh conditions are often more dependent on evolved chemical defences. The Mongolian plants grow under harsh conditions of extremely low and high temperatures and thus could contain PSMs with a wide range of interesting activities.

The common names of plants, their distribution in Mongolia and reported medicinal uses are listed in table 1. This table also contains information on farmers' opinion on the palatability of the leaves by livestock and on their nutritional value. The leaves in particularly of *Artemisia frigida* and *Taraxacum officinale* are highly palatable by animals. The leaves studies are found in different regions of Mongolia and are considered to posses wide medicinal values, ranging from antimicrobial and anthelminthics to kidney- and liver-stimulating effects (Table 1).

The crude protein (CP) content of the leaves varied from 6.3 to 24.5%. The CP content was lowest (3.3%) in root sample of *Bergenia crassifolia* (Table 2). The leaves of *A. frigida* and *T. officinale* were reported by farmers to have high nutritional value. The CP content of these leaves considered good for livestock had high CP values (15.6 and 24.6% respectively); although mature leaves of *A. frigida* have a lower CP content (9.0%).

Tannins are polyphenolic compounds and have a wide range of effects varying from decreasing availability of proteins and other nutrients including amino acids and minerals to protecting ruminants from bloat, enhancing rumen bypass protein, enhancing meat quality and decreasing helminth infestation. Tannin level and activity was very high in *B. crassifolia* roots and leaves of *B. crassifolia, Vaccinium vitisidaea* and *Rheum undulatum*. A moderate tannin activity (33.4% increase in gas on addition of PEG) was present in *Thymus gobicus*. Tannins are also known to have antimicrobial, anthelmintic, antimutagenic, antiinflammatory and antioxidant properties. A number of tannin-rich tree leaves and browses have been evaluated and found to be effective in reducing faecal egg worm and enhancing livestock productivity (13). Parasitism by gastrointestinal nematodes is one of the major constraints on livestock production, especially when the nutritional status of the animals is poor. Subclinical infections of gastrointestinal nematodes decrease feed intake, body-weight gain, and milk and wool production. In subtropical and tropical areas of the world where the animals are on low quality feeds and have poor nutritional status, mortality and morbidity due to nematode infection are widespread. There is a growing awareness that chemical anthelmintic treatment, on its own, may not provide a long term strategy for managing parasites in grazing animals. The widespread development and prevalence of resistant strains of nematode parasites and public concern over drug residues excreted in animal products have stimulated efforts to identify and use plant-based anthelmintic compounds; tannin-containing plants and tannins could potentially be natural anthelmintics.

Among the above-mentioned four plants identified as containing substantial amounts of tannins, only *T. gobicus* has been used by farmers as an anthelmintic to dispel intestinal worms. The presence of etheric oil compounds such as thymine, eugenol and carvacrol in this plant could also be responsible for its anthelmintic effects. The other three tannin-rich plants *B. crassifolia*, *Vaccinium vitisidaea* and *Rheum undulatum* also hold potential for reducing the intestinal worm load in livestock and increasing their productivity. Studies on evaluation of these plants as anthelmintics are being conducted in our laboratory in Mongolia. Similar use of these plant materials for other properties stated above for tannins also needs investigation. The use of *B. crassifolia* root and leaf extracts as mouth cleaner in Mongolia, their known astringent effect and their use for curing infectious disorders of the gastro-intestinal tract (Table 1) could be attributed to the presence of high tannin levels and activities in this plant. The astringent effect of tannins is a well established phenomenon (11).

In Mongolia, farmers also use *A. frigida, Tanacetum vulgare, Iris lacteal*, and *Stellera champaejasme* leaves as anthelmintics (Table 1), although tannin levels were low in these leaves. The data on PSMs in this study could not provide answer to the use of these leaves as anthelmintics. This effect could possibly be due to the presence of some other non-tannin bioactive moiety such as bromelain present in pineapple leaves (13). Enhancement of the nutritional status of animals has also been shown to decrease the burden of intestinal worms due to increased immunity (7). *Artemisia frigida* is highly palatable to livestock and has reasonably high

medicinal plants of Mongolia

Plant	Local names	Plant characteristics	Distribution in Mongolia	Palatability to livestock & known nutritional value	Considered medicinal value in Mongolia
Artemisia frigida	Agi	Dense bunch-forming xerophytic semi-shrub, 10–40 cm tall; leaves: bract leaves with white cork edges, lower surface covered with dense hair and upper surface is hairy along margins, leaf stalks short, blade stipple or double palmate; roots: short rhizomes; inflorescence: 2–4 mm wide, semi-circular involucres form; development cycle: begins to grow early in spring or in late March, flowers in August, and seed matures in September.	Khuvsgul, Khentei, Khangai, Mongol-Daurian, Khovd, Mongolian Altai, Middle Khalkha, Depression of Great Lakes, Valley of lakes, East Gobi, Gobi-Altai. Site preference: Gravelly and stony slopes, foot hills, rocky sites in dry river basins, edges of dry river banks, around ponds in mountain steppe, steppe and desert steppe.	Very palatable for sheep, goats, and camels in summer, and very palatable to horses and cattle in winter and spring. Farmers consider it a nutritious plant animals grazing 'Agi' pasture gain weight rapidly. It is collected, dried and mixed with curd grain, whey, salt and other residues from dairy processing to make feed for nursing, sick and exhausted animals. It is a good component for hand-made feed.	Aerial parts of the plant exert positive effects on liver function and on excretion of bile and are diuretic. Leaves have anthelmintic, antifungal, antibacterial, astringent and anti-inflammatory effects, possibly by volatile oils or thujone present in leaves. Leaves used for treatment of wounds.
Tanacetum vulgare	Maral tsetseg	Tall plant 30–150 cm with leafy stem; leaves: pinnate dissected with pinnate lobes. 10-70 head compound complex shell. Flat-topped clusters of small, button-like yellow flowers, and long fringe of soft white hairs found on the seeds.	Khuvsgul, Khentei, Khangai, Mongol-Daurian, Khovd, Mongolian Altai, Great Khingan. Site preference: deciduous and willow forests and its periphery, rocky sites.	Different palatability recorded, depending on places. Not poisonous in the mixture with hay. Although the plant is considered to be toxic if consumed in large quantities, cases of livestock poisoning are rare, though, because it is unpalatable to grazing animals.	The leaves and flowers used as anthelmintics to dispel or destroy intestinal worms, and as an external applicant to kill scabies, fleas and lice. Seed has herbicidal properties. Oil is considered to be toxic.

Iris lactea	Khos khairst tsakhildag	Mesophytic perennial forb, 20–50 cm tall, grows in dense, large bunches; leaves: numerous leaves, 4–8 mm wide, always longer than flower stalk; inflorescence: tube of perianth much shorter than corolla; blue petals with white outer circle, wider than inner circle; pods 4–8 mm long, shorter than flower and has many folds; development cycle: flowers and seeds mature in May-June.	Khentei, Khangai, Mongol Daurian, Great Khingan, Khovd, Mongolian Altai, Middle Khalkha, East Mongolia, Gobi-Altai, Alashan Gobi. Site preference: Marshy lake shore, riparian areas, edges of springs, and gravelly meadows.	When dried and cured, camels small ruminants, and cattle graze moderately.	Leaves used as antibacterial, anthelmentic agent for livestock, treatment of wounds originated from thermal burn. Root stock, seed and flowers are used in the treatment of pneumonia, bronchitis, chronic gastritis and anthelmintic purposes. In Japanese traditional medicine seeds used for treating swellings and snake bite wounds, and root stock for temperature reduction.
Rheum undulatum	Gishuune, Airgana	Perennial forb 50–100 cm tall; stems: naked, grooved stems, 4 cm diameter; leaves: mostly basal, triangular to oval or broad oval, 10–40 cm long with wavy margins, leaf petioles 10–20 cm long; roots: taproot; inflorescence: compact, divaricated; seeds: 8 mm long, oval-shaped weighing approximately 0.1 g; development cycle: flowers in June-July, and seeds mature in August.	Khentei, Khangai, Mongol Daurian, Great Khingan, Middle Khalkha, East Mongolia, East Gobi. Site preference: forests, gravelly and moist meadows along rivers, ravines, rocky mountain crests, meadow slopes and abandoned land.	Camels graze when green. Sheep and goats moderately graze when dried.	Locals from Gobi and steppe areas make jam from flesh of leaf stalks. Leaves used for treatment of abdominal distension, gastritis, food poisoning and cavity hemorrhage. Root and taproot have soft purgative agents. Flavonoids and anthraquinones of leaves and taproot have anti-inflammatory and irritant laxative effect on the large intestine, causing contractions of the intestinal walls and stimulating bowel movement.
Thymus gobicus Tschern	Gobiin ganga	Semi-shrub with woody base, 2–3 cm tall, prostrate; stem: heavily branched round and evenly hairy; leaves: small, firm circular or oval-shaped narrow, smooth edged, outer surface covered with long hair along ventral margins and leafstalks hairy and red brown; development cycle: flowers in June-July, seeds mature in August and cured litter persists through winter	Khuvsgul, Khentei, Khangai, Middle Khlkha, Mongol Daurian, Depression of Great lakes. Site preference: sandy deposits, sandy steppe, gravelly banks, gravelly and stony slopes, hillside areas, rocky sites and scree.	Green plants not grazed by animals. Dried and cured standing matter grazed by sheep and goats, and only occasionally by horses. Camels and cattle do not graze the dried and cured matter.	The aerial part of the plant is used as an antiseptic, a tonic for enhancing immunity, anti-asthmatic to relieve breathing problems, anthelmintic to dispel or destroy intestinal worms.

Serratula centauroides	Khongorzullig khongorzalaa	Coarse and hairy plant 15–80 cm tall; leaves: double palmate, narrow spear shaped or linear and 15 cm long and 6 cm wide.	Khentei,Khangai, Mongol Daurian, Mongolian Altai. Site preference: sandy, gravelly, and stony slopes in steppe and sandy-steppe.	Not very palatable to animals.	Flowers and seeds of the plant are known to contain glucosinolates, act as skin irritants causing inflammation and blistering, if applied to painful and aching joints, they increase blood flow to the affected area, helping to remove the build-up of waste products. Aerial parts of the plant have purgative properties.
Stellera chamaejasme L-Odoi Dalan tyruu	Teveg zalaa, Deren turuu	Xerophytic perennial forb; 20–40 cm tall; stems: naked straight stems; leaves: alternate, nearly seeile, oblong-ovate, 17–30 mm long, 3–8 mm wide; roots: large, fleshy taproot; inflorescence: dense inflorescence at apex of stem and branches, each inflorescence with 20–25 flowers; corolla bluish pink; development cycle: flowers in June, and seed matures in July-August.	Khentei, Khangai, Mongol-Daurian, great Khingan.	Considered to be a poisonous plant, but no reports of livestock poisoning.	The tincture and decoction of leaves have purgative function and used for the treatment of Brady peristalsis and constipation. Plant decoction is also used for treating gingivitis and dental disorder. Tincture and powder of leaves can be used for mechanical injury and thermal burn. Leaves also used as anthelmintic agent.
Taraxacum officinale	Bagvaakhai tsetseg	Perennial forb 8–50 cm tall; leaves: 5–25 cm long, 1–4 cm wide, nearly glabrous, edged, or serrated but not deeply pinnate; husk: 12-14 mm wide, 12-20 mm long, dull green, leaves in outer circle of leaflets spear-shaped to oval and twice as short as narrow leaflets in inner circle; inflorescence: peduncle 8–50 cm long with woolly pubescence under the head; flowers light yellow; achene fruit about 4 mm wide, brown or light-brown with numerous spots on top; development cycle: flowers from May to September, and seeds mature during the same period.	Khuvsgul, Khentei, Mongol-Daurian, Khovd, Depression of Great lakes, Valley of lakes. Site preference: forest and wet meadows, shrub thickets, forest margins and garden edges and roads.	Palatable to cattle and pigs. Considered to be a good feed by farmers.	Leaves used as salad for human consumption, used for decreasing blood sugar and increasing blood clotting, water extract used for diuretic purpose and alcoholic extract as antifungal agent.

Delphinum elatum	Ber tsetseg	Xerophytic-mesophytic perennial forb, 15–70 cm tall; stems: branched near the top; leaves: compound palmate, round, 10 cm long, 15 cm wide, and dissected to the bases; inflorescence: flowers bright blue, large asymmetrical with spur arranged singly along rachis; development cycle: flowers in July –August, and seeds mature in late August and early September.	Khusgul, Khentei, Mongol-Daurian, Great khingan, East Mongolia, Gobi –Altai. Site preference: plains, slopes and foothills of mountains and dry meadows in river valleys.	In summer, small animals graze moderately, while cattle and horses poorly. In other seasons, small animals graze readily with moderate grazing by horses and cattle.	Plant part on the ground has antibacterial effects and reducing blood pressure. It is used for the treatment of periton disorder. Aerial parts of the plant have antibacterial effects and reduce blood pressure. The plant contains powerful alkaloids, for example vincristine used to treat some types of cancer and atropine used for reducing spasms and relieving pain.
Vaccinium vitis-idaea	Anis, alirs	Perennial, semi-shrub, 5-30 cm tall with whitish hairy branches; long-lasting orange-red berries amidst glossy, fully evergreen oval shaped leaves; flowers are bell shaped and filament of stamen is hairy.	Khusgul, Khovsgol, Khentei, Mongol-Daurian, Great khingan and Khangai. Site preference: Shady gravel slopes, forest margins.	Ruminants graze when green. Sheep and goats moderately graze when dried.	Both the leaves and fruit are useful for treating congestion or the common cold or liver kidney and urethral ailments. Berries are a good source of Vitamin C, A, and is rich in antioxidants and are used for raising blood pressure and in diabetics. Mongolians use extracts of the leaves and fruit for treatment of cold and improving immunity in winter season.
Salsola laricifolia	Budargana,	Shrubs small, 40-90 cm tall. Stem branched; older branches black-brown or brown, slightly fissured; branchlets white, glabrous, sometimes papillate; leaves alternate, fascicular on dwarf branches, yellow-green, fleshy.	East and Western Gobi, Gobi-Altai and Alashaan Gobi. Site preference: Slopes, dunes, rocky deserts on salty clay soils.	Camels graze when green. Sheep and goats moderately graze when dried. Cattle, sheep, and horses will eat it, if nothing better is available.	Extract of aerial parts of the plant have astringent, anti-inflammatory and purgative effects. Root extract of this plant extends lifespan, improve immunity and resistance against diseases. Mongolian scientists have developed medicines, called 'Salorid', 'Salimon' which are considered to improve immune system.
Bergenia crassifolia	Zuzaan navchit badaan	Perennial shrub; flower: regular structured , sepals 4–5, petals 4–5, pistil 1, stamen 4–8, ovary 1 or 2 nests; stems and leaves: thick stem with thick basal leaves; roots: thick, brunched rhizomes with brown color.	Khuvsgul, Khentii, Khangai, and Mongolian Altai. Site preference: Alpine rocky and stony fields, scree and shady gravel slopes, forest margins.	Not very palatable to animals.	Extract and decoction of root stocks used in the treatment of gynecological diseases and gastritis, mouth can be cleaned by extracts of root, taproot and leaves. The plant has expectorant and astringent effects. Mongolian scientists have made a medicine, named 'Badglumecine', from the roots for treatment of infectious disorders of gastro-intestinal tract of animal.

Source: (8, 10, 15, 19).

Table 2
Chemical composition (g/kg dry matter) and plant secondary metabolites in some medicinal plants of Mongolia

Plant	Crude protein	Ether extract	NDF[a]	ADF[b]	TP[c]	TT[d]	CT[e]	Tannin activity[f]	Saponin Activity[g]	Lectin activity[h]	Alkaloids	Cyanogen (µg KCN/g)
Artemisia frigida[1]	156.4	19.4	548.1	431.0	19.7	5.1	0.3	4.3	nd	nd	nd	nd
Artemisia frigida[2]	90.3	14.1	560.7	426.8	21.9	4.0	0.8	0	nd	nd	nd	nd
Tanacetum vulgare	151.8	34.5	462.3	416.0	37.5	5.7	0.4	0	0.02	nd	nd	nd
Iris lactea	103.0	14.7	495.1	436.3	38.1	28.9	14.3	0	nd	0.08	nd	nd
Rheum undulatum	105.2	6.0	227.7	168.5	76.6	55.7	7.1	92.7	nd	0.64	nd	nd
Thymus gobicus	103.6	23.3	540.5	443.0	35.9	11.6	0.2	33.4	nd	0.04	nd	nd
Serratula centauroides	114.9	35.4	625.8	509.4	58.3	46.0	0.5	7.2	0.015	nd	nd	nd
Stellera chamaejasme	133.9	27.7	391.3	312.2	43.8	15.4	0.3	0.4	nd	nd	nd	nd
Taraxacum officinale	245.9	26.2	317.7	270.6	22.7	7.1	0.3	11.0	0.015	nd	nd	nd
Delphinum elatum	136.4	22.4	515.4	387.1	22.2	8.5	0.7	4.1	0.015	nd	nd	nd
Artemisia frigida[2]	156.4	19.4	548.1	431.0	19.7	5.1	0.3	4.3	nd	nd	nd	nd
Vaccinium vitis-idaea	63.2	33.3	476.1	354.1	243.3	149.2	174.5	96.3	nd	nd	nd	nd
Salsola laricifolia	94.8	11.7	574.3	380.3	65.3	32.0	28.0	17.7	nd	nd	nd	nd
Bergenia crassifolia	63.1	23.9	260.9	190.4	320.2	178.4	14.1	169.8	nd	nd	nd	nd
Bergenia crassifolia[x]	32.7	7.7	226.0	197.0	309.3	165.0	33.1	204.7	nd	10.25	nd	nd

nd, not detected; [1] Cut on July 20th 2007, and [2] cut on August 20th 2007; all samples except [x] were leaf samples. [x] was a root sample
[a]neutral detergent fibre, [b]acid detergent fibre; [c, d]TP (total phenols) and TT (total tannins) as tannic acid equivalent in g/kg DM; [e]CT (condensed tannins) as leucocyanidin equivalent in g/kg DM; [f]percent increase in gas on addition of polyethylene glycol; [g] Inverse of the minimum amount of plant-material/ml of assay, which produced haemolysis; the assay comprised of 1: 1 (v / v) of plant-material in PBS and 3% red blood cells, [h] Inverse of minimum amount of plant-material/ml of the assay, which produced agglutination; the assay comprised of 1: 1 (v / v) of plant-material in RBC and 1% trypsinized red blood cells.

crude protein level (young leaves 15.6% and mature leaves 9.0%). The effectiveness of this plant against intestinal worms could possibly be due to the high nutritional quality and high intake of this plant material, thereby enhancing nutritional status of animals.

The use of tannins for reduction of methane (a greenhouse gas) production from ruminants is being considered (3). Recently studies conducted in our laboratory have shown a high correlation between the tannin activity and methane reducing potential of these medicinal plants from Mongolia. Tannin containing plants could possibly be used to prevent diarrhoea in pigs (9).

Saponins are steroid or triterpene glycoside compounds present in a number of plants. These were present in *T. vulgare, Serratula centauroides, T. officinale* and *Delphinum elatum* leaves (Table 2). Saponins have also been known to have several health beneficial effects, for example, enhancement of immunity, reduction in blood glucose and other antidiabetic effects, and reduction in blood cholesterol (4). The plants *T. officinale* and *D. elatum* are used in Mongolia for reducing blood sugar and blood pressure, and this study has shown that these plants contain saponins, which could possibly be responsible for these beneficial effects. Saponins also have anti-protozoal effects and could potentially be used for controlling protozoal diseases. This group of PSMs also has strong antifungal, antinematode, molluscicidal, and insecticidal properties (2, 4, 20). The use of *T. vulgare* for killing scabies, fleas and lice as practiced in Mongolia could possibly be attributed to the presence of saponins. In addition, the saponin containing Mongolian plants could find applications for reducing emission of methane from ruminants and enhancing livestock productivity (20).

Among the PSMs determined, alkaloids and cyanogens were not detected in any of the samples analysed (Table 2). Alkaloids and cyanogens have been reported to have both detrimental and beneficial effects (17).

Lectins or haemagglutins are sugar-binding proteins. Lectin activity was present in the leaves of *I. lacteal, R. undulatum, T. gobicus* and *B. crassifolia* roots; lectin activity being highest in *B. crassifolia* roots. Traditionally lectins have been described as toxic and antinutritional factors; however major developments have taken place during the last decade showing a number of potential applications of plant lectins in biomedical and bioscience fields. To name a few are applications as gut-, metabolic-, hormone- and immune-regulators and their use for protection of intestine against the adverse effects of radio- and chemo-therapy used in cancer therapy (16). Lectins present in leaves of

I. lacteal, R. undulatum, T. gobicus and *B. crassifolia* roots might elicit the beneficial effects of these plants listed in table 1. The roots of *B. crassifolia*, being high in lectin activity could be an interesting candidate for future investigations.

Based on the known activities of secondary metabolites, this study has provided explanation for some of the medicinal uses of the plants for which the local population use them. This study has also identified plant materials such as *B. crassifolia* root which is rich in tannins and lectins; *B. crassifolia, V. vitisidaea* and *R. undulatum* leaves which are rich in tannins; and *T. vulgare, S. centauroids, T. officinale* and *D. elatum* leaves containing saponins, for future investigations leading to their various applications in human and animal health, production and welfare. Future studies should also be directed towards exploring other phytochemicals such as flavonoids, flavanones, phytoestrogens, essential oils etc. in the leaves and other parts of the plants especially roots, which are also used in the traditional Mongolian medicines to a considerable extent.

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Table 1
Plant characteristics, distribution and medicinal uses of some

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