The Use of Naturally Occurring Minerals in Animal Feed

Introduction

The term usually applied to food prepared for domesticated livestock is 'fodder' which is primarily composed of natural organic ingredients such as hay, straw, silage, pelleted foods, oils, grains, legumes, molasses, etc. By – products of the human food chain are another important source e.g. spent grain from breweries and distilleries and DDGS (distiller's dried grains with solubles), from bio-ethanol production.
Compound feed is fodder blended from various natural raw materials plus suitable additives, formulated for the specific needs of the target animal.

A large range of additives are used in animal feed, including: Antibiotics; Vitamins; Antioxidants; Amino Acids; Enzymes; Acidifiers; Probiotics and Minerals.
The term 'minerals' can be used to describe salts and metal compounds, which provide trace elements such as zinc and selenium. To distinguish between laboratory & factory produced chemicals such as these and naturally occurring minerals, FEMAS (Feed Materials Assurance Scheme, UK) defined the latter as: **''Limestone, salt, clays (bentonite, kaolinite, etc.) and other minerals which undergo no further processing beyond extraction, crushing, washing, drying and grading**''.

Global compound animal feed production is estimated by IFIF (International Feed Industry Federation) to be almost 1 billion tonnes per annum, worth approx. US $400 billion. In addition, there is a further 300 million tonnes of feed produced directly on site by farmers. The total number of feed mills globally is estimated at > 28,000 with production by species split approximately as: 46% poultry; 25% swine; 21% ruminants; 4% aquatics; 2% pets and 2% equine.

Major producing companies include:

Country	Feed Production Companies	Approx. Output (million tonnes annum)
China	New Hope	26
Thailand	CP group	23
USA	Cargill	20
UK	BOCM Pauls	4
Germany	Cremer Group	4

Feed is produced in purpose built mills where bulk raw materials are stored in silos, whilst additives might be stored in plastic sacks or containers. Loss in weight screw feeders control the required blend proportions, which are thoroughly mixed and extruded as pellets through a stainless steel die.

Naturally occurring minerals can be sold directly to the feed producers or indirectly to specialist additive suppliers who might sell a broad range of additives or blend various additives to produce more efficient composites. Some suppliers are major international companies operating with global distribution networks and offering detailed technical advice, examples being **Alltech, Nutreco, BASF, Biomin** and **Special Nutrients**. As farms become larger the role of distributors will diminish and direct sales will increase.

Legislation

Legislation governing the quality of additives for use in animal feed is provided in most parts of the world, preventing adverse health affects to both the animals and ourselves (most of us consume meats &/or dairy products).

The IFIF comprises national and regional feed associations to represent the global feed industry. Current membership accounts for more than 80% of global animal feed production and includes USA, Canada, Europe, China, India, South Africa, Japan, New Zealand and others. Although this brings some consistency to legislation there are still variations across the globe, particularly between the more developed and 3rd world countries. The 300m tpa of feedstuff produced directly by farmers presents problems because they are not regularly audited by food safety authorities.

In the USA the Center for Veterinary Medicine (CVA), part of the Federal Food Drug and Cosmetic Act (FFDCA), which itself falls under the umbrella of the FDA, controls animal feed.

In the EU, the European Food Safety Authority (EFSA) is in control. The all-important document is 'Regulation (EC) 1831/2003'. This is regularly updated, with the latest revision of Appendix 1, the list of approved additives, issued 12.05.2014. Other institutions include FEFANA, which is an interface between suppliers & the EU and FAMI/QS & FEMAS, which administer quality control schemes for additive and feed manufacturers, emphasizing prevention of contamination through HACCP (Hazard Analysis Critical Control Points).

In China the Ministry of Agriculture takes control of the inspection and monitoring of feedstuffs.

Health Scares Resulting from Minerals

There have been numerous health scares in recent years associated with contamination of animal feedstuffs and subsequent progression into the human food chain, either as meats or dairy products. The BSE outbreak in the UK in 2009 was caused by feeding cattle (which are herbivorous) infected meat and bone meal derived from sheep. Between 2006 and 2008 it became common practice in China to add powdered melamine, which is rich in nitrogen, to pet foods, milk and other feedstuffs, to make the protein content *appear* higher.

Both incidents led to fatalities and illness on a large scale.

Very few problems have been traced to naturally occurring minerals. However, there are two notable exceptions:

1. 1996, southern USA. Chickens for human consumption were found to contain high dioxin levels. The source was traced to local ball clay added to Soymeal chicken feed as an anti –caking agent.

2. 2004, Holland, Germany and Belgium. Potatoes were sorted for quality in Holland using German ball clay added to water to increase the density, such that high starch potatoes sank whilst lower starch potatoes floated. The heavy potatoes were peeled and washed. The peelings plus some residual clay were added to fodder, which was exported to Belgium and Germany and fed to cattle, pigs, sheep and goats. The discovery of high dioxins caused the temporary closure of hundreds of farms in all three countries.

Dioxins are carcinogenic. They were originally thought to occur in sedimentary ball clays due to ancient forest fires but current scientific opinion is that they formed due to bio-chemical decay of wood by molds, at the time the clays were deposited. Regulations are in place In the EU and elsewhere which impose strict limits on the total quantity of dioxins and associated furans and PCB's in all additives

Why Minerals are used in Animal Feed

Binder

Minerals such as kaolin and bentonites can help to bind pellets together and reduce dust content. Very few companies will buy clay minerals purely for use as a binder preferring to use organic materials such as guar gum or pregelatinised starches, which are more expensive but work at much lower addition rates (0.1% v 2%). Feed pellets provided for marine shrimp and freshwater prawns should not disintegtrate too quickly in water as feeding rate is slow and feed may be lost before it is ingested.

Anti Caking

The high surface area of many clay minerals help to coat sticky ingredients such as molasses and reduce caking of the finished pellets.

Mycotoxins

Mycotoxins are secondary metabolites produced by fungi. Some are good, whilst some are toxic. 'Good', such as penicillin, may be harvested from specially grown colonies and used as an antibiotic.

Toxic mycotoxins originate from contamination in crops including maize, nuts and grass and may subsequently appear in the human food chain, either directly or indirectly by eating contaminated animals. Mycotoxins can occur in in standing crops in wet weather or in stored crops when too moist. They can withstand high temperatures, well above feed processing temperatures, and are rapidly absorbed in the digestion system of animals and humans. When present in animal feed, they can remain in the food chain in meat and dairy products.

Human illness through mycotoxins is rare except in some undeveloped countries, for example 125 people died in Kenya in 2004 after eating Aflatoxin contaminated maize. However, problems with animals are common e.g. lameness in cattle and horses, reduced milk output, sickness and diarrhoea, kidney disorders, liver disorders and potentially, death.

There are numerous mycotoxins, all of which are complex organic structures based on benzene rings. The most common are: **Aflatoxin B1; Deoxynivalenol; Ochratoxin; Zearalenone and Fumonisin.**

Aflatoxin is the most prevalent and presents the most problems. Like some of the other mycotoxins it has an ionic charge, thus clay minerals such as bentonite, sepiolite, illite and kaolin are affective at removing it (> 90% efficiency)….. Aflatoxin bonds ionically with –ve charges on the clay and passes harmlessly through the animal's system.

Economically, Fusarium derived mycotoxins such as Zearalenone are very important as they are oestrogenic and lead to poor fertility and abortions in breeding livestock.

Simple, cost effective and safe processes by which animals may be detoxified and decontaminated are in great demand. There is intense competition from non-mineral substances: i. Bacteria and enzymes, which break down the mycotoxin structure into non-toxic metabolites ii. Esterified glucomannan, obtained from the cell walls of yeast, which works in a similar manner to clays by absorption. However, these ingredients are almost always combined with a clay mineral, for example 'Mycosorb' one of Alltech's best selling products, which is a blend of yeast cell wall and mineral(s).

Radionuclide Containment

Radioactive Caesium (Cs^{137}) and other radionuclides can enter the food chain following incidents such as those at Fukushima and Chernobyl. Radioactive elements can travel large distances before being washed out of the atmosphere by rain, after which they enter freshwater systems, soil and vegetation, thus contaminating meat & dairy products and fruit and vegetable crops. Due to the location of Fukushima, contamination into the Pacific Ocean was another problem due to the affect on fish and other marine life. Zeolite and bentonite have the ability to absorb Cs^{137} such that some of it is excreted rather than absorbed by the animal. EFSA have approved bentonite for emergency use in the EU, with no maximum addition rate.

Poultry Excrement

In large poultry production farms birds such as chickens and turkeys are kept in small crowded pens where they are forced to walk in their own feces, which is alkaline due to the ammonia content. This gives to rise to leg or 'hock' burns which are often noticeable on chicken legs in the supermarket.

Clay minerals such as bentonite, sepiolite or clinoptilite added to the poultry feed will thicken the feces by absorbing moisture, helping to reduce the burns and making it easier to clean the pens. Clinoptilite will also aborb ammonia, reducing odours.

White Fish Farming

When farming turbot and halibut, newly hatched fry can be encouraged to feed by introducing green algae but this has some disadvantages, particularly cost and availability. Research in Scotland indicated that introduction of kaolin can have the same effect – without any addition, the fry turn their faces to the wall and refuse to eat. When algae or kaolin are introduced, it will diffuse the light passing into the water, so that the fry can see the tiny plankton particles better. The Gigha Halibut company in NW Scotland now also use kaolin in the culture of wrasse which are being produced to help with the removal of sea lice from salmon. Recent work has found that the addition of kaolin also appears to reduce bacterial numbers in the culture tanks, but the exact mechanism involved is yet to be established.

Pest Prevention

Diatomaceous Earth can help to kill pests such as mites which infect grain etc stored in silos.

Pellet Production Rate

Platy clays such as kaolin act as a lubricant as feed mix is extruded through a stainless steel die. Significant cost savings can be made either by running with reduced power at the same throughput or at normal power with increased throughput.

Approved Naturally Occurring Minerals

Obtaining proof for the efficacy of mineral additives in animal feed, covering possible contraindications with nutrients & medications etc., is expensive and time-consuming. Where in vivo testing is required, this might involve prolonged health studies of different species, including breeding animals. In vitro tests can also be expensive, for example the analysis by HPLC of mycotoxins as ppb.

In the EU additives are categorized into the following groups:

Technological (binders, thickeners, preservatives, etc.)

Sensory (flavors & coloring)

Nutritional (vitamins, trace elements, etc.)

Zootechnical (digestive, gut flora stabilizers, favorable affects on the environment)

Coccidiostats and **Histomonostats** (parasite / protozoa removal)

Some EU Approved Minerals:

Mineral	Category	EU Approved Use
Bentonite	**Technological**	**Binder / Anti Caking / Aflatoxin B1 reduction* / Control of Radionuclides***
Diatomaceous Earth	"	**Binder / Anti Caking only**
Sepiolite	"	" " "
Kaolin	"	" " "
Vermiculite	"	" " "
Clinoptilite	"	" " "
Natrolite/ Phonolite	"	" " "
Steatite / Chlorite	"	" " "
Perlite	"	" " "
CaCO3 (Limestone / Chalk)	**Nutritional**	**Calcium for bones & teeth etc. / Acidity Regulator**
NaCl (Rocksalt / Evaporite)	"	**Essential salt**

*Bentonite for Aflatoxin & radionuclides must be composed of at least 70% bentonite. Max' addition rate 2%. Bentonite for binder and anti caking only needs to contain 50% bentonite.

EU Maximum Limits for Toxic Substances:

Mineral	Dioxins + Furans WHO TEQ/Kg = ppt	Flourine ppm	Arsenic ppm	Cadmium ppm	Lead ppm	Mercury ppm
Bentonite	**0.75**	**150**	**2**	**2**	**30**	**0.1**
Diatomaceous Earth	"	"	"	"	"	"
Sepiolite	"	"	"	"	"	"
Kaolin	"	"	"	"	"	"
Vermiculite	"	**3000**	"	"	"	"
Clinoptilite	"	**150**	"	"	**60**	"
Natrolite /Phonolite	"	"	"	"	**30**	"
Steatite/ Chlorite	"	"	"	"	"	"
Perlite	"	"	"	"	"	"
CaCo3	"	**350**	**15**	"	**20**	**0.3**

A Closer Look at some of the main Minerals

Bentonite

Ca Montmorrillonite represents the bulk of this vast industry. Biomin (Austria) and BASF (Germany) are major global suppliers.

In 2013, Biomin achieved EU approval for the use of bentonites for Aflatoxin B1 reduction in ruminants, poultry and pigs and the containment of radionuclides, additional to the long-standing approval for use in binding and anti caking. The new approvals have stipulations that the bentonite content must be at least 70% and opal content no greater than 10%, caveats created by Biomin to minimize competition.

For all applications there are warnings that simultaneous use with macrolides (antibiotics) must be avoided and in the case of poultry, it should not be used at the same time as coccidiostats. These contra indications occur due to the high absorptive ability of bentonite, which is characterized by a high cation exchange capacity (CEC) and an ability to swell when hydrated.

Sepiolite

Sepiolite is a magnesium silicate with a micro - fibrous crystal structure. It is extremely fine with a high surface area and is non-swelling. It is used for mycotoxin binding, anti-caking and pellet binding. The natural high pH is an additional benefit in helping with acidosis in sick cattle. Additionally, Sepiolite has a high moisture absorption capacity, which can help to keep poultry excrement drier and reduce hock burns. Tolsa is the main supplier in Europe, operating deposits in Spain and Turkey.

Kaolin

Widely used due to its common occurrence throughout the world, kaolin can be used as a binder for feed pellets, for anti-caking, for prevention of diarrheal problems and to reduce aflatoxins. Imerys in the UK have demonstrated a commitment to quality by achieving FEMAS accreditation earlier this year, for the production and sale of kaolin used for binding and anti caking.

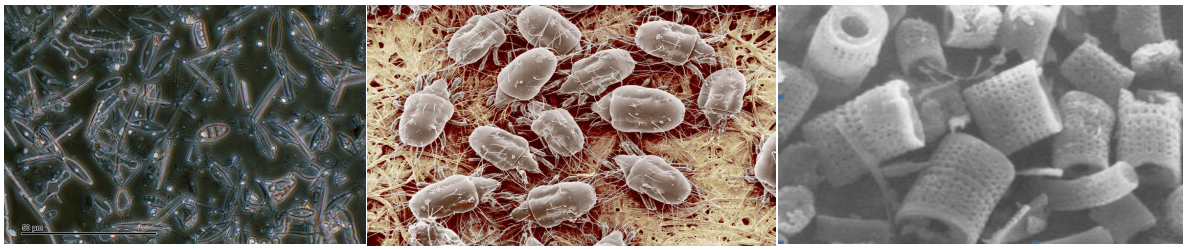
Clinoptilite

Clinoptilite / Zeolite is micro-porous with a very high surface area of approx. 500m^2 /g. It can selectively absorb molecules depending on their size … the maximum size is determined by the dimension of channels in the crystal structure, hence its description as a 'molecular sieve'. It is sold into the aquaculture industry, for example shrimp & fish farms and pet aquariums, due to its ability to absorb ammonia from water. It is also used in animal feed to absorb mycotoxins, particularly aflatoxin and is used in poultry feed to bulk excrement and absorb ammonia. Globally, China and S. Korea are the biggest producers.

Illite

Illite is a potassium aluminum silicate, which often occurs as a mixture with montmorrillonite & /or kaolinite. Special Nutrients in the USA sell an illitic clay ('Myco-Ad') which they claim is affective against a range of mycotoxins at a low dose rate and is compatible with all other feed ingredients i.e. no absorption of vitamins or antibiotics etc.

Diatomaceous Earth



Diatomaceous Earth is composed of the fossilized remains of minute diatoms, some of which are cylindrical. Deposits vary in species of diatom and in purity, as some are mixed with clays and other minerals. It has a strong negative charge and a MOH's hardness of 7.

It is used extensively as an anti caking agent and for control of mealworms and mites etc. in stored grain. In controlling pest infestations the razor sharp edges of the diatoms cause lacerations, after which the powdery diatomaceous earth absorbs body fluids, bringing death by dehydration. It can also be used for control of Alflatoxin, particularly when mixed naturally or artificially with clay minerals.

Calcium Carbonate

Calcium is essential for the skeletal system but also important for nerve impulse transmission**,** blood clotting, milk production and eggshell development. Calcium carbonate also acts as an antacid.

Most production for feed grade is as GCC from pure limestone deposits containing 98% or more CaCO3 content. Omya, Imerys and Huber dominate globally.

Salt

Insufficient salt results in reduced feed intake and subsequent reductions in animal performance. Excessive salt in poultry results in increased water consumption and poor quality excrement, causing leg burns. Salt regulates blood pH and maintains osmotic pressure, acid / base balance and exchange mechanisms through cell membranes.
Salt occurs in most countries and current global production (for use in all industries, including human and animal feed, chemical, etc.) is approx. 284 m tonnes per annum. Different production methods include hard rock mining, solution mining / mechanical evaporation and solar evaporation of seawater.
Salt for animal feed is normally sold in vacuum packed sacks at different sizes, ranging from granules at 1 – 3mm to fine powder. Salt licks direct from the mines are also used for cattle, horses, sheep and goats. Gobal suppliers include K + S (Germany), Compass Minerals (US) and China National Salt.

Poultry Grits

Poultry do not have teeth, hence the expression ‘as rare as hen’s teeth’. Across the world it is common practice to provide suitable insoluble grits, according to the size of the bird, to help with food digestion. The grit passes through the bird into the gizzard where it is used to grind down the food. Flint, granite and limestone are amongst the rock types commonly used, crushed and graded to a narrow particle size distribution ranging from 0.85 to 1.50 mm for chicks to 6 to 12mm for turkeys. Many end- suppliers blend in oyster shell to help with eggshell development. In the UK grouse grit (1 to 4mm) is normally pre-medicated to kill nematode worms and other parasites. It is left to gamekeepers and estate managers to remove medicated grit at least 4 weeks before the shooting season starts to prevent this medication entering the human food chain.

Conclusions

Naturally occurring minerals have an important role to play in animal feed and the market will grow substantially, due to our increasing world population and the need for an adequate food supply.

The UN Food & Agricultural Organization estimates that the world will have to produce circa 60% more food by 2050 and that animal protein production will grow by an even larger margin, as a result of family incomes increasing and greater urbanization. The global market for feed additives (*all* additives, including nutrients etc.) was estimated by IFIF to be worth approx. $16m in 2012 and is expected to reach $20m by 2016.

This gives plenty of scope for companies mining natural minerals…those most likely to succeed will be committed to quality and proving the efficacy of their products.

We are likely to see advances in nanotechnology, for example nanoparticles improving the uptake of nutrients.

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