

# Forage Plant Secondary Metabolites At the Intersection of Animal Health, Productivity, and Sustainability

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## **Abstract:**

The nutritive value of forages and other feeds have long been studied. However, the roles of secondary metabolites produced by forage-plants and their endophytes are an emerging field. Historically, the term *secondary metabolite* was used for compounds that were less abundant in plant tissue than the primary metabolites, such as fiber, sugars, and protein. It has become clear that secondary metabolites play important roles in the ecology of forage plants, and that both the detrimental and beneficial impacts of secondary metabolites to forage-animals should not be underestimated. This thematic session will consider fescue toxicosis, a detrimental outcome of ergot alkaloids produced by the tall fescue/*Epichloë coenophiala* symbiosis. Reports will also be made on isoflavones and condensed tannins from forage legumes. Secondary metabolites in general, must be better understood to be used in management programs that consider foraging behavior and the spatial distribution of bioactive forages in the landscape for enhancing forage-animal health and productivity. Human nutritionists refer to food with pharmacological benefits as a “functional food.” Forage scientists can borrow that idea for “functional feeds”, an interdisciplinary area that combines forage sciences and pharmacology.

## **Introduction**

The challenge is to sustainably maintain grassland ecosystems while simultaneously meeting the nutritional needs of a growing human population, improving the health and welfare of forage-animals, and economic development of those who tend the animals and the grasslands. Everyone wants simple solutions, but neither the production systems, nor the biology behind them, are simple. Most often, when we create a new method or tool to help producers, it does not require them to know less, it requires them to know more. Here is an example from human medicine. The discovery and pharmaceutical development of antibiotics in the last century was perhaps the greatest tool-kit every given to doctors. Many at the time dubbed antibiotics a “magic bullet”, *i.e.*, a universal solution that could be applied without knowledge or strategy. Nothing could be further from the truth. The commercialization of penicillin in the 1940’s was not a scientific endpoint (Sakai and Morimoto 2022). It was the beginning of a new era in medicine and medical research with all new impracticalities, problems, and scientific questions. Likewise, there have not been “magic bullets” in the field of nutrition. The discovery of vitamins was one of the most important eras in nutrition. Dr. Richard Semba of Johns Hopkins University described the golden age of vitamin discovery this way:

“Rather than a mythical story of crowning scientific breakthroughs, the reality was a slow, stepwise progress that included setbacks, contradictions, refutations, and some chicanery (Semba 2012).”

Today researchers in a number of disciplines are actively exploring the characteristics of naturally occurring small molecules that impact physiology, but which do not neatly fit into the categories of either nutrients or drugs. Plant and fungal secondary secondary metabolites sometimes have toxic effects. However, the context, particular chemical concentration and the physiological status of the ingesting animal, is critical. The context can make the outcome of ingesting a secondary metabolite poisonous, a nuisance, a non-issue, or even medicinal. Ruminants and other forage-

animals have consumed plant and fungal secondary metabolites throughout their evolutionary history. In contrast, modern ruminant production systems are based on a limited number of forage species selected by the farmers. Furthermore, there is a limited body of information on the secondary metabolites of even the best-studied forages. We are only at the beginning of the research that is needed to minimize the negative impacts and maximize the benefits of secondary metabolites.

### **Content of the Thematic Session**

This thematic session includes presentations by experts on the impacts of plant and fungal secondary metabolites on ruminants. The goal is to highlight four topics related to forage secondary metabolites in which recent progress has been made.

Dr. Jimmy Klotz, USDA-ARS, Forage-Animal Production Research Unit, will present on the vascular effects of fescue toxicosis, which is caused by the ergot alkaloid, ergovaline (Strickland *et al.* 2011). Ergot alkaloids are produced by a number of fungi, including the endophytes of some tall fescue varieties. The half-century history of research into the etiology of fescue toxicosis since the original hypothesis by Bacon and colleagues (1977) is a perfect example of the stepwise progress noted by Semba. Dr. Klotz talk will cover the newest research on how ergot alkaloids impact animal performance and production at the tissue and cellular level.

Dr. Brittany Davis, USDA-ARS, Forage-Animal Production Research Unit, will present on the beneficial effects of isoflavones from legumes. Isoflavones were previously known only for their estrogenic effects, which can interfere in reproduction in female animals. Research over the last decade has shown that isoflavones also have beneficial activities, including selective antimicrobial activity that positively influences protein and carbohydrate metabolism (Harlow *et al.* 2017). Dr. Davis will also present on the vasodilatory activity of isoflavone-rich legumes, which mitigates fescue toxicosis (Harlow *et al.* 2022).

Tannins are another category of plant secondary metabolites that can be beneficial or detrimental depending on the situation. In high concentrations of tannins inhibit fiber digestibility in the rumen and decrease intake (Waghorn 2008). Dr. Jennifer MacAdam, Utah State University, Department of Plants, Soils, and Climate, will present on beneficial effects of tannin-containing legumes, including improved intake, nitrogen retention, decreased methane output, and improved weight gain.

Current opinion in animal welfare is that animal health and wellbeing will be best when animals are allowed to exhibit natural behaviors. Dr. Juan Villalba, Utah State University, Wildland Resources Department, will make the case that natural animal behavior can also be leveraged to make use of a diverse *chemoscape* from which animals can select the forages containing the plant secondary metabolites that they need (Villalba *et al.* 2019). Furthermore, the beneficial qualities of the botanically diverse diet are passed on in the meat and milk of the ruminants.

### **Conclusions and/or Implications**

Plant and fungal secondary metabolites, sometimes called phytochemicals or plant bioactive compounds, are an emerging area in the field of nutrition. Consider the time and effort invested in other areas of nutrition and medicine that are needed to bring an area of study to maturity. Now consider the comparatively modest resources and small number of researchers dedicated to the health and nutrition of forage-animals. It should not be a surprise that there is still much to do. These presentations represent a snapshot of four topics of research in the area of forage plant secondary metabolites at the time of presentation in the early 2020's. Based on the current state of knowledge, we can say that forage secondary metabolites have important implications for animal health and wellbeing, productivity, and sustainability. Advancement will require expertise in a variety of scientific fields.

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