Introduction

Modern intensive livestock and poultry production has achieved phenomenal gains in the efficient and economical production of high quality and safe animal products and by-products. Furthermore, the overall performance of livestock can be increased by improving nutrients utilization, health status, fertility and efficiency of production. The use of feed additives has been an important part of achieving efficient livestock production. Feed additives are non-nutritive substances, preparations and micro-organisms that are added to animal feed to improve productive, reproductive and health performances. Any substance is considered as a feed additive when, not having a direct utilization as nutrient, is included at an optimum concentration in diet to exert a positive action over the animal health status or the dietary nutrient utilization. Hutjens (1991) defined feed additives as a group of substances that can cause a desired animal response in a non-nutrient role, such as pH shift, growth, or metabolic modifier. Feed additives are added deliberately to animal feed which may favourably influences characteristics of the animal feed, feed intake, gastro-intestinal flora, digestibility of the animal feeds, animal production, health, fertility and characteristics of animal products. Because of their chemical nature as active principles, additives are generally included in very small proportions in diet.

Global economic pressures have driven a tendency of the livestock production to produce more products per unit cost. This has led to changes to animal’s environment like feeding, housing and disease control. Quality of feed nutrition
is influenced not only by the content but also by some other aspects such as, feed presentation, hygiene, anti-nutritional factors, digestibility and palatability. Feed additives provide a mechanism by which such dietary deficiencies can be addressed and also benefits not only associated with the nutrition and thus the growth rate of the animal concerned, but also its health and welfare. Antimicrobial growth promoters are commonly fed to animals to prevent disease and metabolic disorders, as well as improve feed efficiency. However, in recent years, public concern about the potential for antibiotic resistant strains of bacteria, the search for alternatives to replace antibiotics growth promoters has gained increasing interest in animal nutrition. The use of phytogenic feed additives has gained momentum for their potential role as natural alternatives to antibiotic growth promoters in animal nutrition. Compared with synthetic antibiotics or inorganic chemicals, these plant-derived products have proven to be natural, less toxic, residue free, and are thought to be ideal feed additives in food animal production. There are a large number of phytogenic feed additives which have antioxidiant, antibacterial, anticoccidial, antiparasitic and anti-inflammatory effect.

Additives like microbial and plant secondary metabolites offer a unique opportunity manipulating ruminal fermentation. Recent research has been greatly focused to exploit bioactive plant secondary compounds like saponins, tannins, flavonoids, essential oils to improve rumen fermentation such as enhancing protein metabolism, decreasing methane production, reducing nutritional stress like bloat, and improving animal health and productivity. Thus, feed additives can be used to improve feed intake, metabolism and efficiency of feed utilization for economic and eco-friendly livestock production.

**Types of feed additive**

Common feed additives used in livestock and poultry diets include antimicrobials, antioxidants, enzymes, probiotics, prebiotics, organic acids, coccidiostats, mycotoxin binders, immunomodulators, hormones, emulsifiers, pellet binders, phytogenic herbs, essential oils and metabolic modifiers. Sometimes diets of livestock also contain additives used in diets for humans and pets such as flavour enhancers, artificial and nutritive sweeteners, colours, lubricants etc. Enzymes, antimicrobials, probiotics, prebiotics can have a very positive effect on feed intake and nutrient utilization in livestock and poultry. Enzymes increase the digestion capacity in young animal and to help to decrease the risk of digestive problems and therefore increase the health status, nutrient availability and growth performances. In older animals enzymes can be used successfully to increase the use of unconventional feedstuffs rich in dietary fibres or other nutrients with a low digestibility and to reduce environmental
load with nutrients. Antibiotic growth promoters at sub-therapeutic concentrations in the diets of poultry and swine inhibit some microflora of intestinal pathogens, increasing useful intestinal microflora. Metabolic modifiers influence intermediate metabolism (Wenk, 2000). However, mechanism of action varies but positive effect of feed additives are usually expressed through better feed intake, improved feed conversion, stimulation of the immune system and increased vitality, regulation of the intestinal micro-flora, etc. Because of the fact that feed additives have different mechanisms of action, it is necessary to present every group of additive individually as follows.

**Feed enzymes**

Enzymes are naturally occurring proteins that function as catalysts for the vast number of chemical reactions taking place in the living being. Although animals and their associated gut microflora produce numerous enzymes, they are not necessarily able to produce sufficient quantities of specific enzymes or produce them at the right locations to facilitate absorption of all components in normal feedstuffs or to reduce anti-nutritional factors in feed that limit digestion. In today’s ever increasing economic climate, commercial poultry companies are trying to help alleviate adsorbent cost even more so then ever before. The main focus on addressing the feed cost issues has been examining the benefits of adding exogenous enzymes to poultry rations. Some cereal grains (rye, barley, wheat, sorghum) have soluble non-starch polysaccharides (NSP) that can entrap large amounts of water during digestion and form very viscous gut contents. Enzymes that are harvested from microbial fermentation and added to feeds can break these bonds between sugar units of NSP and significantly reduce the gut content viscosity. Lower viscosity results in improved digestion, absorption and health (reducing moisture in manure and nutrients available for harmful gut microflora to proliferate and challenge the birds. NSP degrading enzymes have been used successfully to circumvent problems with high intestinal viscosity in broiler chicken (Bedford *et al*., 2000). Phytates are plant storage sources of phosphorus that also bind other minerals, amino acids (proteins) and energy and reduce their availability to the bird (Singh *et al*., 2003). Birds do not produce enzymes like cellulase, xylanase, phytase etc., required for the digestion of NSPs and phytates. Supplementation of NSPs degrading enzymes and phytase not only reduce the anti nutritive effects of NSPs and phytates, but also releases some nutrients from these, which could be utilized by the birds. Addition of enzymes such as xylanase are useful in the utilization of the non-starch polysaccharide (NSP) component of the ingredients, while others such as proteases may enhance the utilization of protein (Zakaria *et al*., 2010). Phytase enzymes are also available commercially that significantly reduce the negative effects of phytates. An increased use of feed enzymes is expected not only
from the aspect of economic gain but also from the environmental point of view as enzymes enhances nutrient utilization, thereby reducing the manure output and reducing nutrient excretion particularly excess phosphorus, nitrogen, copper and zinc.

In ruminant production system, forages are the main feed component that serve as the major source of energy available to the animal. However, due to slow or incomplete digestion of fibrous substrates only 10 to 35% of energy intake is available as net energy that significantly limits livestock performance and profits in production systems. To improve the ruminal fibre degradability many strategies have been developed to stimulate the digestion of the fibrous components in ruminant feeds. The use of supplemental exogenous enzymes to improve fibre digestibility and feed utilization was first examined for ruminants in 1960s (Beauchemin, 2004). Feeding of enzymes in ruminants was a questionable practice in past decades due to poor characterization of enzyme products, variable animal response and high cost. But now a day, with recent advancement in fermentation technology and biotechnology, economic production of large quantities of biologically active enzymes preparations as animal feed additives has become possible. Supplementation of exogenous fibrolytic enzymes (cellulose and xylanase) to ruminants has the potential to increase the digestibility of fibre and efficiency of feed utilization (Thakur et al., 2010).

**Antioxidants**

The animal body is under constant attack from free radicals. There are a variety of sources of reactive free radicals in normal metabolism as well as those coming directly from feed ingredients. There are many lipid or fat components of feeds, which spontaneously react with atmospheric oxygen and suffer deterioration in the process of auto-oxidation. The oxidation in feed ingredients such as fats and oils decreases their nutritional value, reduces shelf life of feed ingredients and results in generation of undesirable flavours. The widespread use of fats and oils in formulation of high density diets for broiler chicken have increased incidence of auto-oxidation in poultry which ultimately reduces performances and feed utilization efficiency in poultry. Oxidative stress can disrupt normal cellular function, damage tissues and reduce health status. Antioxidants are the chemical compounds, which have the capacity of preventing the oxidation by preferentially taking up oxygen and thus prolonging the lag period of oxidation (Adams, 1997). Ethoxyquin, BHA (butylated hydroxyanisole) and BHT (butylated hydroxytoluene) are commonly used antioxidants in poultry ration. It has been reported that feeding oxidized fat and oils resulted in reduced performances and these harmful effects can be counteracted by supplementation of antioxidants (Surai, 2002).
Antibiotic feed additive

To achieve high level of economic efficiency poultry and pigs are raised under intensive production system in densely populated colonies or flocks during which they are succumbed to various kinds of stresses and diseases which adversely affect their productive performances. To prevent disease outbreaks and promote growth, low, sub-therapeutic concentrations of antibiotics are often added to the diets of poultry and swine. Antimicrobials have been used extensively in intensive poultry operations to minimise disease and improve growth and feed utilisation. Antibiotic inhibit some microflora of intestinal pathogens, increasing useful intestinal microflora, wide activity against positive gram bacteria, decreasing harmful effect of metabolites of intestinal microflora through removing them, decreasing thickness of intestinal mucosa layer to increase food absorption (Niewold, 2007).

However, human health can be affected directly through residues of an antibiotic in meat, or indirectly, through the selection of antibiotic resistance determinants that may spread to a human pathogen. In view of antibiotic resistance the European Union has moved towards a complete ban of in-feed antimicrobials. The ban on the use of antibiotics as a feed additive in animal nutrition has led to a worldwide search and implementation of alternative strategies for preventing the growth of pathogenic bacteria in farm animals, to maintain the health and performance of poultry. The industry is currently evaluating alternatives to chemical therapeutics. However, this goal can be achieved by adopting biosecurity measures as well as by the use of feed additives like probiotics, prebiotics, enzymes, antioxidants, acidifiers and phytojenic additives. These products show promise as alternatives for antibiotics as pressure to eliminate growth promotant antibiotic use increases (Yang et al., 2009). They all in majority of cases demonstrated positive effect on health and performance of poultry.

Probiotics

One of the most well characterized means to reduce enteric disease is through the administration of live bacteria, or probiotics. Probiotics are individual microorganisms or groups of microorganisms which have favourable effect on host by improving the characteristics of intestinal micro-flora (Fuller, 1989). The term probiotic originates from Greek words meaning for life and contrasted with the term antibiotic, which means against life. Probiotics display several ways of action: antagonistic action towards pathogen bacteria by secretion of products which inhibit their development, such as bacteriocins, organic acids and hydrogen peroxide; the other way is competitive exclusion which represents competition for locations to adhere to the intestinal mucous membranes and in
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this way pathogen micro-organisms are prevented from inhabiting the digestive tract, and the third way is competition for nutritious substances (Patterson and Brukholder, 2003). In this way, they create conditions in intestines which favour useful and inhibit the development of pathogen bacteria. Probiotics not only inhibit or block the ability of pathogens to attach to epithelial surfaces, but also limit pathogen colonization through competition for nutrients and production of antibacterial substances such as bacteriocins (Edens et al., 1997). Probiotic supplementation of the intestinal micro flora enhances defense, primarily by preventing colonization by pathogens and offering a greater stability of the intestinal ecosystem, and by an indirect, adjuvant-like stimulation of innate and acquired immune functions of intestine (Fuller 1989). Besides the health benefits of probiotics, it improves growth rate and feed conversion efficiency in calves (Ramaswami et al., 2005), microbial protein flow and DM intake (Putnam et al., 1997) particularly in poor managemental conditions. The dietary use of probiotic is gaining momentum to counteract the stresses because of their beneficial effects on live weight gain, feed conversion efficiency and reduced mortality in broilers and egg production and feed conversion in layers.

Prebiotics

Prebiotics are non-digestible feed components/ingredients which have positive effect on host in their selective growth and/or activation of certain number of bacterial strains present in intestines (Gibson and Roberfroid, 1995). The most significant compounds which belong to group of prebiotics are oligosaccharides: fructo-oligosaccharides (FOS), gluco-oligosaccharides and mannan-oligosaccharides (MOS). Their advantage compared to probiotics is that they promote growth of useful bacteria which are already present in the host organism and are adapted to all conditions of the environment (Yang et al., 2008). Favourable effects of addition of probiotics reflect in presence of antagonism towards pathogens, competition with pathogens, promotion of enzyme reaction, reduction of ammonia and phenol products and increase of resistance to colonization. Prebiotics have shown promise in the prevention and control of exogenous and endogenous intestinal infections and good health of the animals (Grizard and Barthomeuf, 1999).

Synbiotics

Synbiotics are combination primarily of probiotics and prebiotics, as well as other promoting substances which together exhibit joint effect in regard to health of digestive tract, digestibility and performances of broilers. Synbiotic may improve the survival rate of probiotics during their passage through the digestive tract, thus contributing to the stabilization and/or potentiation of the
probiotic effects. Marioka et al. (2000) found significant improvement in weight gain due to dietary supplementation of synbiotic (MOS and Bacillus subtilis) compared to either probiotic (Bacillus subtilis) or prebiotic (MOS) alone. Investigations showed that combinations used in synbiotics are often more efficient in relation to individual additives (Li et al., 2008).

**Organic acids**

Organic acids have a long history of being utilized as food additives and preservatives for preventing food deterioration and extending the shelf life of perishable food ingredients. In recent past organic acids have been used to control microbial contamination and replace antibiotic growth promoters in poultry (Hassan et al., 2010). Organic acids that have shown positive effects on growth performance in poultry include citric, formic, fumaric, and propionic acids. Acidifiers have been used in poultry nutrition for long time, in different forms and combinations. Organic acids reduce pH value of food and in this way act as conserving agents and prevent microbial contamination of feed, and this effect is exhibited also in digestive tract of poultry (Luckstadt, 2005). Organic acids are widely used to inhibit pathogens like salmonellae and in their undissociated forms are able to pass through their cell membrane. Inside the bacterial cell, the acid dissociates to produce H+ ions, which lower the pH causing the organism to use its energy in trying to restore the normal balance. It also disrupts DNA and protein synthesis and thus the bacteria are unable to replicate or its replication slows down. Lower pH conditions thus protect the bird from infection especially at young ages. An experiment with broiler chickens also indicated that benzoic acid at concentrations of 0.2% may have a positive influence on growth (Engberg, 2001). Organic acids (mixture of fumaric acid and salt of butyric, propionic and lactic acids) supplementation @ 520ppm improved egg production, egg size, shell thickness and feed conversion efficiency (Rahman et al., 2008).

**Hormones and beta-agonists**

In growing farm animals metabolic modifiers are used to have a better partition of the energy deposition for growth in the form of protein and fat. Hormones and beta-agonists have high potential for increased protein deposition and simultaneously a reduced fat deposition (Buttary and Dawson, 1987). Hormones as additives are being added in poultry ration to help the animals gain more weight faster and fulfill consumer needs and desires. They help to reduce the waiting time and the amount of feed eaten by an animal before slaughter in meat industries. In dairy cows, hormones can be used to improve milk let down and production. The hormones approved for use in beef production are estradiol
(estrogen), progesterone, testosterone, and their synthetic alternatives zeranol, melengestrol acetate, and trenbolone acetate. Melengestrol acetate, a synthetic progestin, is used as feed additive that suppresses estrus (heat or cyclic sexual activity) and improves gain and feed efficiency in beef females. While hormonal implants have been utilized for decades in cattle production, recent advancements in dietary beta-agonist supplements have offered swine and cattle producers the opportunity to further improve their production efficiency. Beta-agonist can be exploited as nutrient repartitioning agent as it diverts the nutrients from fat deposition to the muscle tissues deposition (Sillence, 2004). Ractopamine and Zilpaterol are approved â-agonists to be incorporated in cattle and hog rations to improve body weight gain and reduce the body fat content (Carr et al., 2009). Recently, some developed countries banned the use of hormone implants due to their residual effect on humans.

**Phytogenic feed additives**

Since ancient times aromatic plants or phytobiotics have been used because of their medicinal properties. Current studies show promising results regarding the use of phytochemicals as growth and production promoters (Toghyani et al., 2010). Garlic (*Allium sativum*), Turmeric (*Curcuma longa*), Thyme (*Thymus vulgaris* L.), Aloe vera (*Aloe barbadensis*), onion (*Allium sepa*), Ginger (*Zingiber officinale, Rosc.*), Astragalus membranaceus, neem etc., are some of the major plant additives which have been extensively reported in poultry feed for enhanced growth effect in broiler and better egg production in laying hens (Guo et al., 2004; Sunder et al., 2014). The positive effects of these herbs are due to the presence of essential oils, fatty acids, alkaloids, flavanoids, fats, minerals fibers, vitamins, protein and carbohydrates. Apart from the digestive and antioxidant prosperities, the herbs and plant additives may exert the beneficial influence through antioxidant, antimicrobial, immunomodulating, antiparasitic and anti-inflammatory effect (Gowda et al., 2009; Khan et al., 2012). Plants like Ashwagandha (*Withania somnifera*), Neem (*Azadirachta indica*), Guduchi (*Tinospora cordofolia*) and others are widely used these days due to their potent immunomodulatory and health beneficial properties (Barnes et al., 2007; Tiwari et al., 2014).

**Metabolic modifiers in ruminants**

Ruminants are provided with a microbial ecosystem (ciliate protozoa, anaerobic bacteria and anaerobic fungi) in the gastro-intestinal tract which helps in the bioconversion of lignocellulosic feeds into volatile fatty acids which are utilized by the animal as a source of energy. This mixture of organisms combines to digest the food, and it is the products of microbial digestion which form the
nutrients that become available to the ruminant animal itself. This microbial biomass is also helpful in synthesis of microbial protein and B-complex vitamins for the host animals. Complex polysaccharides are converted to volatile fatty acids (acetic, butyric, and propionic acid) which provides 70% of the energy available to the rumen. Besides beneficial microbial fermentation process, there is few fermentation process which decreases efficiency of production in ruminant. Proteolysis destroys high quality protein in the feed and therefore proteolysis should be slowed. Protozoal activity is detrimental to the efficiency of microbial protein synthesis; therefore, this activity should be suppressed. Bloat and acidosis are distressing disorders which result from malfunction of microbial digestion in the rumen. Methane, a potent greenhouse gas, and ammonia, which form urinary urea, arise from normal rumen fermentation. They cause atmospheric and groundwater pollution, respectively. Since methane contains energy, its emission during rumen fermentation is considered to be a loss of feed energy that is equivalent to 2-12% of the gross energy of animal feed (Johnson and Johnson, 1995). Therefore, scientists are trying to manipulate ruminal fermentation to enhance ruminal fermentation and animal productivity. The rumen is such a delicately balanced eco-system that rumen modifiers rarely have one single effect on rumen fermentation. A number of strategies have been used to enhance ruminal fermentation.

Feed additives are used for manipulating ruminal fermentation to enhance ruminal fermentation and animal productivity. Rumen modifiers which manipulate the digestion and increase the retention of protein and energy without depressing feed intake should enhance productivity of ruminants. Direct-fed microbials offer arguably the greatest potential for manipulation of ruminal fermentation. They offer a huge spectrum of metabolic activities and enzymes as well as metabolites. Its cell envelope is quite different to that of ruminal microorganisms, which may be important in the delivery of nutrients or the absorption of toxic or undesirable compounds. It is metabolically active in the rumen but does not grow, which means that its concentration and activity can be readily controlled by its dietary inclusion level, ensuring maximum efficacy. Any compounds which can shift the fermentation from acetic acid production to propionic acid will trap more useful energy for the animal. Monensin, lasalocid salinomycin are polyether ionospheres which reduce methane production, alter volatile acid production and improved nitrogen metabolism patterns. Ionophores enhance the glucose status of dairy cows through increased production of propionate and thus improves milk production, and control ketosis and of bloat (McGuflfey, 2001). The process of making the rumen of animals free of rumen protozoa is called defaunation and the animal is called defaunated animal. Feed additives can be used to defaunate ruminants. Defaunation can
be an important tool to improve the productivity of animals in tropical countries, where majority of livestock are maintained on sole diet on low grade roughage. Plants are part of herbivore diets, therefore, recent research has been greatly focused to exploit bioactive plant secondary compounds saponins, tannins, flavonoids, essential oils to improve rumen fermentation such as enhancing protein metabolism, decreasing methane production, reducing nutritional stress like bloat, and improving animal health and productivity (Wallace et al., 2002; Patra and Saxena, 2010).

Evaluating feed additives

New feed additives are rapidly adopted by the livestock and poultry industry. There are some factors which should be used to evaluate a feed additive. These factors are 7 R’s (anticipated response, economic return, available research, field responses, reliability, repeatability, and relativity) (Hutjens, 1991). Response refers to expected performance changes. The performances changes may be in terms of improved feed intake, growth rate, milk yield, milk quality, health and fertility and ultimately better economic return. Research is essential to determine if experimentally measured responses can be expected in the field. Studies should be conducted under controlled and unbiased conditions, have statistically analyzed results (to determine whether the differences are repeatable), and have been conducted under experimental designs that would be similar to field situations. Reliability is based on the research database that has been published on a feed additive. Reliability refers to other products, management changes, or on-farm practices that could replace the feed additive being used. The bottom line of evaluating criteria of a feed additive is the probability of a profitable response. Repeatability represents the statistical data results (mean and standard deviation). Each feed consultant must determine the level of risk when selecting a feed additive (Hutjens, 1991).

The future of feed additive

Although additives have been developed over the years for most species of livestock, the major uses today are with growing and finishing beef cattle, swine and poultry. Feed additives are gaining importance due to various functions such as growth promotion, controlling infectious diseases and enhancement of feed digestibility in animals. The animal feed additives market is growing at a steady pace and the market is to grow in the future due to the increasing demand for meat and meat products around the globe. Many additives have been a normal part of diets for animals. It is only recently that we have come to recognize and understand their importance in achieving high production and efficiency, maintaining health and wellbeing, improving product quality.
and safety and reducing the industry’s impact on the environment. More work is required to further identify the positive effects of additives and minimise the negative effects they may have if not used correctly or if they interact with other additives or feed ingredients.

References

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