XXIV Reunión de la Asociación Latinoamericana de Producción Animal
XL Congreso de la Sociedad Chilena de Producción Animal, A.G.
Puerto Varas (Chile) 9-13 Noviembre, 2015

Using condensed tannin containing forages to establish sustainable and productive forage-based cattle production systems

Tim A. McAllister[1], Surya N. Acharya, Yuxi Wang and Edmond T. Sottie[2]
Agriculture and Agri-Food Canada, Lethbridge Research Centre,
5403 – 1st Avenue South, Lethbridge, AB, Canada T1J 4B1.

Abstract
Legumes play a key role in ruminant production systems, with alfalfa being the most common legume forage in temperate climates. Alfalfa can maintain high production levels in grazing livestock, but its propensity to cause bloating discourages its inclusion at high planting densities. Alfalfa produces high molecular weight polyphenols known as condensed tannins, in their seed coat, while other legumes such as the corniculated lotus (*Lotus corniculatus* L.), wild chickpea (*Astragalus cicer* L.), purple prairie clover (*Dalea purpurea* Vent) and sainfoin (*Onobrychis vicifolia* Scop.) produce condensed tannins in varying degrees. Condensed tannins (CT) are responsible for their bloat-safe nature, improving the use of ruminal N, controlling intestinal parasites, reducing Escherichia coli in faeces and possibly enteric methane emissions. Tympanism of grasses is almost always of the foamy type and arises as a result of complex interactions between the animal, the forage and the rumen microbiome. The risk that lucerne causes bloating is greater when it is in the vegetative stage and becomes considerably smaller as it enters the flowering stage. The risk of bloating in cattle pasturing alfalfa can be reduced through various management practices. Cutting and withering the alfalfa before allowing cattle access to the paddock can drastically reduce the incidence of bloat. The sainfoin is comparable to alfalfa in nutritional quality and results in average daily gains in cattle that are similar to alfalfa. The CTs they contain are of high molecular weight and show a greater affinity for Rubisco than most other CT scans, which possibly gives them a superior ability to prevent tympanism. Among TC forages, foam is perhaps the most adaptable for use in a high-performance grazing system where it is grown in mixed stands with alfalfa.
Key words: Alfalfa; Condensed tannins; bloating; grazing system.

Uso de taninos condensados que contienen forrajes para establecer sustentables y productivos sistemas de producción ganadera basados en forrajes

Resumen
Las leguminosas desempeñan un papel clave en los sistemas de producción de rumiantes, siendo la alfalfa el forraje de leguminosas más frecuente en climas templados. La alfalfa puede mantener altos niveles de producción en el ganado a pastoreo, pero su propensión a causar timpanismo desalienta su inclusión a altas densidades de siembra. La alfalfa produce polifenoles de alto peso molecular conocidos como taninos condensados, en su cubierta de la semilla, mientras que otras leguminosas como el loto corniculado (*Lotus corniculatus* L.), garbanzo silvestre (*Astragalus cicer* L.), trébol púrpura de pradera (*Dalea purpurea* Vent) y esparceta (*Onobrychis vicifolia* Scop.) producen taninos condensados en diversos grados. Los taninos condensados (CT) son responsables de prevenir el timpanismo, mejora la utilización del N ruminal, controla los parásitos intestinales, reduce la *Escherichia coli* en las heces y posiblemente las emisiones de metano entérico. El timpanismo de los pastos es casi siempre de tipo espumoso y surge como resultado de interacciones complejas entre el animal, el forraje y el microbioma del rumen. El riesgo de que la alfalfa provoque timpanismo es mayor cuando se encuentra en la etapa vegetativa y se vuelve considerablemente menor a medida que entra en la etapa de floración. El riesgo de timpanismo en el ganado que pastorea alfalfa se puede reducir a través de varias prácticas de manejo. Cortar y marchitar la alfalfa antes de permitir el

[1] Corresponding author: Tim.McAllister@agr.gc.ca
[2] Agriculture and Agri-Food Canada, Semiarid Prairie Agriculture Research Centre, Swift Current, SK. Canada S9H 3X2

acceso del ganado al potrero puede reducir drásticamente la incidencia de timpanismo. La esparceta es comparable a la alfalfa en calidad nutricional y da como resultado ganancias diarias promedio en ganado que son similares a la alfalfa. Los TC que contienen son de alto peso molecular y muestran una mayor afinidad por Rubisco que la mayoría de los demás TC, lo que posiblemente le confiere una capacidad superior para prevenir el timpanismo. Entre los forrajes de TC, la espuma es quizás la más adaptable para el empleo en un sistema de pastoreo de alto rendimiento donde se cultiva en rodales mixtos con alfalfa**.**
Palabras clave: Alfalfa; taninos condensados; timpanismo; sistemas de pastoreo.

Introduction

Legumes play a key role in ruminant productions systems with alfalfa being the most prevalent legume forage in temperate climates with North America production worth more than $ 7 billion annually (Graham and Vance, 2015). Alfalfa can sustain high levels of production in pastured cattle, but its propensity to cause bloat discourages its inclusion at high seeding densities. Alfalfa only produces the high-molecular weight polyphenolics known as condensed tannins in its seed coat, whereas other legumes such as birdsfoot trefoil (*Lotus corniculatus* L.), cicer milkvetch (*Astragalus cicer* L.), purple prairie clover (*Dalea purpurea* Vent) and sainfoin (*Onobrychis vicifolia* Scop.) produces condensed tannins within foliage to varying degrees (Berard et al., 2011). Condensed tannins (CT) within these legumes are responsible for their bloat-safe nature. In addition to preventing bloat, CT improves ruminal N utilization, control intestinal parasites; reduce *Escherichia coli* in feces and possibly enteric methane emissions (Berard et al., 2009; Piluzza et al., 2013). At Agriculture and Agri-Food Canada we have been using sainfoin to develop high performance grazing systems by growing it in mixed stands with alfalfa. We have also been exploring the utility of novel sources of CT such as those in purple prairie clover, a legume that is native to North American grasslands with unusually high levels of CT (Berard et al., 2011).

Alfalfa – sainfoin high performance grazing systems

Forage legumes are valued for their high protein content, rapid ruminal digestibility and high intake and beef production potential. In North America, beef production has been enhanced through the widespread use of alfalfa (*Medicago sativa* L.) which has been described as the 'Queen of forages'. Genetic enhancement of alfalfa through selective breeding has occurred since the 20th century and has resulted in substantial improvement in yield, nutritional quality and its agronomic distribution in Northern latitudes (Berg et al., 2000). Due to these properties and the availability of export markets in Pacific Rim and Middle East, most western Canadian producers prefer alfalfa over most other legume crops. Alfalfa's nitrogen fixing capacity and the ability of its deep roots to prevent wind and water erosion also makes it a common ingredient in mixed-species improved pastures. However, owing to its ability to cause bloat, alfalfa is seldom included in pastures at levels that exceed 30% of pasture dry matter (DM) as increasing the level of grass and reducing the level of alfalfa in cattle diets lowers the risk of bloat (Wang et al., 2012).

Pasture bloat is almost always of the frothy type and arises as a result of complex interactions among the animal, forage and rumen microbiome. It is believed that soluble proteins and in particular ribulose-1,5-bisphosphate carboxylase oxygenase (Rubisco) contributes to stabilizing the foam in ruminal contents which inhibits the eructation reflex. Release of Rubisco into the rumen is associated with the rupture of chloroplasts, so cattle that have bloated also tend to have higher concentrations of chlorophyll in rumen contents. Bloat arises as a result of interactions among the forage, the grazing animal and the rumen microbiome, creating a complexity that makes it difficult to predict under field conditions. Ruminants harbour active populations of bacteria, protozoa and fungi within their rumen. These microorganisms are responsible for the digestion of the majority of the feed consumed and produce large amounts of CO2 and CH4 in the process. Normally the gases separate from liquid and solid contents and rise to the ruminal dorsal sac, where they exit the rumen through the esophagus during normal rumen contractions

(Wang et al., 2012). Typically, this contraction cycle occurs about every minute and prevents the accumulations of gas within the rumen. With bloat, stable foam forms in the rumen which interacts with sensory nerves that control the esophageal opening and gas accumulates in the rumen (Cheng et al., 1998). As the rumen swells it places pressure on the diaphragm and lungs, resulting in respiratory failure.

The risk of alfalfa causing bloat is highest when it is at the vegetative stage and becomes considerably less as it enters the flowering stage. Pure stands of alfalfa at the full-flower stage can be grazed with minimal bloat-risk, but at this stage protein levels are lower and increased lignification reduces cell wall digestibility. The ratio of cell wall constituents to cell contents gives an indication of the nutritive value of the forage with a lower ratio indicative of higher quality. Consequently, from a pasture productivity perspective it is desirable to graze pastures in the vegetative state, but such a practice is dubious for alfalfa owing to the high bloat risk. The risk of bloat in cattle grazing alfalfa can be reduced through various management practices. Cutting and wilting the alfalfa to a lower DM prior to allowing cattle access to swaths can dramatically reduce the incidence of bloat. In addition, there are pluronic detergents that can be administered through water that are almost completely effective at preventing pasture bloat, provided that they are consumed daily be cattle grazing alfalfa. However, all of these practices require increased investment either in the form of purchasing of additives or time to more intensively manage cattle and pastures.

Among the CT forages, sainfoin is perhaps the most adaptable for employment in a high-performance grazing system (HPG) where it is grown in mixed stands with alfalfa. This is owing to its high nutritive value, winter hardiness, drought tolerance and resistance to some alfalfa insect pests (Bolger and Matches, 1990; Ditterline and Cooper, 1975). It is also well adapted to dry and calcareous soils and grows best on deep soils with a pH of above 6.0 (Frame, 2005). Sainfoin is comparable to alfalfa in nutritional quality and results in average daily gains in cattle that are similar to alfalfa (Parker and Moss, 1981).

The CT it contain are of high molecular weight and exhibit a greater affinity for Rubisco than most other CT, possibly giving it a superior ability to prevent bloat. Moreover, the low to moderate levels of condensed tannins in sainfoin reduces the degradation of soluble proteins in the rumen, without negatively inhibiting rumen bacteria involved in plant cell wall degradation to the same degree as other CT sources. As a result, the absorption of protein in the small intestine is increased in comparison with some legumes.

Furthermore, at the comparable growth stages, sainfoin results in a higher daily weight gain, in cattle and young lambs as compared to other CT containing legumes such as birdsfoot trefoil (Wang et al., 2015).

Sainfoin also retains its leaves longer than alfalfa and can be harvested at a more mature stage without as great of loss in quality with the highest yields obtained at 75 to 100% bloom. Our laboratory has conducted studies that show that as little as 10% sainfoin in alfalfa pastures can dramatically reduce the risk of pasture bloat (McMahon et al., 2000; Wang et al., 2006). Unfortunately, currently available sainfoin cultivars in Canada (Melrose and Nova) fail to persist in mixtures with alfalfa and their poor re-growth limits their value as a pasture forage for grazing ruminants (Acharya, 2007). Therefore, there is great interest in developing sainfoin cultivars that are capable of producing high yield with the ability to survive in mixed alfalfa stands and grow back quickly after grazing. A sainfoin variety with these characteristics has the potential to prevent bloat and improve protein utilization in mixed alfalfa-sainfoin pastures.

With this objective in mind, several new sainfoin populations were developed at the Lethbridge Research Centre that are capable of surviving in mixed alfalfa stands under a multiple cut system. These populations were developed from clones selected for rapid growth/regrowth and high biomass production in competition with alfalfa and with consideration for grazing condition such as trampling (Acharya, 2012). Recent studies in western Canada determined that some of these newly developed sainfoin populations when grown in alternate rows with alfalfa prevented bloat in cattle rotationally grazing mixed legume pastures (Acharya et al., 2013; Sottie et al., 2014). In these studies, pasture DM yield decreased over time for both new and old sainfoin populations. However, yield of the mixed alfalfa stand containing the new sainfoin populations were significantly higher than the older sainfoin variety, Nova in three year old stands (Sottie et al., 2014). The proportion of new sainfoin in the mixed

alfalfa stand was 20% higher than Nova, even though both sainfoin types accounted for a similar amount of pasture biomass at the beginning of the experiment.

The severity and incidence of bloat in the alfalfa-sainfoin stands with new sainfoin population was reduced by 95% as compared to mixed stands with Nova. Neither the nutritional quality nor levels of CT differed between new and old sainfoin populations. The higher proportion of DM from new sainfoin populations in mixed stands was likely responsible for the significant reduction in bloat. These studies indicated that the ability of sainfoin populations to persist at 25-30% of the pasture biomass over three years, dramatically reduced the risk of bloat. As a result of this work a new sainfoin cultivar, 'AAC Mountainview' was recently released for commercial production in western Canada (Acharya, 2015).

Purple Prairie Clover

Purple prairie clover (PPC) is a legume that is native legume to the North American prairie and has excellent nutritional properties for ruminants (Stubbendieck and Conard, 1989).In a survey of CT containing forages across the Canadian prairies, purple prairie clover had the highest concentration of CT measured as 68 g kg-1 of forage DM (Berard et al., 2011). Futhermore, purple prairie clover CT appear to possess unique chemical properties exhibiting activities against *Escherichia coli* O157:H7 activity (Wang et al., 2009) that are higher than other sources of CT and lower the levels of *E. coli* shed in cattle feces (Jin et al., 2015). Despite having high levels of CT, the ruminal DM digestibility of purple prairie clover was still high. Studies are ongoing to define the chemical characteristics that are responsible for the unique traints of PPC CT. Agronomic studies are also under way to characterize the growth traits and nutritional value of this unique source of CT.

Summary and Concluding Remarks

Although CT are often associated with anti-nutritional traits, it is clear that through selection and with an appreciation for their chemical activity, it is possible to use CT to deliver favorable outcomes in ruminant grazing systems. Indications are that sustained efforts in developing mixed legume pastures through improved sainfoin populations will benefit western Canada producers in terms of both forage and cattle productivity. Enhanced levels of alfalfa/sainfoin mixed pasture grazing along with the further characterization of unique sources of CT such as those in PPC could lead to the development of HPG that help alleviate public concern over beef production practices that rely on high grain diets in intensively managed feedlots.

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