Benefits of Botanical Feed Ingredients in Animal Nutrition

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L. A. Tucker / Dr. Braes Feed Ingredients, UK

Introduction

Plants and their extracts have formed part of animal diets as preservatives, flavours, digestive enhancers and remedies for millennia (Deans & Richie, 1987; Piccaglia *et al.*, 1993). The increase in demand for cheap meat and the advent of modern production methods in agriculture has given rise to the use of synthetic compounds in feed, for example sub-therapeutic anti-biotic supplementation. Recently the safety of such practices has been questioned, and their use is becoming restricted in many regions of the world. Therefore there is great renewed interest in developing natural alternative supplements to maintain animal performance and wellbeing. Increased research into botanical ingredients for nutrition applications mean that we now understand how many of these ingredients work, and how we can exploit the benefits of these additives to improve animal performance and wellbeing in both intensive and extensive meat production. Research and commercial animal trials have identified efficacious forms and mixtures of plant extracts, giving rise to a range of botanically-based products specifically designed for animal feed applications. These products have been shown to give benefits in poultry and pig feed at doses that are relevant to the feed industry.

Correct formulation of botanical supplements based on the requirements of individual animal species and ingredient activities is the key to a product that can deliver consistent

benefits *in vivo* and optimise the balance between cost of inclusion and overall efficacy. Research has been conducted over several years to determine the best forms of botanical ingredients, including selection of certain plant cultivars and characterization of the active ingredients responsible for specific modes of action. Understanding the interactions between botanical ingredients is another area of importance, as many act synergistically (Shelef *et al.*, 1980; Piccaglia *et al.*, 1993). A strong technical basis in formulating botanical products is particularly important, as the components can exert powerful deleterious effects if overdosed or used inappropriately.

Modes of Action

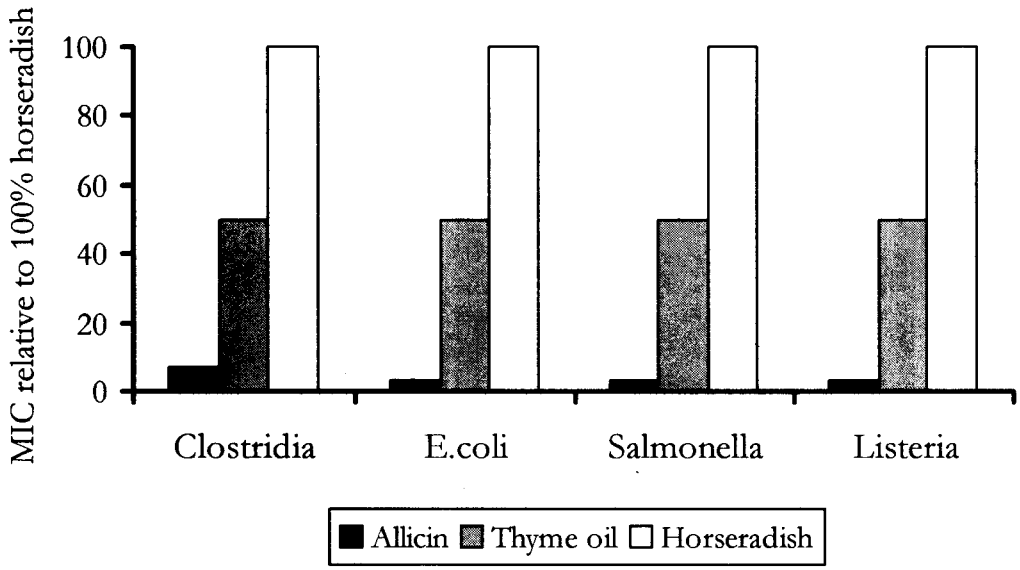
Botanical products contain ingredients which are active in three main areas: gut microflora and gut environment, anti-oxidation and liver function.

Gut environment and microflora

Initial screening trials to investigate the beneficial properties of botanical ingredients have been conducted, and certain specialist products have been developed that are unique to certain commercial botanical products. Many of these ingredients have been shown to facilitate useful changes on the gut environment and bacteria (Dabbah *et al.*, 1970; Rao & Nigam, 1970), however few have an effective dose at the levels required for feed applications.

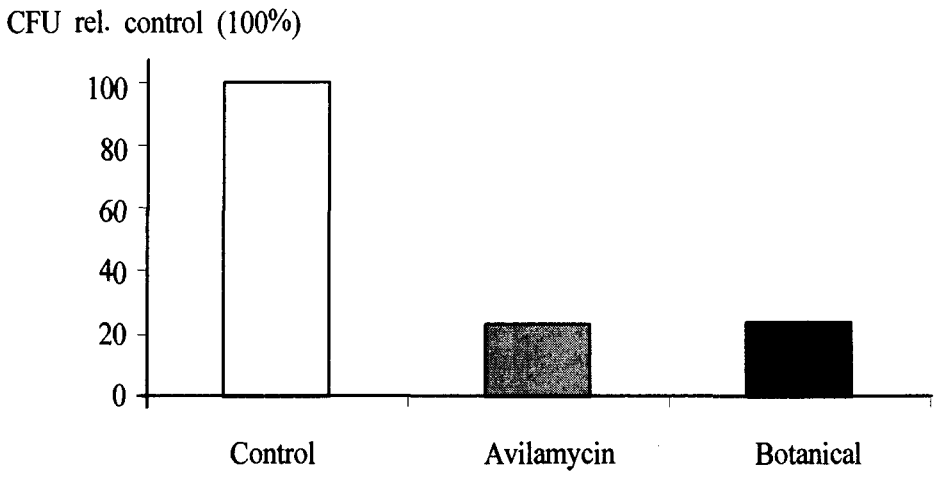
One that does is a unique stable version of an ingredient called allicin that is derived from garlic. Allicin exerts a powerful anti-microbial action on gut microflora. Initial screening trials to investigate the relative minimum doses (MIC) required to inhibit growth of various bacteria important in animal production and health revealed that the dose of

allicin required to control important pathogens was very low relative to other herbal anti-microbial ingredients. This made it an ideal component of a product destined for animal feed applications (figure 1).



〈Figure 1〉 Relative efficacy of allicin versus other anti-microbial botanicals against common pathogenic bacteria found in animal production.

Trials conducted both *in vitro* and *in vivo* have shown that botanical extracts can replace sub-therapeutic anti-biotic growth promoters (AGPs) in animal feed without any loss in animal performance. In a broiler trial conducted in the UK the effect of a botanical product on clostridia numbers versus an unsupplemented control and a diet containing commercial sub therapeutic levels of AGP were compared. Broilers were dissected at the end of the trial and the caeca removed. Anaerobic culture analysis of the caecal contents was performed to quantify clostridial numbers (figure 2).



Trial Ref. 2001 01 05 UK

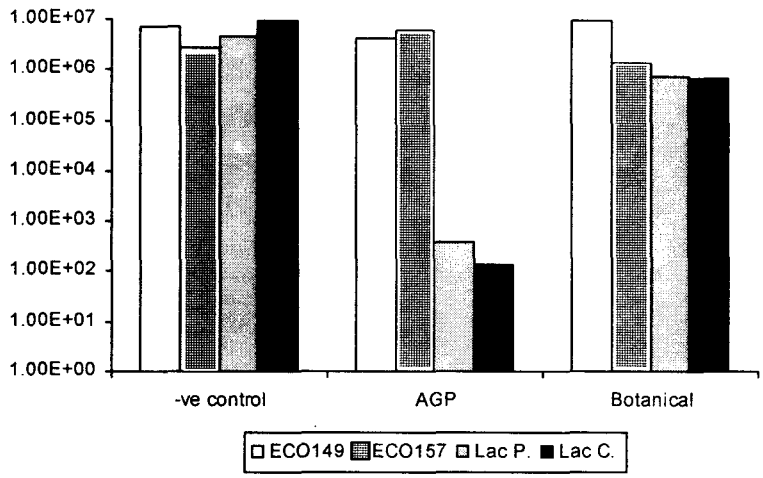
〈Figure 2〉 Broilers fed a botanical product had fewer caecal clostridia colonies than those receiving no supplementation, and similar levels compared to birds receiving AGPs.

Birds receiving the botanical product had reduced levels of clostridia in their caeca, in the same order of magnitude as the AGP diet. This was probably due to a combined effect of the natural activity against cell enzyme pathways, coupled with improved digestibility in the gut influenced by the mixture of other components in the product.

Certain plant-derived ingredients active at gut level have a specific anti-bacterial activity, unlike typical AGP drugs used in feed applications that reduce all microbial populations (figure 3). This can be illustrated by the mode of action of the unique garlic-derived component allicin, which disrupts enzyme-mediated reaction within cells. In most cells (e.g. mammals, birds, lactobacillus species) there exists a repair mechanism that automatically reverses such damage. However in certain pathogenic species, this repair mechanism does not exist, and the allicin inhibits protein synthesis and ultimately cell growth and multiplication.

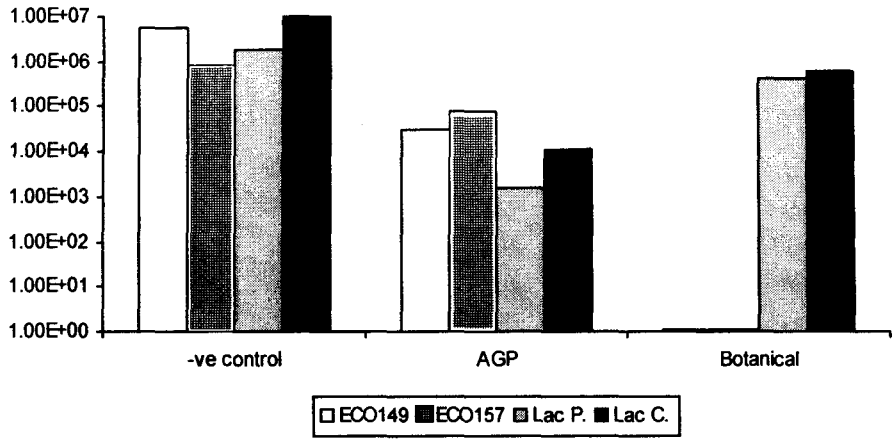
To establish this specific mode of action, a trial was conducted on pig feed. A sample of commercial feed with and without botanical supplementation was produced and inoculated with known levels of *E. coli 0157* and *0149* variants and *Lactobacillus plantarum* and *casei*.

The feed was placed in ambient storage in the UK, and monitored for bacterial growth at 0, 7 and 14 days. The results are shown in figures 3 and 4 below.



〈Figure 3〉 Effect of supplementing commercial pig feed with botanical extracts on *E. coli* and *Lactobacilli* numbers immediately after inoculation.

Immediately after inoculation with the bacteria, the AGP in the positive control diet reduced the level of lactobacilli. Such an effect within the gut of an animal is not desirable, as *Lactobacilli* are important beneficial microbial species in the hind gut, where they positively contribute to fermentation. They are also an important group for out-competing pathogenic species such as *E. coli*, and establishing stable hind gut function. At this time, there was no change in bacterial loading in the botanical supplemented diet relative to the negative control. After one week of storage however, the different effects of the AGP and the botanical extract diets can be clearly seen (figure 4). The AGP had a broad effect on both types of micro-organism in the feed. However the botanical product only affected the levels of *E. coli*. The beneficial *Lactobacilli* strains have been allowed to flourish to a similar level as the negative control, and only the *E. coli*, which do not possess the intracellular enzyme repair mechanism, have been reduced in the feed. This response was maintained at 14 days after storage.



〈Figure 4〉 Effect of supplementing commercial pig feed with botanical extracts on *E. coli* and *Lactobacilli* numbers after 7 days storage at ambient temperature.

Some botanical products contain components that stimulate gastric secretion, such as enzyme production from the pancreas. This is particularly important in young animals, where gut maturation can dictate digestive efficiency. Improved secretion increases digestion of protein and starch in the upper ileum, making more nutrients available for absorption in those areas of high villi population. This reduces the amounts of undigested feed particles or unabsorbed nutrients passing down the gut and being utilized by bacteria within the caeca in birds or colon in mammals. Changes in nutrient fermentation by gut microflora are associated with many digestive disorders. Increasing nutrient flow to the hind gut bacterial population allows proliferation of uncontrolled bacteria. This is especially true for *Clostridia*, which are particularly encouraged by increases in nitrogen availability. *Clostridia perfringens*, the organism associated with necrotic enteritis in poultry, requires high levels of nitrogen to grow well, for example they are often cultured on high protein media such as horse tissue. Increasing levels of undigested nitrogen combined with a coccidiosis challenge has been shown to spontaneously increase incidence of necrotic enteritis without further inoculation with clostridia.

Anti-oxidation

Oxidation is a necessary phenomenon of cell functions. Oxygen is required by animals for respiration and energy production. However, oxygen is highly reactive, and the mechanism of respiration results in the production of oxidizing compounds called Reactive Oxygen Species (ROS). These are highly reactive and facilitate various reactions which damage cell membranes and tissue function. They have been identified as causative agents for cancer, pulmonary hypertension syndrome (ascites), inflammation and reproductive disorders. Essentially ROS reduce cell function and interfere with cell growth.

Anti-oxidants are compounds of increasing interest and importance that are found in a variety of plants. Certain botanical ingredients have strong anti-oxidant properties. In the field of human health, these ingredients have demonstrated value in alleviating oxidation problems such as heart disease, membrane function and inflammation. Current research is investigating the extent of benefit in alleviating oxidative stress conditions in animal production.

Plant-derived anti-oxidants function in one of three ways. They can interfere in the initial reactions that create the ROS that are so damaging, thereby removing the source of oxidation and stabilizing metabolism. They can also scavenge for free oxygen molecules, that are required to begin the production of ROS, absorbing and limiting their availability for further, negative cellular reactions, and they can also chelate oxidative elements that speed up oxidative processes, such as iron, again removing the reactive cofactors required for generating ROS.

Protecting Liver Function

The liver is a prime site for the utilization and transformation of nutrients into useful materials within the body. The metabolism and distribution of important compounds such as

amino acids, glucose and fat all require correct and efficient liver function. The hepatic portal vein carries nutrients from the intestine to the liver, where they are processed and removed or utilized. As a result, the liver is open to attack by undesirable compounds present in animal feeds, such as fungal toxins present in grain. Specific botanical components have been shown to be active against damaging compounds, such as mycotoxins, that they strongly bind and inhibit (Leung & Foster, 1996). Other extracts are associated with protecting cellular function directly or via anti-oxidant properties to stabilize metabolism, allowing the liver to function optimally (Fahim *et al.*, 1999). A major problem in animal nutrition is fatty liver syndrome, which is seen commonly in layer hens. To build on the knowledge already obtained regarding these activities, research is being conducted into the direct benefits of these activities in animals, both *in vitro* and *in vivo*.

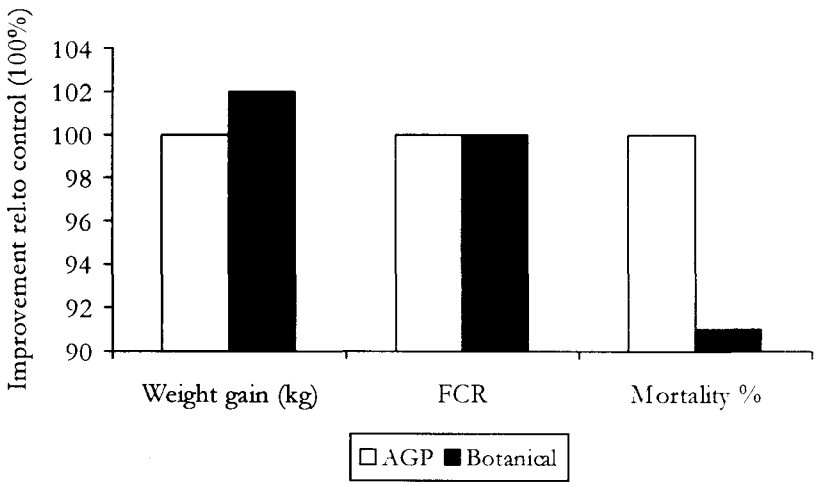
Commercial trials

The active development and research into the use of commercial botanical feed ingredients in poultry and pigs has been ongoing since 1998. Trials have been conducted in both institute and commercial conditions across Europe and more recently have expanded into the USA and Asia. Many of the trials have been concerned primarily with the replacement of AGPs in animal diets, particularly in Europe, where use of AGPs is now severely limited. Botanical-based products are also useful in niche markets sectors such as organic or naturally grown' livestock and welfare friendly schemes, where AGP use must be kept minimal. Trial results show that certain combinations of plant extracts can give physiological responses above and beyond those directly comparable with AGP effects, indicating that such products are having an important performance, welfare and economic impact on animal production.

Poultry Trials

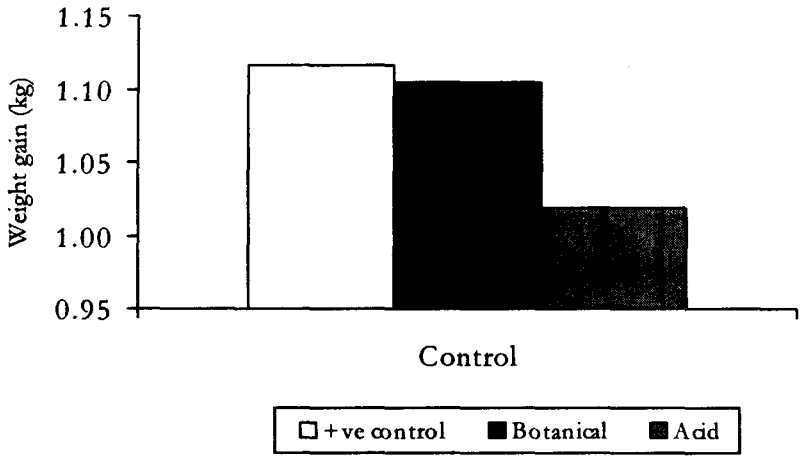
Trials to investigate the effect of botanical ingredients on broiler performance in comparison to AGP diets have been conducted in several European countries in both controlled pen trials and commercial conditions. Figure 5 shows the average response to these ingredients compared to AGP controls from six European commercial trials.

In each commercial trial used to calculate the average responses, birds received diets containing either 150g/t of a commercial botanical product or commercial doses of different AGPs. Overall the botanical product improved weight gain by 2%, whilst FCR remained the same. It also improved mortality by 9% relative to AGP control.



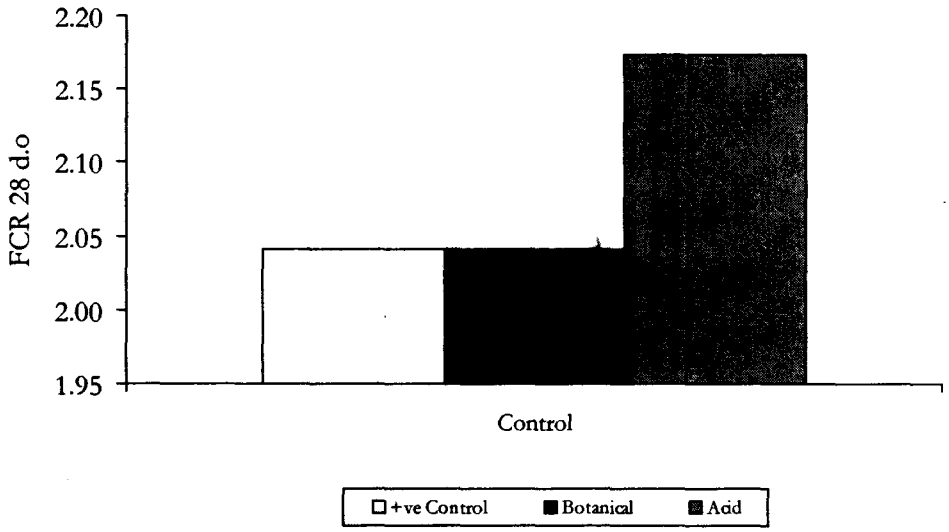
〈Figure 5〉 In six commercial trials a botanical supplement improved broiler performance and mortality above AGP-supplemented feed.

Botanical products have also been compared against other AGP-replacement strategies. A trial was conducted with male broilers in small pens, fed either zinc bacitracin supplemented mash feed, organic acid or a botanical supplement from 0 to 28 days old. The results are shown in figures 6 and 7 below.



〈Figure 6〉 Effect of a botanical product versus acid or AGP on weight gain of male broilers fed mash diets from 0~28 days old.

Broilers fed the botanical product had better weight gains and feed conversion ratios than those receiving acid, as the acid depressed feed intake, probably due to palatability problems.



〈Figure 7〉 Effect of a commercial botanical product versus acid or AGP on the FCR of male broilers fed mash diets from 0~28 days old.

A replicated pen trial was run in France to compare the performance of 0~20 day old broilers fed botanical product against the effects of AGPs and essential oils products, which have also been marketed as AGP replacement alternatives. The results are shown in figure 8 below.

〈Figure 8〉 Botanical-based product improved broiler weight gain and feed conversion ratio compared to unsupplemented, AGP and essential oil diets.

	Control	AGP	Essential Oils	Botanical
Feed intake (kg)	1.806	1.834	1.828	1.844
Weight gain (g/d)	57.5a	59.5ab	59.1abc	60.2bc
Bodyweight (kg)	1.336a	1.373abc	1.365abc	1.388bc
FCR	1.572	1.543	1.550	1.531

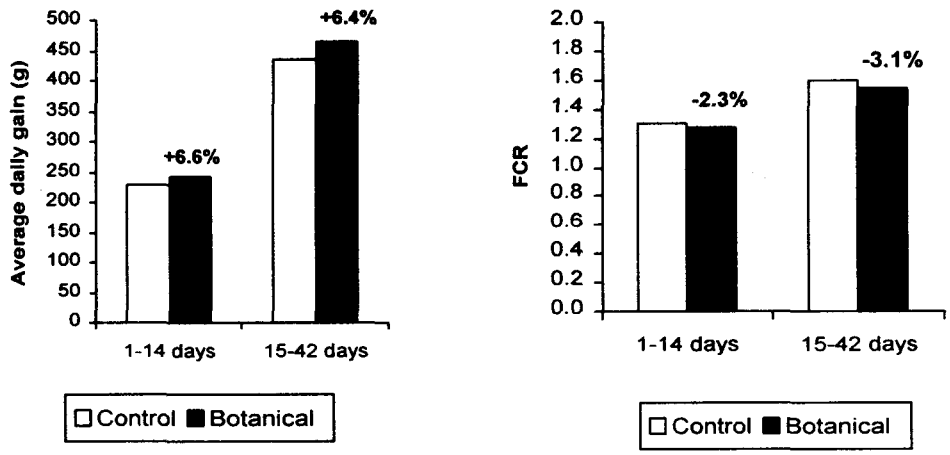
Means not sharing a superscript significantly differ by $P < 0.1$.
Trial Ref. 1998 01 02 Fra

Botanical supplementation significantly improved broiler weight gain compared to the unsupplemented control. The essential oils and AGP treatments resulted in more variable responses that were not significantly different from the control, and numerically poorer than the botanical extract-fed birds. The supplement also improved both feed intake and feed efficiency, probably via improving the gut environment, microflora profiles and cellular efficiency, thereby increasing nutrient digestion, uptake and utilization.

Swine Trials

Trials have been conducted with botanical products for pigs in Europe and USA, showing improvements in performance relative to AGPs and other alternative products. Weanling/ starter, grower and finisher studies on pigs up to 90kg slaughter weight have been conducted

in both controlled pen and commercial facilities. Results from these studies are shown below, and demonstrate the efficacy of botanical feed ingredients in pig production. Two trials were conducted using starter pigs in Belgium and Denmark. The Belgian trial was conducted under research conditions, where a botanical product at 500 g/t inclusion was fed from weaning for 14 days. After that point, the botanical ingredient was withdrawn from the feed, however the separate groups were monitored for performance until 42 days after weaning, to see if the benefits of botanical supplementation in early pig diets could improve performance in later ages. The response to botanical products inclusion for both trials, relative to an unsupplemented AGP-free control diet is shown in the figures below.



〈Figure 9〉 Response of young and weanling pigs to botanical product fed under Belgian growing conditions.

Botanical supplementation improved the daily gain and FCR of the young pigs 14 days after weaning and for the whole 42 days monitoring period. Mortality of the young pigs was also measured during the trial, with the non-supplemented control diet having approximately 3% mortality over the trial period. No mortalities were recorded for the botanical-fed pigs over the same period.

The Danish trial was run at a commercial site and again compared botanical extracts to an AGP-free control diet.

〈Figure 10〉 Response of young and weanling pigs to botanical products fed under Danish growing conditions.

	Control	Botanical	%
No. days on trial	14	11	
No. of Pigs	156	183	
Start Weight (kg)	6.56	6.70	
Finish Weight (kg)	9.35	9.02	
Weight gain (kg)	2.79	2.32	
Daily Weight gain (g)	200	210	+ 5.7
FCR	1.14	0.94	+ 21.6

The pigs receiving the botanical product improved their daily gain by nearly 6%, due to improved feed conversion efficiency. Trials run in the USA in young pigs fed corn-soy based diets have also shown good responses to botanical supplementation. A replicated trial run at a mid-west University facility compared a commercial botanical product at 500 g/t inclusion against an AGP, and a negative control diet and showed that the botanical product improved performance above that of the control and equivalent to the AGP diet. The pigs were fed the experimental diets from weaning for 4 weeks, and performance was monitored at 14 and 28 days after weaning. Results are shown in the table below. The pigs receiving the botanical product grew significantly more than the control and had the best FCR over the whole period of the trial.

〈Figure 11〉 Young pigs fed botanical supplements in US corn soy diets in a research facility improved performance to a similar level as AGP supplemented diets.

	0~14 days after weaning			0~28 days after weaning		
	Control	AGP	Botanical	Control	AGP	Botanical
ADG (g/d)	113a	154b	139ab	349a	405b	385b
Feed intake (g/d)	220	235	242	556a	625b	557a
FCR	1.89a	1.54b	1.69ab	1.61	1.52	1.47

A trial conducted under US commercial conditions, with 5~22 kg young pigs. A botanical product included at 500 g/t in feed was compared against an AGP control diet until the pigs weighed 12kg. After that they received only the commercial diet, however performance was recorded at 22 kg, to observe if the benefits continued in later growth stages. Figure 11 show the outcome of the trial. The supplemented pigs had higher daily gain and better FCR at 22 kg, even though they had only received the botanical product during the first half of the experimental period.

〈Figure 12〉 The effect of botanical products on subsequent growth of young pigs which had received supplemented diets until 12 kg.

	AGP	Botanical
Body weight (kg)	22.64	22.71
Daily gain (kg)	0.372	**0.387**
FCR	1.575	**1.528**
% Mortality	2.35	2.65
% Liveability	97.6	97.4

Trial Ref. 2001 01 22 USA

The effect of botanical supplementation on grower-finisher pigs has been tested in Europe. The trial below shows data from 20-35 kg commercial grower pigs fed either AGP diet or a botanical feed ingredient at 300 g/t inclusion (figure 12). Pigs receiving botanical supplementation had improved the FCR by 3.5%, and showed reduced mortality during the trial: from 2% in the AGP control to zero in the experimental group.

〈Figure 13〉 Effect of botanical supplementation compared to AGP control diet on 20~35 kg grower pigs under commercial conditions in the UK.

	Control	Botanical
No of Groups	4	4
Total Pigs	100	100
Wt gain (kg)	13.98	13.69
FCR	1.78	1.72
Mortality (%)	2	0

Finisher pigs have also been shown to benefit from botanical supplementation, even though they have more mature and established digestive tracts than younger animals. A trial run at a high performance pig unit in the UK comparing a botanical product at 150 g/t against an AGP examined the impact on performance of 50~90 kg pigs (figure 13). The results showed that the botanical treatment exceeded the AGP control diet by 1% in weight gain and improved feed efficiency by 4%, thereby achieving better feed efficiency whilst maintaining and improving nutrient utilization and growth. The pigs on both diets attained slaughter weight 6 days quicker than the 49 day finisher standard period in the trial(figure 14).

〈Figure 14〉 Impact of botanical product versus AGP diet on the growth of high performing finisher pigs under commercial UK conditions.

	Control	Apex
No of Pigs	30	30
Start Weight (kg)	52.5	52.4
End Weight (kg)	92.9	92.9
Weight Gain (kg)	40.3	40.6
Days on trial	42.5	43
Daily Feed Intake (kg)	2.39	2.30
FCR	2.51	2.46

Summary and Recommendations for Practical Applications

Research into the technical utilization of botanical feed ingredients has shown them to be efficacious and applicable in feed applications. They key to the production of a botanical feed additive is understanding mode of action and synergy between ingredients, and best application method in the feed and animal. Trials with a commercial botanical product run in both research and commercial conditions with pigs and poultry, have shown that it can maintain animal performance and wellbeing without requiring anti-biotics. Results show that botanical supplementation can increase performance via improved efficiency of feed utilization and modulating feed intake. This is due to the combined activity of the gut environment, anti-oxidant and hepatoprotectant activities contained in the ingredients used in formulating such products.

Botanical products should be formulated specifically for different species, which have varying requirements for the three main modes of action of the product, and react differently

to certain botanical ingredients. As a result there are distinct formulations for pigs and poultry. The dose recommendations depend upon the level of stress the animal is under. For example one commercial product has a dose recommendation of 150 g/t for poultry grown under normal commercial conditions, and 300 g/t in challenged (stress or diseased) conditions. Similarly a commercial swine product has a dose recommendation of 500 g/t in very young challenged or stressed pigs, 300 g/t in starter and grower rations and 150 g/t in finisher rations.

Botanical-based supplements can be used as part of an AGP-free feeding strategy or to improve animal performance in both pigs and poultry of all stages of production.

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(* 이 자료는 ㈜아세아향미의 협조로 제공, 발표되었습니다.)