Herbs and Botanicals as Feed Additives in Monogastric Animals**

Caspar Wenk*
Institute of Animal Sciences, ETH Zurich, Switzerland

ABSTRACT : Animal feed additives are used worldwide for many different reasons. Some help to cover the needs of essential nutrients and others to increase growth performance, feed intake and therefore optimize feed utilization. The health status of animals with a high growth performance is a predominant argument in the choice of feed additives. The use of feed additives is more and more questioned by the consumers. Therefore, the feed industry is highly interested in valuable alternatives which could be accepted by the consumers. Probiotics, prebiotics, enzymes and highly available minerals as well as herbs can be seen as alternatives. Herbs, spices and their extracts (botanicals) have a wide range of activities. They can stimulate feed intake and endogenous secretions or have antimicrobial, coccidiostatic or anthelmintic activity. A major field of application of herbs is the protection of animals and their products against oxidation. ***(Asian-Aust. J. Anim. Sci. 2003. Vol. 16, No. 2 : 282-289)***

Key Words : Feed Additives, Herbs, Botanicals, Essential Oils, Pig, Poultry

INTRODUCTION

Herbs and botanicals as alternatives for antibiotics

The way in which human food is produced today is intensively discussed and questioned in modern society. We expect food from plants, farm animals and microorganisms to be of good quality, healthy and inexpensive. But we are increasingly concerned about environmental matters and look for low energy input production systems. In addition, arguments for food that is produced as naturally as possible (organic farming) come primarily from consumers organizations.

In highly developed countries we do not always feel the impact of the steady growth of world population. In twenty five years from now there will be almost 9 billion inhabitants (FAOSTAT, 1998) on earth who expect to get enough food to meet their nutritional needs. The goal to produce sufficient food for everybody can only be achieved in future if the world food production increases by about 2% per year. It is expected that world animal production will follow this trend. According to IFPRI (1999) world production will grow about 2.0% for pigs and chicken, respectively in the next 20 years, mainly in the developing countries with an annual growth between 2.5 and 3%. World food production must grow without increasing the environmental waste load.

This precondition demands the efficient use of all available resources of traditional and modern technologies also of feed additives in a responsible way! There is no doubt that today's worldwide agriculture productivity must be increased.

A ban of antibiotics as feed additives in animal nutrition is realized since 1986 in Sweden and since 1999 in Switzerland. Today in the European Union only three antibiotics are still permitted as growth promoters (Salinomycin-Na, Flavophospholipol, Avilamycin) and a general ban is foreseen in some years from now, because of the increased occurrence of pathogens resistant against therapeutical antibiotics used in animals and humans.

With the restricted use or ban of dietary antimicrobial agents we must explore new ways to improve and protect the health status of farm animals, to guarantee animal performance and to increase nutrient availability. This goal can be attained by good housing or climate conditions as well as by the best possible combination of the so called pronutrients (Rosen, 1996) available including pro- or prebiotics, organic acids, dietary fibers, highly available nutrients and herbs. Rosen defined the pronutrients as "microfeedingstuffs used orally in a relatively small amount to improve the intrinsic value of the nutrient mix in an animal diet".

Even at low levels pronutrients can contribute to the nutrient requirements. The main activities are expected in the feed intake regulation, in the digestive tract or after the absorption of the active substances in the intermediate metabolism. The effect of a pronutrient on the performance of farm animals can vary over a wide range. Many reasons can be considered. Generally it is more effective in animals with a low performance, diets with a low nutritive value, at low health conditions, with an unfavorable environment, under stress and a bad management of the animals.

WHAT ARE HERBS, SPICES OR BOTANICALS?

Beside the feed enzymes, probiotics (for monogastric animals mainly lactobacilli), prebiotics (oligosaccharides), organic acids, the herbs and botanicals can be used as feed additives. In the last years the modern western world has been learning what many Asians and native Americans

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* Corresponding Author: Caspar Wenk. Tel: +41-1-632-3255, Fax: +41-1-632-1128, E-mail: caspar.wenk@inw.agrl.ethz.ch

(Bye and Linares, 1999) have known for centuries, namely that plant extracts and spices can play a significant role in health and nutrition.

A definition can be derived from Webster's Encyclopedic Unabridged Dictionary of the English Language (1989):

Herb : A flowering plant whose stem above ground does not become woody and persistent. A plant when valued for its medical properties, flavor, scent, or the like.

Spices : Any of a class of pungent or aromatic substances of vegetable origin, as pepper, cinnamon, cloves, and the like, used as seasoning, preservatives, etc.

Botanical : A drug made from part of a plant, as from roots, leaves, bark etc. Essential oils are any of a class of volatile oils obtained from plants, possessing the odor and other characteristic properties of the plant, used chiefly in the manufacture of perfumes, flavors and pharmaceuticals. (Extracts after hydro - distillation)

Plants have evolved a wide range of low-molecular-weight secondary metabolites. Generally these compounds enable the plants to interact with the environment and may act in a defense system against physiological and environmental stress as well as predators or pathogens. Beside compounds with toxic properties, several of these secondary plant metabolites have been reported to show beneficial effects in food products and also in mammalian metabolism. They are of main relevance in herbs and are specifically enriched and eventually standardized in botanicals.

In the last years the number of studies with herbs or botanicals has significantly increased especially in Europe. At the annual meeting of the German "Society of Nutrition Physiology" in 2002 almost 50% of the papers on feed additives referred to herbs in relation to growth performance and carcass characteristics. In one of the paper the effect of herbs on coccidiosis in poultry was evaluated.

MODES OF ACTION OF HERBS AND BOTANICALS

Beneficial effects of herbs or botanicals in farm animals may arise from activation of feed intake and secretion of digestive secretions, immune stimulation, anti-bacterial, coccidiostatic, anthelmintic, antiviral or anti-inflammatory activity and inhibition or - particularly - antioxidant properties. Most of these active secondary plant metabolites belong to the classes of isoprene derivatives, flavonoides and glucosinolates**,** and a large number of these compounds has been suggested to act as antibiotics or as antioxidants in vivo as well as in food. Several authors have given some overview on physiologically active secondary plant metabolites (e.g. Rhodes, 1996 or Hirasa and Takemasa, 1998) and their principles of antioxidative characteristics (e.g. Halliwell et al., 1995).

Herbs develop their initial activity in the feed of farm animals as flavor and can therefore influence the eating pattern, secretion of digestive fluids and total feed intake. A main activity takes place in the digestive tract. Herbs or the phytochemicals can influence selectively the micro-organisms by an anti-microbial activity or by a favorable stimulation of the eubiosis of the microflora. The consequence can be a better nutrient utilization and absorption or the stimulation of the immune system. Finally herbs can contribute to the nutrient requirements of the animals and stimulate the endocrine system and intermediate nutrient metabolism.

During the growth period of the animal the diverse activities of herbs or other feed additives have a variable relevance. In the very young animal metabolism and nutrient digestion are not yet functioning optimally. Furthermore the immune system and a stable, beneficial microflora (eubiosis) must be build up. For that a regular intake of feed and water is of a high priority. Later the digestion processes can be optimized and adapted to the available feedstuffs. In the later stages of growth processes that are in relation with the product quality play a major role.

Often the desired activity of herbs is not constant. Conflicting results may arise from the natural variability of the composition of plant secondary metabolites. Variety and environmental growth conditions, harvesting time and state of maturity, method and duration of conservation and storing, extraction method of the plants, as well as possible synergistic or antagonistic effects, anti-nutritional factors or microbial contamination are factors which may substantially affect the results of *in vivo* experiments. For example, rosemary and sage from different geographical locations and types of processing (dried herbs and essential oils) or from different suppliers (Wenk et al., 1998) showed significant differences in antioxidative capacity. Furthermore, several secondary plant metabolites are showing strong flavors, which may affect sensory characteristics of the feed and, therefore, feed intake. Additionally, antibacterial properties and - probably concentration dependent - effects on feed intake and on digestion of nutrients can be expected and should be taken into consideration when conducting *in vivo* experiments with phytochemicals using farm animals.

INFLUENCE OF HERBS OR BOTANICALS ON FEED INTAKE

After the ban of antibiotics in practical pig production more and more herbs are used as feed additives for a better

growth condition. A product from rhizomes of Sanguinaria canadensis is frequently used in Europe for pigs and poultry. With other herb mixtures or botanicals effects on feed intake as well as growth performance in piglets and growing finishing pigs as well as poultry could be achieved.

In an experiment with piglets after weaning we have studied the influence of five single herbs and two mixtures on feed intake and growth performance in doses of 0.5% (Table 1). The basal diet corresponded to a practical diet based on barley, wheat, oats, corn, soybean meal, potato protein, fish meal, fat, amino acids and a mineral/vitamin premix (Gebert et al., 1999a).

The analyzed nutrient content of the eight experimental diets was almost identical. There were no animal losses during the four weeks experimental period. In Table 2 body weight, feed intake, body weight gain and feed conversion efficiency are given.

The supplementation of the basal diet with the seven different herbs or herb mixtures had partly a significant effect on feed intake. Especially rhubarb root caused a 18% reduction of overall daily feed intake, probably caused by anthrachinone derivatives. As a consequence, performance was negatively influenced. The influence of rhubarb root on daily feed intake was therefore studied in piglets and broilers in a series of growth experiments. In Figure 1 the results of these experiments are summarized. It has to be noted, that the herb preparations and therefore effects of active substances like anthrachinones were different between experiments.

There was a big variation in the effect of rhubarb root on feed intake in relation of the amount of supplementation between experiments. But in both species (piglet and broiler) a slight increase in feed intake could be observed at least partly at low levels and then a dramatic decrease at higher levels.

Similar observations were made in laying hens with turmeric, a powder of the rhizome of Curcuma longa, a spice that is frequently used in the south Asian kitchen (Wenk and Messikommer, 2002). 0.25% Turmeric improved feed intake. At higher levels up to 1% feed intake returned to the control treatment without supplementation.

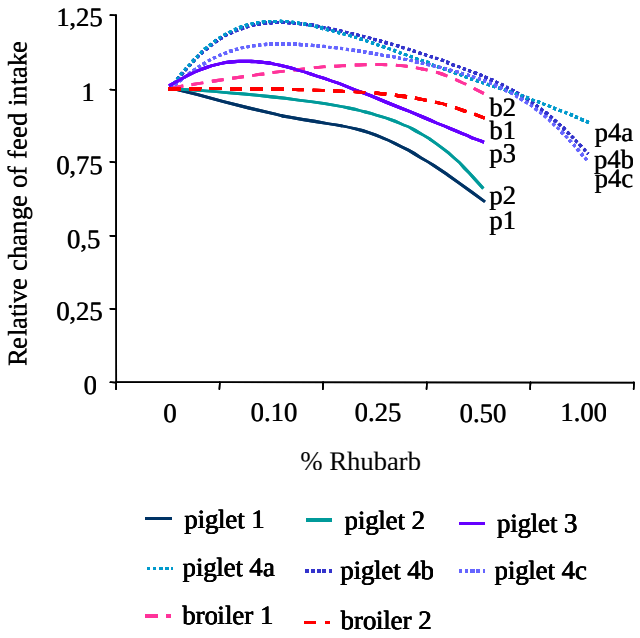

Figure 1. Effect of rhubarb root on feed intake relative to control of piglets and broilers (Gebert et al., 1999b; Straub et al., 2002).

Samarasinghe and Wenk (2002) did not find an influence of Turmeric on feed intake in broilers, but on nutrient utilization, performance and carcass characteristics.

ANTIMICROBIAL AND COCCIDIOSTATIC ACTIVITY OF HERBS AND BOTANICALS

The antimicrobial activity of herbs and botanicals has been studied in many different *in vitro* essays (Huang, 1999; Baratta et al., 1998; Lis–Balchin and Deans, 1998; Deans and Richie, 1987). In Table 3 some examples for Chinese herbs are presented (Spring et al., 1998). Some of the tested herbs had a wide anti-microbial activity against gram + and gram - bacteria. Others were mainly active against gram +.

Results of *in vitro* tests as shown in Table 3 indicate that

Table 1. Growth experiments with herbs in piglets (Gebert et al., 1999a): experimental design

	Treatment							
	A	B	C	D	E	F	G	H
Supplements (%)								
Epimed		0.5						
Rhubarb			0.5					
Magnolia vine fruit				0.5				
Gold thread					0.5			
Tibet bitter root						0.5		
Phyto starter 004							0.5	
Porah Herba W-15								0.5
Basal diet (%)	100	---------- 99.5 ----------						

Table 2. Effect of different herb supplements on body weight and feed intake of piglets

Treatment	Body weight start, kg	Body weight middle, kg	Body weight end, kg	Daily feed intake, g week 1-2	Daily feed intake, g week 3-4	Daily feed intake, g week 1-4
Control	9.58	13.66	21.90	506	883[a]	698
Epimed	9.91	13.54	21.40	502	836[ab]	672
Rhubarb root	9.37	13.31	19.50	444	689[c]	570
Magnolia vine fruit	9.58	14.47	21.97	530	878[a]	703
Gold thread	9.79	14.69	21.93	519	800[abc]	662
Tibet bitter root	9.45	12.93	19.53	466	727[bc]	598
Phyto starter 004	10.28	15.12	22.18	626	827[ab]	728
Porah Herba W-15	9.88	14.11	21.48	545	853[a]	703
SEM	0.27	0.41	0.51	18	26	19
p-values	0.158	0.050	0.100	0.352	0.038	0.149

Table 3. Antimicrobial activity of Chinese herbs in comparison to garlic

Goldhead rhizome	gram$^+$	gram$^-$
Scullap root	gram$^+$	gram$^-$
Arnefia root	gram$^+$	
Barberry root	gram$^+$	
Cassia seed	gram$^+$	gram$^-$
Flavecent Sophora root	gram$^+$	
Forsythia fruit	gram$^+$	
Honeysuckle fruit	gram$^+$	
Honeysuckle stem	gram$^+$	
Houttuynia	gram$^+$	gram$^-$
Oriental wormwood	gram$^+$	
Phellodendron bark	gram$^+$	
Quad leaf	gram$^+$	
Tibet bitterroot	gram$^+$	gram$^-$
Ash bark	gram$^+$	gram$^-$
Garlic (positive control)	gram$^+$	gram$^-$

(Spring et al., 1998)

herbs can have a specific anti-microbial activity. The transformation of such results into the *in vivo* situation in the digestive tract of an animal is not easy. Herbs or botanicals which are added to a diet have to compete with the major nutrients as well as with other possible secondary plant constituents that are present in the diet. Furthermore the microbial situation in the digestive tract is well balanced (eubiosis) and depends on many factors like animal species, feed composition and technological treatment, pH, transit time, nutrient density, absorption rate etc.

HERBS AND BOTANICALS AS ANTIOXIDANTS

The antioxidative status of an animal depends on many different factors. The animal itself represents a homeostatic system with the available enzymes. With the feed it ingests nutrients with a variable potential for oxidation, the polyunsaturated fatty acids (PUFA) representing the highest risk. With the feed it also ingests substances like iron, copper or phytase that can catalyze the nutrient oxidation. Finally antioxidants like tocopherols, carothenes, flavonoids etc. protect the sensible substances (see Figure 2).

The different antioxidants can have a variable activity. This depends on the polarity and solubility, but also the place of activity. Some antioxidants are used to protect the nutrients in the feed during storage. Others have their main activity in the digestive tract where they may also help that the substances sensible for oxidation can be absorbed. In the intermediate metabolism antioxidants are responsible for many functions like reduced aging or the protection of intact membranes. In farm animals antioxidants can have a direct influence on the product quality.

The antioxidative activity of herbs can be detected by different methods as in the Rancimat test (in our studies Metrohm, Herisau, Switzerland). Herbs or botanicals are supplemented to an oil that is heated and ventilated by an air stream for accelerated oxidation. The results are expressed as an antioxidative factor (AF) which is corresponding to the induction time of oxidation relative to the untreated oil. Thus high values indicate high oxidative stability. In Figure 3 the antioxidative capacity of rosemary and it's extract (Oxyless U), olive oil and olive leaf extract as well as different tea samples is given with the Rancimat test using olein fraction as carrier.

Rosemary and it's extracts are well known as a potent antioxidant especially in countries around the

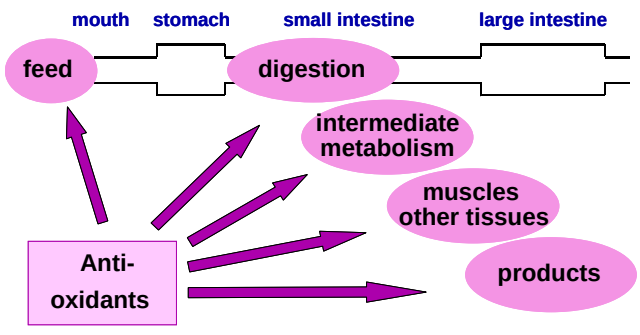

Figure 2. Activity of antioxidants in monogastric animals.

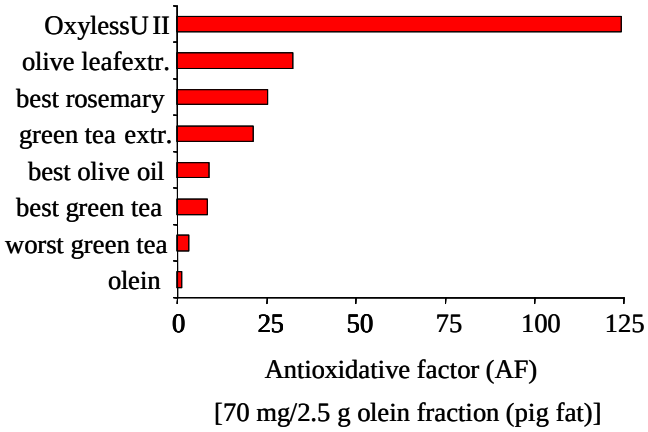

Figure 3. Antioxidative capacity of rosemary and it's extract (Oxyless U), olive oil and olive leaf extract as well as different tea samples measured with the Rancimat system (Scheeder, 2000).

Mediterranean Sea. But extracts from olive leafs or olive oil as such as well as different tea preparations can also be effective antioxidants. Scheeder (2000) tested also different Chinese herbs as antioxidants. In comparison to rosemary only Radix et Rhizoma Rhei showed similar effects on AF. The ethanol extracts of Herba Epimedii, Magnoliavine fruit, Radix Puerariae and Ramulus Taxilii had also some antioxidative activity.

The Rancimat test used as described selects primarily for lipid soluble antioxidative substances. But it is of interest to know whether other constituents that are water soluble also have an antioxidative activity. Therefore in a further study the rancimat test was compared with the microsome peroxidation assay in which thiobarbituric acid reactive substances were measured after starting oxidation of rate liver microsomes using $FeCl_2/H_2O_2$. In the microsome peroxidation test mainly water soluble antioxidants are detected. The values given are relative to control, low values indicating delayed oxidation. In the Rancimat test oleic acid was used instead of soybean oil.

In the Rancimat test Cortex Eucommiae and Magnoliavine fruit were the most effective antioxidatives. But also other Chinese herbs showed a significant activity. Herbs like Herba Epimedii or Radix et Rhizoma Rhei had an excellent antioxidative activity in the water soluble fraction. Again we conclude that *in vitro* tests for selection will not be able to characterize the antioxidative activities of a herb properly.

Deans et al (1993) studied the antioxidative activity of essential oils from different herbs in detail. Some of the results are shown in Table 4.

The effects of phytochemical antioxidants on lipid oxidation in meat and meat products is of major concern. Plant oils used as feedstuffs in monogastric nutrition may readily alter fatty acid composition of all body lipid fractions by generally increasing the amount of PUFA and, therefore, their susceptibility to oxidation. Concomitantly, plant oils usually contain natural antioxidants, which may contribute to an improved oxidative stability of meat and meat products, compensating for the increased degree of unsaturation. These antioxidants are mainly tocopherols. However, phenols present to appreciable amounts in olive oil may serve as examples for effective non-tocopherol antioxidants (Baldioli et al., 1996). Their antioxidative capacity (Papadopoulos and Boskou, 1991) and free radical-scavenging properties (Visioli et al., 1998) have been shown as well as specific antioxidative effects on biomembranes (Saija et al., 1998) and inhibition of low density lipoprotein oxidation *in vitro* (Visioli et al., 1995) and in rabbits (Wiseman et al., 1996).

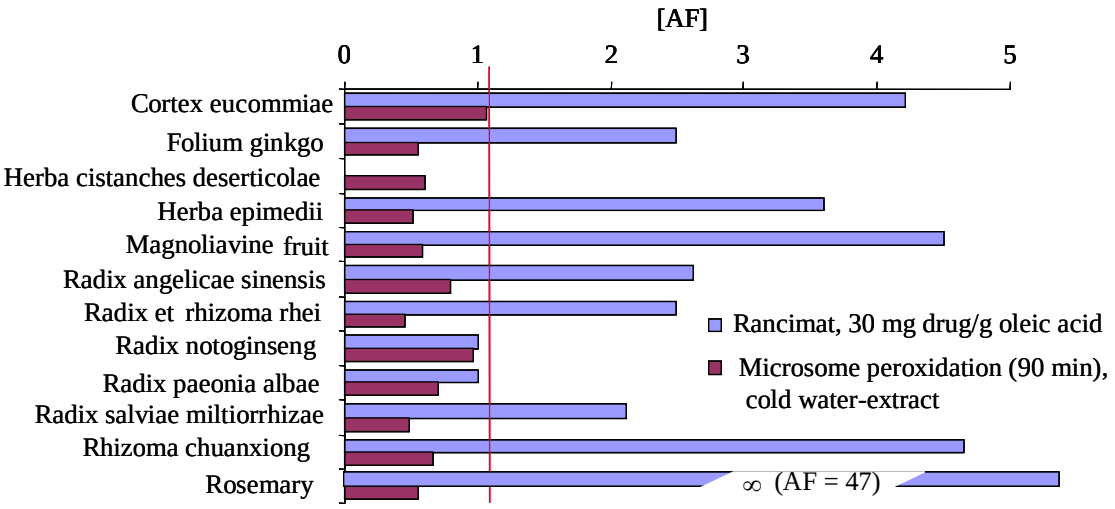

Figure 4. Antioxidative capacity of different herbs in the Rancimat as well as microsome peroxidation test (Scheeder et al., 1999).

Table 4. Anti- and pro-oxidative properties of essential oils (examples)

Anti-oxidative	Pro-oxidative	No activity
Almond bitter	Cardamom	Almond sweet
Clove	Coriander	Anise
Cinnamon	Estragon	Fennel
Laurel	Eucalyptus	Ginger
Mint	Lime	Lemon
Mutmeg	Sage	Marjoram
Pepper	Verbena	Melissa
Peppermint		
Rosemary		
Thyme		

(Deans et al., 1993)

In a recent study, we could show that the supplementation of olive oil to pig diets led to a significantly increased proportion of oleic acid in the lard and, consequently, decreased firmness of salami produced thereof (Scheeder et al., 1998). On the other hand, the antioxidative stability, was higher in the lard of olive-oil supplemented pigs than expected from the degree of unsaturation compared to lard of pigs fed diets without fat supplements or supplemented with soybean oil or lard (Gläser et al., 1999; Figure 5).

The effects of herbs or herb extracts used as dietary supplements were examined in two other studies. Gerber (1997) fed sage as dried herb to pigs and reported a significant decrease of TBARS in the lard with increasing concentration of sage from 0.6 % to 1.2 % in the diet. In contrast, the Rancimat test showed no significant effect. Lopez-Bote et al. (1998) also reported, that they did not find an antioxidative effect in pork when oleoresins of rosemary and sage were fed. However, feeding the same oleoresins (500 mg/kg) to broilers led to an improved oxidative stability in red (leg) and white (breast) meat measured as TBARS as well as a lower amount of cholesterol oxidation products compared to unsupplemented animals (Lopez-Bote et al., 1998). The oleoresins were not as effective as α-tocopherol acetate (200 mg/kg), but it may be concluded, that at least part of the ingested antioxidative compounds were retained in the muscle and that they were still active in the meat. However, investigations into effects of dietary administered secondary plant metabolites on muscle and adipose tissues of farm animals are still rare and knowledge about effects of secondary plant metabolites in feed and guts, their bioavailability by means of extent of absorption and metabolism, and the extent to which they might be retained in animal tissues is not readily available.

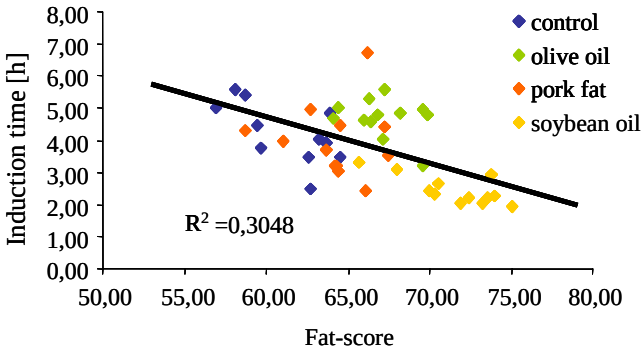

Figure 5. Relation between oxidative stability of lard from pigs fed different fat supplements and the fat-score, a measure of double bonds, showing the elevated oxidative stability of lard from olive oil supplemented pigs (Gläser et al., 1999)

CONCLUSIONS

The beneficial effect on wellbeing, growth performance as well as nutrient and energy utilization are mainly the reasons, why animal feed additives are widely used. With the trend towards more “natural” animal production systems, anti-microbial agents are being banned. Therefore agriculture is looking for friendly supplements with higher acceptance at the consumer. Whether herbs, spices or botanicals (e.g. essential oils) are appropriate has to be considered in each practical application. Only the best combination of the possible alternatives can be recommended.

With the ban of antibiotics strategies of alternatives are often discussed. They are essential in veal calve production and in young pigs, but also relevant in other farm animals. The strategies must be based primarily on optimal management and housing conditions. The main aspects are:

- adapted space and appropriate floor
- if possible straw bedding
- adapted temperature (microclimate of the calves and piglets)
- fresh air, no draft
- low humidity and minimal dust
- good rotation system

The nutrition of the animals must primarily focus that the animals are supplied with all essential nutrients and energy in adequate amounts. In big groups adequate feeding troughs must allow that all animals can get sufficient amounts of food and fresh water. On the other hand overeating of the heavier animals should be avoided so that digestive disorders do not occur. With the following measures the risks of digestion problems mainly in the young pig can be minimized:

low acid binding capacity

- reduced mineral content (< 6 g Ca and < 5 g P per kg feed)
- adequate protein supply (avoid high protein quantities

but essential amino acids according to requirement)
- use of organic acids (mainly fumaric and lactic acid)

use of enzymes, prebiotics and dietary fibers
- use of mainly phytases and carbohydrases
- use of fructose and mannose oligosaccharides
- use of pectins or other soluble dietary fibers

liquid feeding systems with the possibility of fermentation before feeding
use of herbs, botanicals, spices or essential oils
use of probiotics (lactobacilli)
avoidance of anti-nutritional factors (ANF)

In the concept of the production of healthy farm animals without the use of antibiotics herbs can be relevant in many different ways. They can regulate feed intake and stimulate digestive secretions. An optimized digestion capacity and reduced risk of digestive disorders are the consequence. Several phytochemicals like essential oils or dietary fiber can contribute to a balanced microflora (eubiosis), an optimal precondition for an effective protection against pathogenic micro-organisms and an intact immune system. Herbs and botanicals contain many different antioxidants with a high potential for the protection of nutrients against oxidation in the digestive tract, in metabolism as well as in the products.

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