PHYTOGENICS: NATURAL ADDITIVES TO IMPROVE PERFORMANCE IN DAIRY

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Meeting consumers' expectations for sustainable agriculture while providing animal-derived products, such as milk, to feed the growing global population has become a new challenge for the industry. These two objectives seem somewhat challenging to conciliate. Yet, there are ways to use natural plant-based feed additives to improve the performance of the animals and reduce their environmental impact.

WHAT ARE PHYTOGENICS?

Today, "phytogenic feed additive" (PFA) represents an established and technical term. Analyzing its etymology reveals that "phytogenic" consists of the Greek words "*Phyton*," which stands for "plant," and "*genes*," meaning "creating, yielding." Thus, phytogenics consist of plant-derived, bioactive substances.

When thinking about phytogenics, especially in animal nutrition, the most well-known substances are essential oils (EOs), consisting of a wide range of potent active ingredients. However, PFAs do not restrict to EOs, representing only a sub-category, and should not be used instead of phytogenics. This explains the broad spectrum of PFA modes of action in animal production. Saponins, flavonoids, mucilages, tannins, pungent substances, bitter substances… also belong to PFAs (Figure 1), each with their specific modes of action.

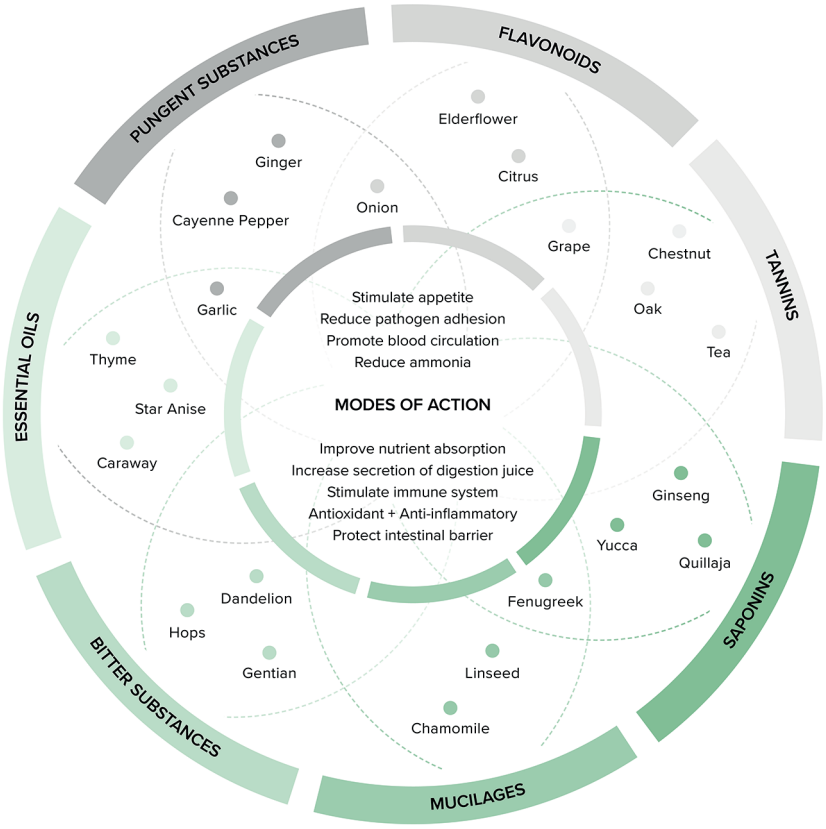

Figure 1. *Overview of the phytogenic universe available for animal nutrition and related modes of action (©Delacon)*

Most of these classes are summarized by the scientific term "secondary plant products," referring to substances produced by a plant in relatively small amounts related to survival strategies. They are used as a defense against herbivorous, to prevent some parasites, or to attract pollinators by producing a particular smell or causing a typical plant color. Thus, although they are not directly needed for the plant's survival like primary products (carbohydrates, proteins, vitamins…), secondary plant products can have a crucial impact on its lifespan. When taken up by livestock, they may influence the animal's physiology and improve milk production.

A single plant can produce different types of extracts or substances. The composition of active ingredients of a plant can vary depending on the type of extract, the weather conditions under which it developed, the geographical origin, or even its subspecies and cultivars. On the other hand, a given active component can be found in different plants (like thymol, found in thyme and oregano, for instance), making the supply of that substance more flexible. Therefore, when formulating a PFA, it is better not to refer to the amount of plant extract itself but consider the concentration of active ingredients inside. To do so, some lead substances are identified as the active components selected to obtain the desired mode of action of the product. They are analyzed and dosed in the different raw materials used to formulate the PFA, to guarantee the consistency of the final product batch, independently of the plant's origin.

ACTIVE INGREDIENTS AND TECHNOLOGY TO IMPROVE AVAILABILITY

Based on the extraction methodology, the active components differ. For instance, if we consider spices, it is possible to extract oleoresins or essential oils (EOs). Oleoresins are a natural mixture of EOs and resin extracted from the plant source by solvent extraction, whereas EOs result from steam distillation since they are not miscible with water. They can then be analyzed by spectrometry to determine the different lead substances composing them to ensure the final PFA's expected composition will be met.

Saponins are another example: depending on the part of the plant they are originating (bark, root, seeds, etc.), the extraction method is different, as is the mix and concentration obtained of the various saponins. To quantify the effect of the resulting saponin extracts, some such as the HPLC methodology can be performed.

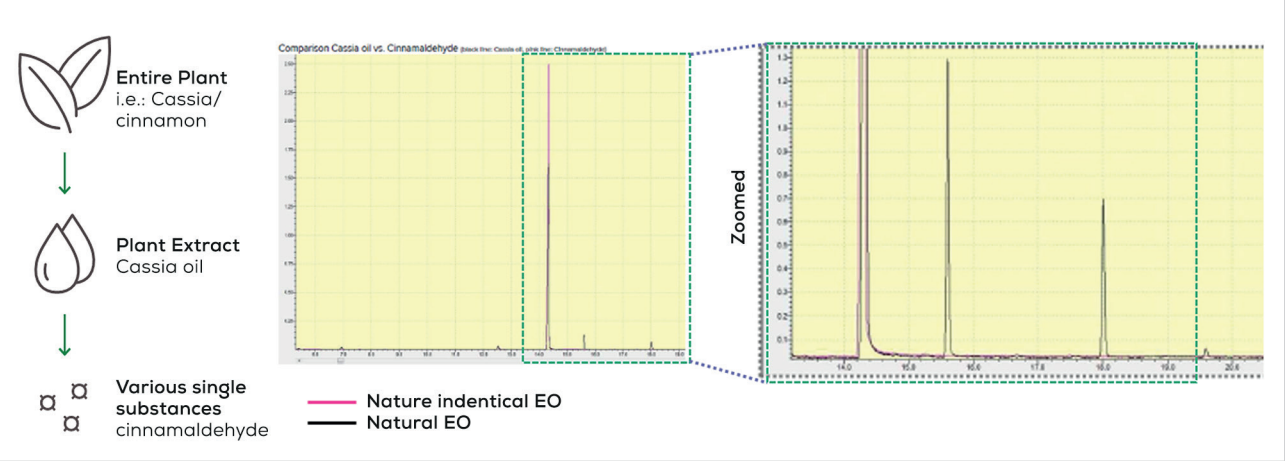

Figure 2. Differences in mass spectrometry profile of cinnamaldehyde (nature-identical, in pink) and cassia oil (natural, in black), showing minor components present in the latter (©Delacon)

Once the active components are produced, they have to be stored and processed to deliver the expected effect of the PFA in the animal. EOs are, by definition, volatile components, so there may be losses during storage (degradation by oxidation, volatilization, light) or processing of the feed (heating) if they are included in pellets. To prevent this phenomenon, it is possible to encapsulate the EOs. The kind of encapsulation matrix and method differ depending on the target. EOs can be encapsulated to be protected from losses during the feed production process, to be slowly released to have the active components diffusing in the digestive tract, or even to make sure the delivery is done in the gut and not before via rumen by-pass encapsulation.

WHAT IS THE DIFFERENCE BETWEEN NATURAL AND NATURE-IDENTICAL?

Some phytogenics products available on the market are based on nature-identical substances, whereas some others are from natural origin. This happens particularly for essential oils. In Nature, EOs are composed of major and minor components that create the unique "fingerprint" of the plant's essential oil. As seen above, the composition of plant extracts can vary, so it is not easy to standardize the EOs composition and guarantee the stability of the PFA characteristics between batches. To reduce the variability of the EOs composition, the identified lead active substances amongst the major components, such as thymol in thyme oil or cinnamaldehyde in cassia oil, have been chemically reproduced.

However, PFAs using natural plant extracts show a wider range of modes of action in animal nutrition than chemical nature-identical substances. This advantage is based on the synergistic effects of all agents within a plant extract, which have not been reduced to the effects of a single lead substance (Figure 2).

Table 1 shows that EOs, like all plant extracts, should be carefully selected according to a specific target, as they have different potencies. In this example, aldehic EO reduces ammonia (NH_3) production more efficiently than phenolic EO. It is of particular interest when aiming to reduce the NH_3 in the rumen, leading to a better protein efficiency of the cow. It participates in the increased nutrient supply for the animal, improving milk production and protein yield while reducing milk urea nitrogen.

Table 1: Effect of different essential oils on the ammonia production (Delacon, in vitro)

Essential oil family	Effect on NH_3 production
Phenolic EO 1 (nature-identical)	-12.5%
Phenolic EO 2 (nature-identical)	-17.5%
Phenolic EO 2 (natural)	-30.0%
Aldehic EO 1 (nature-identical)	-36.5%
Aldehic EO 1 (natural)	-47.0%
Aldehic EO 1 (natural, encapsulated)	-50.0%

WHAT IS THE ADVANTAGE OF A COMPLEX PRODUCT?

As shown in Figure 1, each plant extract has its specific modes of action like stimulating the production of digestive juices and intestinal nutrient transporters, antioxidant and anti-inflammatory effects, quorum sensing interference, and gut wall protection. On top of this, combining different extracts can bring added value to the final PFA: there are some synergistic (or antagonistic) effects between various sub-categories ingredients.

Using the example of NH_3 reduction again, we have seen that an aldehic EO is more efficient than a phenolic one. Figure 3 is a ternary plot showing the effects of different PFA combinations on the NH_3 level *in vitro* by different colors. According to the scale, the redder, the weaker NH_3 reduction, and the bluer, the stronger reduction than the negative control. Each triangle axis represents the quantity (from 0 to 100%) of the different PFAs considered in all the possible combinations between two essential oils (EO 1 and EO 2) and tannins. Based on the color scale, several conclusions can be drawn from this figure:

- Each compound has a positive impact, when used individually, on NH_3 reduction, as shown at each angle of the plot.

- The even combination of the three compounds (33% of each) leads to a lower NH_3 reduction than each substance individually, as shown in the center of the plot. This means that there is an antagonistic effect between these substances.

- The most efficient NH_3 reduction is obtained when there is no EO 2 in the combination, as shown at the bottom of the plot. The reduction is more important than just adding the respective individual effects of EO1 and tannins, meaning a synergistic effect between them.

Therefore, a thorough evaluation of the single ingredients and their combination must be performed to obtain a high-quality and potent complex PFA based on the targeted effects on the animal.

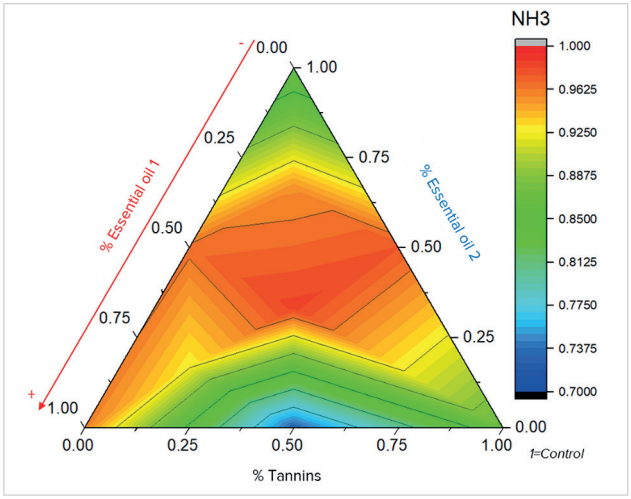

Figure 3. *Ternary plot showing the effect of different PFA combinations on the ammonia reduction in vitro (Adapted from Macheboeuf et al., 2006)*

Once those targets are determined, individual plant extracts are screened based on literature, availability and evaluation of the plant extracts on the market, the regulation status of the substances, and in-house expertise to formulate combinations. The prototypes are produced in a small amount to check the galenic characteristics, such as granulometry, color, smell, etc., before being upscaled for in-vitro and/or in-vivo trial purposes. These trials are meant to generate data on the product's efficacy, adjust the recommendations, and give confidence to customers.

Finally, strict sourcing of the different active substances, standardized production, quality check by an in-house laboratory, and compliance with quality labels lead to consistent and traceable high-quality products, ready to be shipped to customers for improving the efficiency of livestock.

Therefore, formulating a PFA results from ingredients provided by Nature and their potentiation by identification, selection, combination, and encapsulation.

HOW CAN PHYTOGENICS HELP IMPROVE MILK PERFORMANCE?

Phytogenics feed additives developed at Delacon can address different challenges. In dairy, based

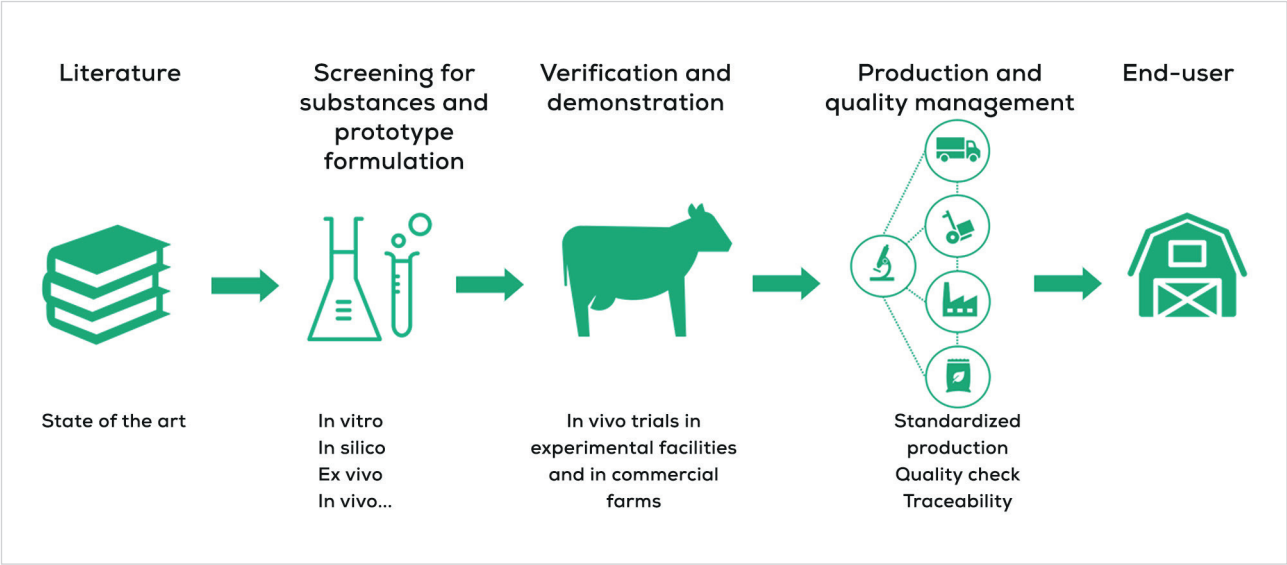

Figure 4. *Process of complex PFA development (©Delacon)*

on the improved palatability of the feed they are included in and the related feeding behavior and nutrient supply, they participate in the improved feed efficiency through better protein and energy efficiency in all kinds of diets and the support of animal's resilience. Improved protein efficiency impacts favorably the farm's margin (e.g., less protein needed for the same production) and the environment due to reduced manure losses.

In dairy, the trials resulted in increased milk yield and milk protein, better performance under heat stress conditions. They improved the overall status of the animal through body condition score, milk SCC, feeding behavior, rumination and rumen pH, blood parameters related to inflammation, and antioxidant status... when PFAs were added to a balanced diet, compared to the negative control. In countries where their use is allowed, comparisons have been run with antibiotic growth promoters such as monensin; results have shown similar milk performance between animals of the different groups, leading to consider PFA as a potential natural alternative to these compounds.

Based on these positive results, in other trials, it has been possible to reformulate diets by reducing the protein content or profile, successfully maintaining the milk performance compared to the initial diet. This allowed greater flexibility in selecting raw materials to formulate dairy cows' diets, thus improving the farm's margin by reducing the feed cost.

Plants have much more to offer than someone might probably think. With the natural power of plants and exploring and documenting their modes of action for animal nutrition, we are on a more natural path to improved milk performance.

About Delphine Lacombe

Delphine Lacombe joined Delacon in April 2018 as Customer Technical Manager for the ruminant team. She is an agronomist engineer, graduated from Agrocampus Ouest in France, and started working as a dairy nutritionist for a feed mill. Delphine has been working within the animal nutrition industry for the past ten years, mainly in the feed additive business. Currently, she is responsible for the technical support of the EE and Latam regions.