MJF COLLEGE OF VETERINARY & ANIMAL SCIENCES, CHOMU, JAIPUR (RAJ.)

DEPARTMENT OF ANIMAL NUTRITION

FEED ADDITIVE
DATE- 16/03/24 – 28/03/24

Delivered by-
Dr. Vijay Prakash Saini
Dr. Abhishek Mehta

What are Feed Additives?

Feed additive is an ingredient or combination of ingredients added to the basic feed mix or parts there of to fulfil the specific need. Usually used in microquantities and requires careful handling and mixing.

Any chemical incorporated in an animal feed for the purpose of improving rate of gain, feed efficiency, or preventing and controlling disease is feed additive.

A feed additive need not be a drug. A dose of a few mg/kg added to the feed of animals acts as a protection against untoward environmental influences.

Types of Feed Additives

Feed additives are broadly classified into 2 types-

- Nutrient feed additives (e.g., amino acids, minerals and vitamins) and
- Non nutrient feed additives (e.g. antibiotics, arsenic and copper supplements, hormones, beta agonists, immunomodulators, coccidiostats, enzymes, probiotics, yeast culture and acidifiers, antioxidants, sequestrants, mycotoxin binders, anticaking agents, humectants, feed preservatives, flavouring agents, colouring agents, pellet binders, dietary buffers, methane inhibitors, roughage substitutes, propionate promoters, defaunating agents, ketosis and bloat controlling agents, surfactants, sweetening agents, tranquilizers, emulsifiers and stablilizers, bile acid, methyl donors, sweeteners, etc).

Five Categories of Feed Additives-

European Union recognized 23 functions for feed additives (having added that of binding mycotoxins as recently as February 2009) indicating that each feed additive is recognized to explain its functionality.

- **Technological additives:** This refers to products that influence **the technological aspects of the** feed while not directly affecting its nutritional value, although there may be indirect effects such as through improvements in the **feed's handling or hygiene characteristics**. Example, organic acid as preservative of feed.

- **Sensory additives:** These improve the palatability and thereby voluntary intake of a diet by stimulating appetite, usually through the effect they have on the **flavour or colour** of the feed. Examples, vanilla extract, essential oils.

- **Nutritional additives**: They supply **specific nutrients required by the animal for optimal growth**. Examples vitamins, amino acids, trace minerals. This category of additives is simply the concentrated forms of nutrients supplied in the natural ingredients in the diet.

- **Zootechnical additives**: The products in this **case improve the nutrient status** of the animal, not by providing specific nutrients but by enabling more efficient use of the nutrients present in the diet. Examples, enzymes and direct-fed microbials/probiotics (often referred to as pronutrients).

- **Coccidiostats and histomonostats:** These are used to **control intestinal health of poultry** through direct effects on the parasitic organism concerned. They are not classified as antibiotics.

Advantages of use of Feed Additives-

1. **Increase feed quality and feed palatability:** Emulsifiers, pelleting agents are used to meet the demands of feed manufacturers while antioxidants, fungistatic agents and fermentation inhibitors ensure proper shelf life of feed.

2. **Improve animal performance:** Feed additives are mixed with feeds in nontherapeutic quantities for the purpose of promoting animal growth, lowering feed consumption, protecting the animal against all sorts of harmful environmental influences (stresses).

3. **Improve the final product:** Addition of antioxidants to diets produce grades of meat in which the fat does not rancidify or does so more slowly. The use of additives such as enzymes also makes end products more homogenous and of better quality.

4. **Economise the cost of animal protein:** Low levels of additives, mainly of antibiotics or other growth promoters and related compounds in animal feed contribute to increased production of animal proteins for human consumption. Feeding antibiotics and other additives lower the cost of meat, milk and egg production.

Antibiotic Feed Additives: Antibiotics are a group of soluble organic substances produced from microorganisms, which in small concentrations have the capacity of inhibiting the growth of other microorganisms and even destroying them. The quantity of antibiotics to be added as an additive is much less than that used for therapeutic purpose.

Factors such as age of the animal, kind of production, nutritional status of the animal, level of hygiene in the farm, stress of the animals, etc. are to be considered before deciding the quantity.

Antibiotic feed additives are of two types: Ionophore antibiotics and Non-ionophore antibiotics.

a) Non-ionophore antibiotics: e.g., chlortetracycline, oxytetracycline, zinc bacitracin, virginiamycin, flavomycin, bambermycin, avoparcin, tylosin, etc.
b) Ionophore Antibiotics

These are produced by several strains of streptomyces spp. e.g., monensin, lasalocid, salinomycin, lysocellin. The most studied single group of antimicrobial compounds used in animal feeds are the ionophores. These are small molecular weight molecules that bind ions of various minerals and modulate their movement across cell membranes.

Effect of Feeding Antibiotics: Both the ionophore and non-ionophore antibiotics have been used in nonruminants and pre ruminants, while only the ionophores have been successfully used in adult ruminants.

1. Ruminants-

- Reduce incidence of diarrhoea in young calves.
- Check the subclinical infections and improves growth rate and feed efficiency.
- Most of the growth improvement occurs before the calves are 8-10 weeks of age and beyond that age no beneficial effect has been reported.
- Reduce the incidence of liver abscesses in beef cattle fed high grain rations.
- Increase production efficiency.

2. Swine: Growing-finishing Pigs-

- Feed efficiency is improved to the extent of 5-8%.
- The greatest beneficial effect is observed during the early growth period between weaning and 50 kg body weight. But antibiotic feeding has to be continued till the pigs reach the market weight. Runty pigs give better response.
- A mixture of two or more antibiotics is no more effective than the single effective antibiotic.

Sows- Feeding of 40 mg of virginiamycin per kg feed to young gilts (sows) at their second oestrus showed improvement in their weight at first farrowing (4%), second farrowing (9%) and third farrowing (14%). It was also observed that weight losses in lactation were less. Milk fat content is increased; total milk solids also increased with 50% increase being in the milk protein.

Poultry

- Antimicrobial feed additives are included in diets for the prevention and control of coccidiosis, etc. and to improve growth, efficiency of feed utilization and livability.
- Increase nutrient utilization, especially with several ingredients which are lower in digestibility.
- Direct-fed antimicrobials supplemented continuously at low levels can be beneficial for maintaining intestinal health. These are included in diets at relatively low concentrations (1 to 50 mg/kg), depending on the age and stage of development of poultry.
- Egg production is also frequently improved by dietary supplementation with antimicrobial agents. Antimicrobials do not stimulate growth of chicks kept in a germfree environment.

Effect of Ionophores on Rumen Fermentation-

1. Increase the rumen propionate and decrease the acetate concentration **and decrease the acetate: propionate ratio.**
2. **Decrease methane production.** Monensin achieves this by affecting electrolyte transport across the cell walls of methanogenic and other bacteria while not disturbing propionate-producing bacteria. In this way more energy is conserved as propionate.
3. Ionophores depress the activity of some rumen enzymes like proteases, deaminases and urease which leads to improved efficiency of dietary protein utilization.
4. Monensin and lasalocid inhibit biohydrogenation resulting in the release of unsaturated fatty acids from the rumen which are deposited in the **body tissues.**
5. **Lower calcium and potassium concentrations.**
6. **Decrease passage rate** and this is associated with an increased amount of organic matter fermented in the rumen. This effect of rumen fermentation modification should increase the ME value per unit of feed intake. When ionophores which do not result in reduced feed intake are used, the effective ME value of the diet may be increased by approximately 10%

- **Absorbable and Nonabsorbable Antibiotics**
- Antibiotics are absorbable and nonabsorbable depending on their absorption into the bloodstream. **Tetracyclins, oxytetracyclins and chlortetracyclins** are absorbable antibiotics.
- Nonabsorbable antibiotics are **zinc bacitracin, avoparcin, monensin, virginiamycin, halquinol.**
- The growth-promoting effects of these antibiotics are primarily due to their beneficial effects on the microflora of the intestinal tract. These are gut active agents.

Arsenicals-

1. 3-nitro-4-hydroxy phenylarsonic acid (3-nitro)
2. P-amino phenylarsonic acid (arsanilic acid)

Arsenicals improve growth of broilers and such birds have bright red combs and wattles. Capillaries are enlarged and engorged through the dilator effect of arsenic. Arsanilic acid is tolerated up to 0.1% in the diet of chicks and up to 0.02% in the diet of turkeys.

Anabolic Steroids- These are banned in European Union since 1989, because of health problems they might cause. e.g. Oestradiol, Trenbolone acetate (TBA) + Oestradiol, Zeranol (Ralgro) + TBA. Oestradiol-17 ß is a natural oestrogen produced by ovaries and testes. Hormone implants are legal and routinely used in USA.

Copper supplements: These are routinely added to pig grower diets as growth promoters. Copper is believed to be an effective growth promotant with a mode of action at the intestinal level due to its bactericidal properties. A study in growing pigs revealed that a combination of copper sulfate and betaine resulted in an improvement of 15% in feed efficiency compared to a control diet containing betaine only. Copper level, 250 mg/kg diet produces soft fat. In EU countries, level is limited to a maximum of 35 mg/kg. Copper sulphate is added at 0.01% of the diet in fattening pigs to improve rate of gain and feed efficiency between weaning and slaughter. Sheep are particularly susceptible to copper poisoning. It causes partial defaunation in ruminants

Hormones- The active principles secreted by the endocrine glands into the blood for transportation to target organs and tissues are known as hormones. These are of endogenous origin.

These are broadly of two types.-

1. Anabolic hormones: e.g. Somatotropin, Thyroxine, Androgens

Somatotropin stimulates growth of endo-chondrial bones and epiphysis of long bones while in protein metabolism it aids nitrogen retention and overall protein synthesis. Thyroxin also stimulates growth of long bones as well as protein synthesis. Testosterone is a potent androgen and at low dose testosterone increases the epiphyseal diameter, promotes muscle growth by augmenting nitrogen retention.

2. Catabolic hormones: e.g. Oestrogens, Glucocorticoids Oestrogens inhibit skeletal growth although in ruminants it increases nitrogen retention. Glucocorticoids decrease growth of epiphysis and also aid in degrading protein and amino acids and thereby inhibit protein synthesis in extrahepatic tissues.

Milk Production- In 1982, D.E. Bauman, Cornell University, USA reported increased milk production in cows with exogenous injections of GH. Numerous studies have shown that BGH increases milk yield by 15- 40% when administered to lactating dairy cows. The availability of recombinant somatotropin (rST) and its effective use in both dairy little and growing pigs (PST) has provoked several studies in which the mechanism of action of the hormone has been investigated. These have confirmed the classical action reported in nonruminant species, with the protein mass of all the tissues increasing approximately equally, probably through increases in protein synthesis. the availability of a slow-release device of BST has eliminated the necessity for daily injection. Lactating dairy cows injected 640 mg bST at 28 day intervals for a period of 112 days gave 11.8 to 15.2% higher milk yield per control animals.

Goitrogens: These are antithyroid principles which depress the activity of thyroid gland and depress growth and often increase the rate of fattening. e.g. Thiourea and thiouracil fed to pigs and lambs at 2 mg/kg, BW. In poultry, thiouracil in combination with diethyl stilbesterol improves finish and market quality without depressing growth rate.

Phenethanolamine Repartitioning Agents: Phenethanolamines are often referred to as leanness-enhancing repartitioning agents because of their ability to redirect nutrients away from adipose tissue and toward muscle. In general, the effects of phenethanolamines are increased rate of weight gain, improved feed utilization efficiency, increased leanness, and increased dressing percentage. These are $ß_1$-selective phenethanolamines (eg. ractopamine) and B_2-selective phenethanolamines (clenebuterol, cimaterol and L-644 and 969).

Immunomodulators: These are compounds obtained from organisms or synthesized chemically which are capable of enhancing the defence mechanism of animals, including fish and shrimps. The use of the immune response potentially has a lot to offer the animal production industry as a method of growth promotion and manipulation of carcass composition.

These are classified as:

1. Natural immunomodulators
2. Synthetic immunomodulators

Potent immunomodulators: Cell wall preparations, Vitamin C, Vitamin E, Levamisole, quaternary ammonium compounds (QAC).

1. They act as a barrier to infection against specific and non-specific pathogens.
2. They enhance the microbe killing activity lymphocytes and natural killer cells.
3. Some activate the complement system also and enhance the phagocytosis of the cells, resulting in the development of the resistance and protection from various infections.

Glucans are one of the most important structural elements of fungal cell walls, *Saccharomyces cerevisiae*.

Macrogard is the commercial name of one of the glucans marketed by a Norwegian company.

Selenium along with vitamin E develop resistance against disease.

Chitin is an immunomodulator. It is a polysaccharide obtained from crustacean shells, insect exoskeletons and cell walls of certain fungi.

Copper supplements: These are routinely added to pig grower diets as growth promoters. Copper is believed to be an effective growth promotant with a mode of action at the intestinal level due to its bactericidal properties.

Hormones The active principles secreted by the endocrine glands into the blood for transportation to target organs and tissues are known as hormones. These are of endogenous origin.

These are broadly of two types.

1. Anabolic hormones: e.g. Somatotropin, Thyroxine, Androgens

Somatotropin stimulates growth of endochondrial bones and epiphysis of long bones while in protein metabolism it aids nitrogen retention and overall protein synthesis. Thyroxin also stimulates growth of long bones as well as protein synthesis. Testosterone is a potent androgen and at low dose testosterone increases the epiphyseal diameter, promotes muscle growth by augmenting nitrogen retention.

2. Catabolic hormones: e.g. Oestrogens, Glucocorticoids Oestrogens inhibit skeletal growth although in ruminants it increases nitrogen retention. Glucocorticoids decrease growth of epiphysis and also aid in degrading protein and amino acids and thereby inhibit protein synthesis in extrahepatic tissues.

Exogenous Hormones and their Effect

- Some oestrogenic activity is present in some clovers, soybean, sesban etc; some are synthesized chemically. These are exogenous sources of hormones. These are administered orally as feed additives, s/c implants or parenteral injections.
- Anabolic agents enhance nitrogen retention in the body and particularly in the muscle, by way of significantly decreasing blood and urinary urea and urinary nitrogen (i.e., controlling partition of nutrients absorbed) and result in the production of leaner carcasses.
- Androgens are mainly used in females and castrated males while oestrogens are used in males.
- Combination of oestrogens and androgens gave higher average daily gain than when a single agent was used.
- The mode of action of androgens and oestrogens in increasing nitrogen retention and average daily gain is different.

Hexesterol is synthetic oestrogen. Melengesterol is synthetic progesterone.

Zeranol (Ralgro): Implanted (12 mg pellet) subcutaneously on the backside of the ear. It stimulates pituitary gland to secrete increased amounts of somatotropin growth hormone. It is approved for growth promotion in cattle in an implantable form.

Trenbolone acetate (TBA): It is very effective growth promoter especially in ruminants. Implanting steers with TBA and oestradiol-17 ß made their growth rate comparable to that of bulls but, rather surprisingly, their carcass composition was still essentially that of steer.

Synovex plus: This implant contains 20 mg of oestradiol and 200 mg of TBA which is a 1:10 ratio of the drugs. Implanted steers gained more rapidly and converted more efficiently than unimplanted animals. Re implanted cattle gained more rapidly than cattle implanted only once and they also tended to convert more efficiently. Implanting did increase the weight of saleable lean beef without increasing trimmable fat.

Synovex-S (Oestradiol benzoate, 20 mg and progesterone, 200 mg)

Synovex-H (Oestradiol benzoate and testosterone propionate)

Revelor-S (Trenbolone acetate and oestradiol)

Synovex-S and somavubove (R) (rbST)- act in an additive manner to improve growth and protein deposition in young growing steers.

- Saccharomyces cerevisiae yeast cell wall (YCW) Yeast cell wall is composed of complex polymers of B-(1-3/(1,6) glucan, mannan-oligosaccharide (MOS) and chitin.
- MOS is located on the surface of the cell wall. Yeast glucans are major cell wall components often present as the inner wall layer and associated with other cell wall components such as chitin.
- Typically commercial YCW are composed of 30 to 60% polysaccharides (15 to 30% of β-1, 3/1, 6-glucan and 15 to 30% of mannan sugar polymer), 15 to 30% proteins, 5 to 20% lipids, and no more than 5% of chitin.
- Most of the protein is linked to the mannan oligosaccharides (MOS) and is referred to as the mannoprotein complex. The ß-1, 3/1, 6-glucans present in YCW should be recognized as an immune modulator substance in animals and humans.
- MOS is able to play important roles in binding mycotoxins and improving the micro-environment of the animal digestive tract.

Coccidiostats: Amprolium, clopidol, lasalocid sodium, monensin sodium, salinomycin, robenidine, maduramicin, 3,5-dinitro-o-tonensie (DOT), diclazuril, narasin.

Phytoestrogens Phytoestrogens are a diverse group of naturally occurring non-steroidal plant compounds. Soya proteins contain phytoestrogens and the phytoestrogens have been shown to help prevent heart disease and slow osteoporosis, just as oestrogen replacement therapy does, but apparently without increasing the risk of breast or uterine cancer. Researchers see no harm in suggesting that menopausal women include Soya in their diets to reduce the discomfort of menopause due to hot flushes, night sweats, etc.

Feed enzyme additives act as biocatalysts to assist the digestion process and support utilization of nutrients that otherwise go unused. Feed enzymes such as B-glucanases and xylanases have enabled barley or wheat in poultry diets up to 50 or 60%. A combination of endo-1-4-ß galactanase and ß-galactosidase could be used to improve the ME of soybean meal. Feed enzyme complexes containing arabinases, xylanases and pectinases (pectin esterase, pectin lyase and polygalacturonase) breakdown the arabinoxylans and pectins present in sunflower seed meal, rapeseed meal, lupin seed meal, etc. and release the protein and other nutrients.

Probiotics: Parker coined the term 'probiotic' in 1974 and defined it as "organisms and substances which contribute to intestinal microbial balance". The term probiotic means " for life" and has a contrast with the term antibiotic means "against life". Probiotics are advocated as an alternative to antibiotics for growth promotion. Probiotics are live cultures of non-pathogenic organisms which are administered orally. Later Fuller (1989) redefined probiotics as live microbial feed supplements which beneficially affect the host animal by improving its intestinal microbial balance. Probiotic products are available in the form of oral pastes, water dispersible powders or liquids or directly fed feed additives and include microbial cells, microbial cultures and microbial metabolites. Most probiotics get destroyed by up to 80% in the presence of antibiotics or when mixed with antimycoplasma drugs in the feed.

The term 'pronutrients' is used in place of probiotics. The US Food and Drug Administration used the term direct fed microbials instead of probiotic and the manufacturers were directed to write DFM on their products. Some firms developed 'thermo-positive process' to formulate microbial cultures and microbial viability is assured in the pelleted feeds. e.g 'Primalac' DFM. Some probiotics supply viable bacterial spores of selected Bacillus strain which are heat resistant. The recovery rate of organisms after pelleting is 95%. Microgranulated probiotic is available facilitating reduced dust and improved flowability, homogenous mixing even at very low inclusion levels with improved stability during storage and pelleting e.g. Paciflor Microgranulated

Microorganisms used as probiotics: Some important are *Lactobacillus acidophillus*, *L. bifidus*, *L. bulgaricus*, *L. casei*, *L. fermentum*, *L. lactis*, *L. plantarum*, *Loruminis*, *L. salivaricus*. *Bifidobacterium bifidum*, *Aspergillus oryzae*, *Torulopsis*, *Streptococcus faecium*, *S. thermophilus*, *Sacchergillus cerevisiae*. *Bifidobacterium bifidum* is found commonly in mother's milk and the intestine of humans and animals. *Aspergillus oryzae* produce enzyme cellulase. *Torulopsis* is the mother culture of yeast. The enzyme lipase is exhibited by Torulopsis

Characteristics of a Good Probiotic-

1. The culture should exert a positive effect on the host. It should be gram positive, acid resistant, bile resistant and contain a minimum 30 x 10^9 CFU (colony forming unit) per gram.
2. The culture should possess high survival rate and multiply faster in the digestive tract. It should be strain specific.
3. The culture microorganisms should neither be pathogenic nor toxic to the host.
4. The adhesive capability of microorganisms must be firm and faster.
5. Be durable enough to withstand the duress of commercial manufacturing, processing and distribution so that the product can be delivered alive to the intestine.

Mode of action may be competitive with the harmful enteric microorganisms, stimulatory for increasing growth rate and thus the productivity and nutrient sparing or the combined effects. e.g. The main metabolites of Lactobacilli are lactic acid and H_2O2. The former is responsible for preventing the growth of coliform organisms by reducing the pH while the latter has bactericidal effect. Finally, an acid environment is conducive to increased enzymatic activity within the digestive system.

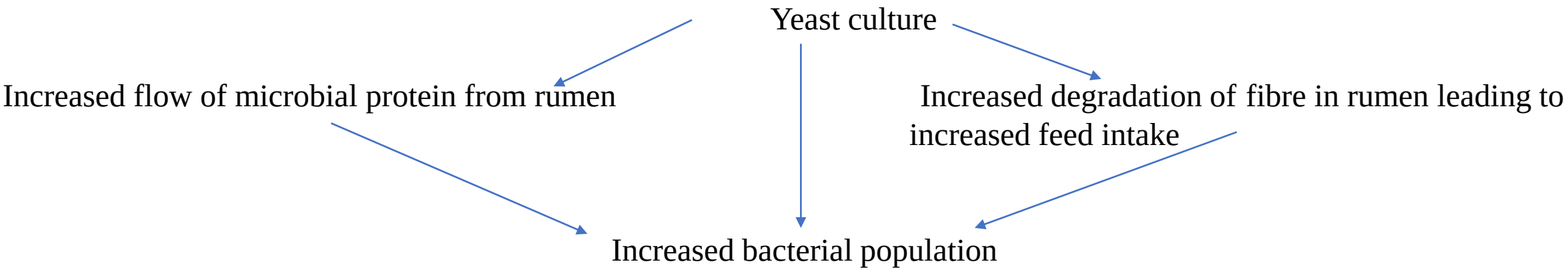
Yeast Cultures Vs Yeast Blends- True Yeast cultures composed of the entire culture-the yeast cells capable of fermentation and the media on which they were grown. So when it is dried, the product composed of live yeast and the growth media is rich in nutrilites. **Yeast culture products do not contain many live yeast. Yeast blends are marketed as yeast culture even though these products are only blends of active dry yeast and a diluent.** Various diluents such as distillers dried solubles, wheat middlings, hominy feed or rice hulls are frequently used and may be augmented with saccharins, sucrose and traces of mineral salts. Yeast is a relatively fragile living organism that is easily killed by heat, humidity and rough handling. Hence yeast cells are destroyed by pelletising the feed and storage conditions. Yeast packaged in a vacuum or inert gas has a much greater stability than yeast packaged in air. Significant losses of viable yeast cells can also occur over time for yeast products held at 35°C in paper bags. The rate of deterioration is time and temperature dependent under normal conditions. Yeast cells in products blended with minerals deteriorate more rapidly due to the action of the mineral salts.

Live Yeast Culture as a Feed Additive- The feeding of live yeast culture, *Saccharomyces cerevisiae* has attracted the attention of Animal Nutritionsts to improve the microbiological balance of the host animal and thereby extract the nutrients to the maximum extent and get them deposited in end products (milk, meat and eggs) for human use which simultaneously reduce environmental pollution. Live yeast species are highly probiotic.

Effects of Live Yeast Culture

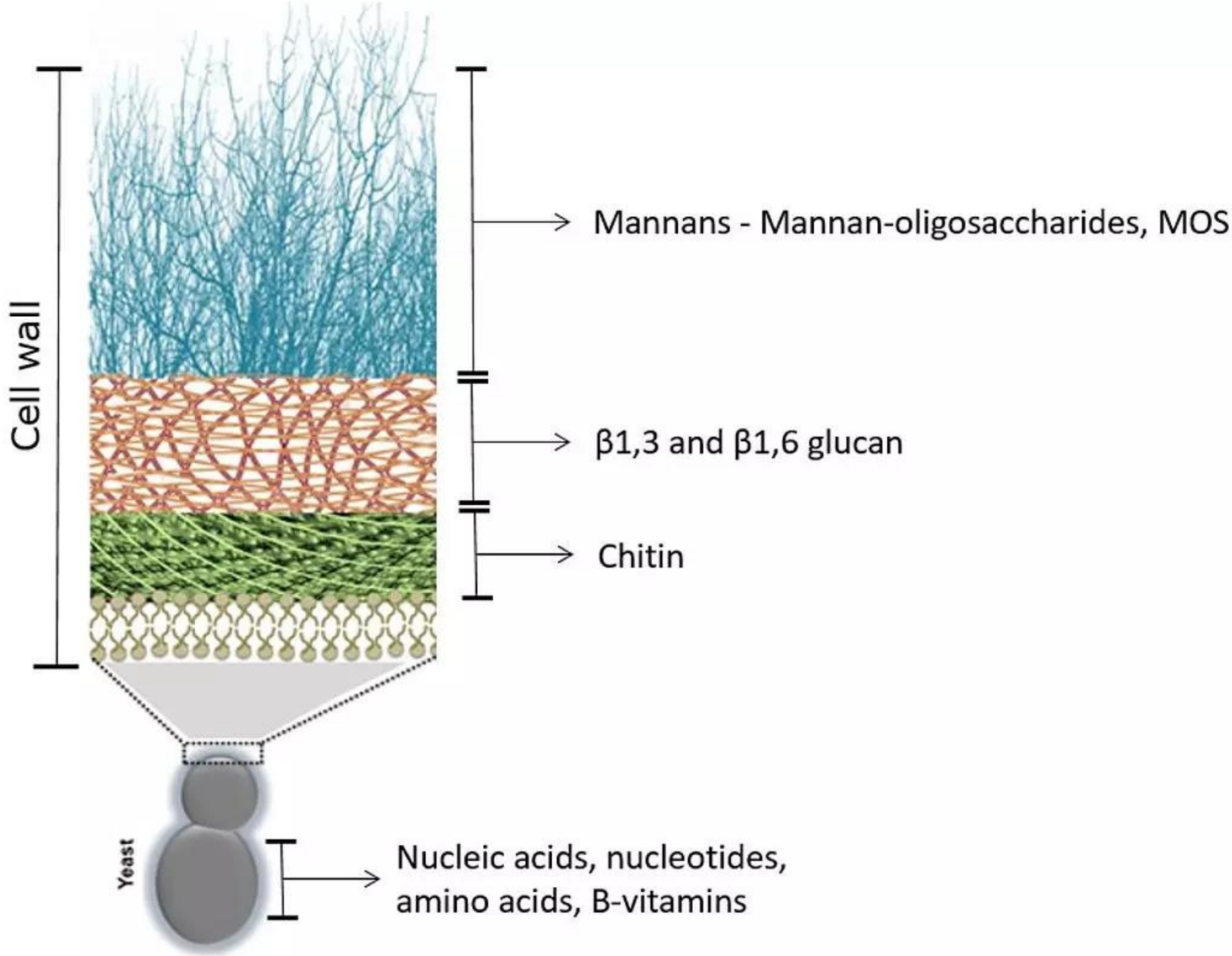
1. Effect on the animal physiology: Reduces the temperature in heat stressed animals. The greatest benefit occur during the hotter months. Fungal cultures (Aspergillus orizae, Armillaria heimii, etc.) (3 to 5 g/d) in the diet decreased body temperatures and respiration rates in hot, but not in cool weather. The mechanism of action exerted by fungal cultures on body temperature and respiration rate is unclear.

2. Effect on the rumen: *Saccharomyces cerevisiae* could act by production of growth stimulating factors in the rumen,



Action of Yeast Culture in Ruminants.

Mannan Oligosaccharides (MOS)- MOS, a complex carbohydrate extracted from yeast cell wall, improves the health and performance of monogastric animals. MOS blocks attachment of pathogenic bacteria to the animal's intestine and prevents colonisation that can result in disease. In addition, MOS may stimulate the animal's immune system, thereby further reducing the risk of disease MOS increased the release of cytokines, which coordinate activity among diferent cells the release of cytokine MOS also enhanced interleukinel Concentration. The immune function requires interleukin-2 for T-cell Proliferation and differentiation.


Cell wall
Mannans - Mannan-oligosaccharides, MOS
β1,3 and β1,6 glucan
Chitin
Yeast
Nucleic acids, nucleotides,
amino acids, B-vitamins

Fructooligosaccharides (FOS)- are basically obtained from plant sources and comprise 3–10 fructose units with the terminal fructose linked to a glucose residue by β-(1→2) glycosidic bonds, that is, they have a nonreducing sucrose end. Short chain fructo oligosaccharides encourage the growth of beneficial bacteria in the gut such as Lactobacillus spp., Bifidobacterium spp. and Bacteroides spp. Feeding FOS helps proliferation of these probiotic bacteria which inhibit growth of more harmful bacteria and reduction of flatulence (since FOS are not digested by host intestinal enzymes) in animals. So these (FOS, MOS) are termed as 'prebiotics'.

Prebiotics- A prebiotic is a **non-digestible food ingredient that** beneficially affects the host by selectively stimulating the growth and/or activity of **one or a limited number of bacteria in the colon** and thus improves host health (Gibson et al., 1996). Prebiotics are normally simple sugars, oligosaccharides of between 3 to 6 fructose units in length or may also comprise soluble fibres, with longer monosaccharide chain lengths. Examples of prebiotics which are commonly used in the companion animal feed industry include inulin, MOS, FOS or oligofructose. Prebiotics are substrates for probiotic bacteria such as Bifidobacteria spp.In companion animals, prebiotics improve gut microbial ecology and enhance stool quality. They are known to improve the efficiency of nitrogen utilization in the intestine resulting in less wastage through ammonia recycling and a more complete digestion of nutrients in the large intestine. This also helps to ward off the production of undesirable odours.

Silver Nanoparticles as a Potential Antimicrobial Additive Alternative to Antibiotics

Nanoparticles Most scientific data is reported in terms of metric measurements as mentioned here below. In general, particles are considered to be nanoparticles if one of their dimensions is less than 100 nanometers (nm) across.

Direct-fed Microbials (DFM) Direct-fed microbials, particularly bacteria and yeast can replace antibiotics in livestock and poultry feed. The FDA defines direct-fed microbials as "a source of live (viable) naturally-occurring micro- organisms". One major difference between antibiotics and direct-fed microbials is that direct-fed microbials are living organisms. Direct-fed microbials include Lactobacillus, Streptococcus, Bacillus and yeast (Saccharomyces cerevisiae). These microorganisms vary considerably in their ability to withstand various environmental conditions. Lactobacillus are delicate microorganisms that are unable to withstand environmental extremes, such as the heat and pressure of pelleting. Bacillus are very stable microorganisms that can survive pelleting due to their ability to form spores that are resistant to changes in temperature, pressure, and moisture. Yeast and Streptococcus fall somewhere between Lactobacillus and Bacillus in their ability to survive pelleting. The ability of yeast to grow in the rumen is limited, but is able to remain alive and metabolically active in the rumen and postruminally.

Acidifiers

Organic acids usually are added only as preservatives, but they do positively influence performance when included at higher quantities. Liquid acidifiers are-

1. Formic acid 6-8 kg/ton and
2. Propionic acid 8-10 kg per ton.

Organic acids in powder form are 1. Fumaric acid 12-15 kg/ton and 2.Citric acid 20-25 kg/ton.

The optimal dose depends on the age of the pig and the environment in which it is being grown as well as on the acid-binding capacity of the dietary ingredients.

Acidifying the feed always reduces the number of piglets with diarrhoea after weaning. Certain feed plants installed corrosion resistant stainless steel pumps, pipes and nozzles to allow formic acid to be used more readily as a preservative and acidifier. At pH 6.6-6.8 in the small intestine, the formic acid becomes totally dissociated so that only the formate anion is active. This anion exerts a positive influence on the microflora of the digestive tract which improves the utilization of feed nutrients.

Antioxidants- The use of antioxidants limits this oxidative spoilage. Antioxidants prevent fat oxidation and so help avoid rancidity. The addition of antioxidants mops up the free radicals. Primary antioxidants are capable of interrupting and terminating the free radical propagation step. Secondary antioxidants are chemicals that can prevent free radical formation. Primary antioxidants are natural and synthetic. Natural ones are vitamin E (alpha tocopherol), rosemary extract, carotenoids, flavenoids, sulfides and thiocyanates.

In biological systems the alpha-tocopherol is most active.

The most common synthetic antioxidants are ethoxyquin, tertbutyl hydroxyquinone (TBHQ), propyl gallate, butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT). BHT and BHA tend to be more effective in preventing oxidation of animal fats than of vegetable oils while ethoxyquin is most effective in protecting both animal fats and vegetable oils.

Sequestrants: Certain metals such as copper and iron are active catalysts of oxidation (pro-oxidants) and therefore need to be immobilised. Sequestrants are the compounds added to do this. Sequestrants or sequestering compounds are also referred to as metal scavengers since they combine with trace metals such as iron and copper and remove them from solution. So these compounds should have affinity to the metal ions e.g. calcium salt of EDTA, polyphosphates and citric acid.

Anticaking agents: In the preparation of mash type feeds, problem of cake or lump formation is observed. This can be considerably minimised by using certain anticaking agents. Anticaking agents not only retard caking due to humidity but also cause the mash feeds to flow much easier. These are anhydrous substances that can pick up moisture without themselves becoming wet. They are added to dry mixes to prevent the particles clumping together and so keep the product free flowing. They are either anhydrous salts or substances that hold water by surface adhesion yet themselves remain free flowing. e.g. salts of long chain fatty acids (calcium stearate).Cal. phosphate, ferrous ammonium citrate, yellow prussiate of soda, potassium and sodium ferrocyanide, magnesium oxide, kaolin, attapulgite clay, ball clay, sodium aluminium silicate, hydrated sodium calcium aluminosilicate (HSCAS), calcium aluminium silicate. HSCAS is used at 0.5% level.

Mycotoxin binders:

Mycotoxins are diverse group of chemicals that are harmful to animals and humans and have the greatest impact on human animal health. The three major mycotoxin producing fungi are Aspergillus, Fusarium and Penicillium and the toxins are aflatoxins, zearalenone, trichothecenes, fumonisins, ochratoxin A, etc.

Mycotoxins are stable compounds and, are not easily removed from finished feeds. Basic hygiene and good management of grain and other feeds, use of mould inhibitors are the initial steps often used as a preventive measure. But once mycotoxins are suspected in the feed addition of mycotoxin binder is the only solution. Mycotoxin binding agents include activated charcoal, yeast cell wall products, synthetic zeolites and mined mineral clays such as aluminosilicates, sodium bentonite. Effectiveness of these compounds depend upon the adsorptive capacity, their molecular structure, their purity and the characteristics of the targeted mycotoxin. Mineral clays bind to mycotoxins through electrical charges (e.g. aflatoxins) and thereby prevent their absorption in the intestine. All mycotoxins do not have electrical charges. Thus mineral clays only bind a narrow spectrum of toxins and offer little or no protection against toxins such as zearalenone or trichotecenes.

Commercial preparations: UTPP-5 (Ultimate Toxin prevention programme), Vetcare, India-contains organic acids and treated Aluminosilicates

Humectants: These are the substances which are required to keep the product moist, as for example, bread and cakes.

Anticaking agents immobilise moisture that was picked up.

Firming and crisping agents: These are substances that preserve the texture of vegetable tissues and by maintaining the water pressure inside them, keep them turgid. They prevent loss of water from the tissues.

Preservatives: The aim of preservatives is to prevent microbial spoilage. e.g. nisin, benzoic acid, methyl-4-hydroxybenzoate, ethyl-4- hydroxybenzoate, propyl-4-hydroxybenzoate, sodium nitrate, sodium nitrite, propionic acid, sorbic acid and sulphur dioxide.

Antifungal agents: sodium propionate, sodium benzoate, nystatin (antifungal antibiotic).

Deodourising Agents Odour of litter in poultry and other species is more than a nuisance to Odours/breeders. Urea/uric acid is present in urine and stools of all farmals. Urease enzyme hydrolyzes the urea to ammonia. The level of ammonia should be less than 25 ppm in farmhouses. Yucca shidigera extract blocks the action of urease enzyme. Lower doses are sufficient for ruminants while high doses are required for swine. Ammonia concentration in the shed was decreased when yucca shidigera was added to the diet while growth rate was increased. Feeding oligasaccharides to pigs reduce objectionable smells. Tea based polyphenol is applied as a feed additive. It stops bacteria producing ammonia and other malodorous compounds.

Flavouring Agents Flavours are used to improve palatability and thus food appeal. Palatability and feed conversion ratio are interdependent. Types of are spices and sweeteners. Taste and odour are important properties of a food or feed by which they are recognized and enjoyed. The four basic taste qualities are salt, sour, sweet and bitter. Commercial flavouring agents only try to influence sweetness. Flavouring compounds are nonvolatile water soluble substances which have little or no taste of their own, but modify or potentiate the flavour of a product. e.g. esters, alcohols, terpenes, etc.

e.g. monosodium glutamate (MSG) at 0.2%.Flavours can be used in conjunction with antioxidants in high fat dairy feeds to mask the rancid taste. Meat flavours, cheese flavours, mint, onion and garlic flavours are used in feeds for pets at less than 0.1%.Yeast products are also used at 0.25% in combination with MSG for the improvement of dry dog food. Capsicum, red pepper, MSG, fennel, fenugreek seed, ginger are examples of spice and seasoning.

Food colours: They make the food more attractive and pleasing. e.g. acid fuchsine, amaranth, brilliant blue. brilliant black, eosin, indigo carmine, sudan red, azolutin, erythrosine, B-carotene, canxanthin, bixin (obtained from annatto seed), crocation (saffron), beetroot red, chlorophyll, anthocyanins.

Pigments- Colour of an egg yolk or egg shell may due carotenoids or porphyrink Pale yolk is no deficiente vitamin A (vitamin A is colourless). 5 major carotenoids: lutein (xanthophyll), cryptoxanthin, zeaxalth has laxanthin and neoxanthin. These produce yellow pigmentation of the skin and fat of chickens also. Under normal feeding practices, 70% of the yellow colour of egg yolk is due to xanthophyll, and most of the remainder is due to zeaxanthin. Bixin produces red yolks while canthaxanthin produces orange-coloured yolks.

Pellet Binders Calcium lignosulphonate, sodium lignosulphonate are byproducts from wood pulp manufacture. These are widely used as pellet binders in animal feeds. Lignin is the most widely used feed binder in the world today advantages being improved pellet quality, more control over the additions of fat and moisture, greater pelleting efficiency, improved press capacity and die life, lower power consumption, lower production costs, less fines returns and feed rejections and less dust in the mill. Sodium bentonite at 2.5% is used.b Sepiolite is an effective pellet binder in swine diets especially when diets contained 4% added fat. The others are molasses 5-10%, calcium aluminates 0.6-1%, and guar meal 2.5-5%.

Buffers: Feeding high grain (low fibre) diets to meet the energy requirements of high yielding (over 35 kg milk/day) cows to minimize the energy crisis during early lactation leads to changes in rumen pH and rumen fermentation pattern. Buffers are used to correct these changes. e.g sodium bicarbonate 200 g/cow/day or 1.5% of grain ration, sodium sesquicarbonate, magnesium oxide, calcium carbonate, sodium bentonite. Salt level of the ration may be reduced to half normal.

Methane inhibitors: Methane production could be inhibited by fatty acids and related compounds and related compounds, particularly unasaturated fatty acids. Other methane inhibitors and chloroform, carbon tetrachloride, chloral hydrate, bromochloromethane (BCM), sulphites and nitrites, amichloral (very Potent) and halogenated methane analogues. Rumen microbes require 22 days for adaptation for the latter.

Roughage substitutes: In Western countries and other places where high concentrate diets are used for ruminants in huge mechanized feedlots the possibility of using roughage substitutes is examined. Polyethylene cubes sold as Rufftabs produced beneficial responses sponses in gain and feed conversion in beef cattle fed high concentrate rations.

Propionate production promoters: Ionophores affect principally gram positive bacteria, Ruminococcus albus, R. flavefaciens. e.g. monensin, lasalocid.

Defaunating agents: Examples are copper sulphate, sodium lauryl diethoxy sulphate, sodium lauryl sulphate, oil rich in PUFAs and dioctyl sodium sulphosuccinate.

Ketosis controlling agents: Examples are sodium propionate, propylene glycol.

Bloat controlling compounds: Examples are poloxalene (Bloat guard), a non-ionic surfactant 10-20 g/day.

Microbial growth factors (for ruminants): These include niacin, thiamin, branched chain fatty acids (isobutyric acid, 2-methyl butyric acid and isovaleric acid) and straight chain fatty acid (n-valeric acid).

Surfactants: These act like antibiotics or arsenicals by selective inhibitory effects on intestinal microorganisms. Surface-active agents possess the property of stimulating the growth of chicks. e.g. alkyl benzene sulfonate, lauryl ethelene oxide condensate, ethmiod C-15.

Tween 80 (Poly oxyethylene sorbitan monoolate) is a surfactant and appears to have some effect on protozoa, gram negative bacteria and non cellulocytic bacteria. Tween 80 was added along with enzyme as a surfactant, to facilitate the action of enzyme.

Non-ionic surfactant (NIS) is well known as an effective surfactant that stimulates the release of enzymes from a range of aerobic microbes. When NIS was included at a concentration of 0.5g in the 1L of anaerobic growth medium, this material increased the growth rate of rumen bacteria and fungi, and the rate of cereal grain and rice straw digestion, and polysaccharide-degrading enzyme activities.

Biopreservative- Nisin is a natural antimicrobial peptide produced by strains of Lactococcus lactis subsp., lactis that effectively inhibits Gram-positive and Gram- negative bacteria and also the outgrowth of spores of Bacilli and Clostridia. Nisin has been used as a biopreservative and a potential agent in pharmaceutical, veterinary and health care products.

Sweetening agents: Molasses, dextrin, sugars are added to improve palatability.

Tranquilizers: Bring about weight gains in farm animals by controlling stress. Energy otherwise spent in restlessness and irritability is conserved for body gain.Examples for Sheep:Hydroxyzine hydrochloride1-2 mgs/day, Triflomephazine and Reserpine5-10 micrograms/day.

Emulsifiers: A substance which aids in the formation of a stable mixture of two otherwise immisible substances (e.g. fat and water) is called an emulsifier. It should have one group with an affinity for water and another with an affinity for fat. e.g. lecithin, glycerides esterified with acetic acid, lactic acid, citric acid, glyceryl monostearate, propylene glycol monostearate.

Stabilizer: Any substance that helps to maintain an emulsion when it has been formed is called a stabilizer. e.g. alginic acid or its sodium/calcium salt, tragacanth, acacia, karaya gum, etc.

Bile acid: Mixed bile acid for shrimp feed and broiler chicken feed are available and are claimed as natural growth promoter. This increases fat utilisation, improves absorption of fat soluble vitamins, growth rates and feed efficiency.

Natural growth promoters: These include acidifiers, probiotics, prebiotics, synbiotics, feed enzymes, phytogenics, and immune stimulants.

Nutricines - Nutricines are components of food which are considered for their beneficial effect upon health rather than their direct contribution to nutrition. Nutricines provide the crucial link between health and nutrition. Nutricines play important roles in delaying the onset of diseases, controlling microbial spoilage of food, improving the digestion of food and helping the absorption of nutrients from the gastrointestinal tract. Examples include antioxidants, nondigestible carbohydrates (NDC) natural acids, enzymes, lecithins.

Nutraceuticals- A nutraceutical can be defined as a food or part of a food that provides medical or health benefits, including the prevention and/or treatment of a disease. Nutraceuticals may range from isolated nutrients (antioxidants, minerals, amino acids, fatty acids and vitamins), herbal products, dietary supplements and special diets to genetically engineered 'designer' foods and processed products such as cereals, soups and beverages.

Essential Oils (EO) Essential oils are a secondary metabolite present in spices, tree leaves and bulbs of some plants. Essential oils are described as follows: volatile aromatic compounds with an oily appearance extracted from plant materials typically by steam distillation; alcohol, ester or aldehyde derivatives of phenylproponoids and terpenoids. EO compounds available include thymol (thyme and oregano), eugenol (clove), pinene (Juniper), limonene (dill), cinnamaldehyde (cinnamon), capsaicin (hot peppers), terpinene (tea tree), allicin (garlic), anethol (anise), peppermint oil, eucalyptus oil. They have antimicrobial activity and have been shown to modify rumen microbial fermentation.

Feed Additive Sweeteners: A number of lab and field trials with sweeteners have demonstrated increased feed intake in young animals, especially pigs. In many cases, sweeteners also improved feed conversion.
Natural Sugars: Natural sugars such as sucrose, dextrose, fructose and lactose are the first feed sweeteners. Sucrose (cane or beet sugar) is included up to 2% in certain young animal diets as a highly palatable energy source. However, the 2% dose of sucrose proved far from adequate to sweeten a finished feed and this led to the search for cheaper alternatives.

Alternatives to sucrose: Modern alternatives to sucrose include blends of 'high intensity' sweeteners (HISs). High intensity sweeteners are of two types:
1. High intensity sweeteners that have short term effects e.g. aspartame, cyclamate, saccharin, moneline, alitame.
2. High intensity sweeteners that have long lasting effects or potentiators e.g. thaumatine, neohesperidin dihydrochalcone (NHDC).

Sweetner	**sweetner power where sucrose equal 1**
Cyclamate-	30
Saccharine	180
Moneline	1500-2000
Alitame	2000
Thaumatine	1000-2000
Neohesperidine dihydrochalcone	1500-1800

Plantants: Aromas, Flavours, Sweetners and/ or their Combination to improve the palatability of feeds.

Amino acids and Amino acid anologues: Methionine is the most limiting amino acid in lactating cows. Structural manipulation of amino acids is one of the potential methods for rumen bypass of amino acids by making them resistant to rumen degradation. An ideal analogue would have to survive rumen degradation, absorb from the small intestine and must have biological potency at the cellular level for metabolism. Many analogues of methionine have been tried effectively in ruminant diets by encapsulation, (rumen bypass methionine) e.g. methionine hydroxy analogue Ca (MHA), N-Hydroxymethyl-L-methionine Ca (HMM-Ca), L-Stearyl-L-methionine, a-hydroxy-Ţ-methyl mercapto butyrate Ca-(HMB-Ca).

HMB-Ca is not completely protected from rumen degradation. The most consistent response of these amino acids is to increase milk fat percentage or milk yield or both. Rumen-stable methionine is used in lactation feeds. 25 to 35 grams daily or 0.2 to 0.25% of the grain mixture is used during early lactation per day for high producing cows.

Carnitine: Lysine and methionine are carnitine precursors. L-carnitine significantly increased the cholesterol in egg yolks and had some positive effects on hatchability (3 to 4%) when fed to broiler breeders. The U.S. FDA stated that L-carnitine can be added to swine diets at levels not exceeding 0.1% and finfish feed at 0.25%. e.g. Lonza-L-carnitine.

ß-carotene: It is precursor of vitamin A with an activity of 400 IU of vitamin A per milligram. It has been reported that beta carotene has been linked to bovine fertility.

Niacin: It helps the animals to do better and visibly better. It prevents ketosis in dairy cows. Dose is 12 gms/day. Feeding niacin daily in early stages of ketosis decreases fat mobilization and increases blood glucose levels, usually correcting ketotic condition within a week.

Meat and Bone Meal (MBM) –
Protein- min 45% Fat, min 4%
Moisture- Max 8%
Sand and Silica- max 1%
Mesh size-6 mm

Dicalcium phosphate-

Moisture -	Max- 7%
Ca-	Min – 23%
P	Min- 18%
AIA-	Max- 1%
Fluorine	Max- 0.1%

Mineral Mix – 1 kg/ 100 kg of concentrate mixture
28 gm per animal per day for adult cattle and buffaloes.
5 to 15 gm daily for calves, sheep and goats.

Chromium supplements- improve glucose metabolism in swine.
Available Chromium picolinate, chromium nicotinate
Effect- increased muscle and decreased lipid depositon when fed to pigs of 20 to 105 kg B.W at 200ppb.
Increased greater efficiency of insulin action