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Nutraceuticals and its application in livestock

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Abstract
Livestock production plays a pivotal role in meeting the growing global demand for animal-based protein and other valuable products. To enhance production efficiency, optimize animal health, and address sustainability concerns, researchers and livestock producers have turned to nutraceuticals—bioactive compounds derived from natural sources with potential health benefits. Nutraceuticals (such as probiotics, prebiotics, enzymes, and herbs/spices) is backed by scientific and empirical research on these alternatives as herbs and their extracts (botanicals) have been found to have a wide range of activity which cannot only stimulate feed intake but also stimulate endogenous secretions or have antimicrobial, coccidiostat, or anthelmintic activity. Ban of antibiotic use as growth promoters, cost-effectiveness, and increased awareness about harmful residual effect cause herbal feed additive to gain importance in sustainable livestock production. Medicinal properties of the herbs to improve antimicrobial, anti-inflammatory, antioxidant, digestibility, and immune-stimulant activity must be explored in the feeding of animals. Nutraceuticals is a broad umbrella term used to describe any product derived from food sources that provides extra health benefits in addition to the basic nutritional value found in foods. Standardization of correct dosage regime of nutraceuticals for a particular function is the demand of situation so more research should be conducted in this direction. Additionally, compliance with regulatory guidelines and considerations of cost-effectiveness are essential. The application of nutraceuticals in livestock production represents a promising avenue for meeting the demands of a growing global population while addressing sustainability and animal welfare concerns. Continued research and innovation in this field hold the potential to revolutionize the way we approach and enhance livestock production for a more sustainable and productive future.

Keywords: Nutraceuticals, livestock production, probiotics, prebiotics

Introduction
The livestock sector is a pillar of the global food system and a contributor to poverty reduction, food security and agricultural development. According to the FAO, livestock contributes 40% of the global value of agricultural output and supports the livelihoods and food and nutrition security of almost 1.3 billion people. Nevertheless, there is a lot that can be done to make the practices in the livestock sector more egalitarian, sustainable, and low-risk to both animal and human health. The livestock sector is one of the fastest-growing agricultural sub-sectors in middle- and low-income nations because to rising incomes, changing diets, and population growth. The primary objective of livestock production is to produce safe food for the human population while taking into account environmental issues and animal welfare. Many factors like breed improvement, modern housing management, balanced feed, veterinary care etc. have been given special attention to enable the massive growth of the livestock sector, but major credit goes to the lakhs of livestock farmers who have demonstrated commitment and perseverance despite many obstacles. Nutraceuticals are a promising solution for farms looking to maximize the productivity of their livestock.

What are Nutraceuticals?
The term 'nutraceutical' was coined from 'nutrition' and 'pharmaceutical' in 1989 by Dr Stephen DeFelice, founder and chairman of foundation for innovation in medicine (FIM), an American organization that encourages medical health, Cranford, New Jersey and was originally defined as "a food (or part of the food)" that provides medical or health benefits, including the prevention and/or treatment of a disease (Kalra EK, 2003) [1].
Due to growing recognition of the potential advantages of dietary supplements used to supplement pharmacological therapy, the field of nutraceutical is a young one that is developing quickly.

Food that has been prepared or cooked with "scientific intelligence" is referred to as "functional food." As a result, functional food gives the body the proper balance of vitamins, lipids, proteins, carbs, and other nutrients for a healthy existence. Nutraceuticals are functional foods that assist in the prevention and/or treatment of disease(s) and/or disorder(s). Fortified dairy products (like milk) and citrus fruits (like orange juice) are examples of nutraceuticals. There are many nutraceuticals available, including probiotics, prebiotics, antioxidants, and herbal extracts.

Classification of Nutraceuticals

The food sources used as nutraceuticals are all natural and can be categorized as

1. Dietary Fiber
2. Probiotics
3. Prebiotics
4. Polyunsaturated fatty acids
5. Antioxidant vitamin
6. Polyphenols
7. Spices (Kalia AN, 2005) [2]
8. Minerals

Dietary fiber: Dietary fiber, or DF, consists of non-digestible carbohydrates and lignins found in plants. Functional fiber, or FF, includes isolated non-digestible carbohydrates with positive effects on human health. Total fiber is the sum of both types. This broader definition allows for the inclusion of resistant starches, oligosaccharides, and other non-digestible carbs as functional fibers (Birt *et al.*, 2013) [3].

Probiotics: Probiotics are beneficial live bacteria and yeasts, particularly for digestive health. The term ‘probiotics’ was first coined by the Metchnikoff in 1908 (Mackowiak, 2013) [4]. Despite the common association of bacteria with illness, our bodies contain both good and bad bacteria. Probiotics are often referred to as "helpful" bacteria because they contribute to gut health. While they naturally occur in the body, they can also be found in certain foods and supplements. The interest in probiotics and their health benefits has grown since the mid-1990s, with doctors often recommending them for digestive issues. They have become popular additives in various products, from yoghurt to chocolate. Lactobacillus is a common probiotic found in yoghurt and fermented foods, with different strains offering benefits such as aiding in diarrhea relief and assisting those who struggle to digest lactose. Bifidobacterium, also present in some dairy products, may alleviate symptoms of conditions like irritable bowel syndrome (IBS). Probiotics are known to promote gut health, and while researchers are still determining their efficacy for specific health issues, they are commonly used for conditions such as IBS, inflammatory bowel disease (IBD), infectious diarrhoea, and antibiotic-related diarrhea. Additionally, some studies suggest probiotics may have positive effects on skin conditions like eczema and urinary/vaginal health.

Prebiotics: Prebiotics are substances that support the growth or activity of beneficial microorganisms, like bacteria and fungi, in the body. They are often associated with the gastrointestinal tract but can have applications elsewhere. In the context of diet, prebiotics are non-digestible fibers that reach the large intestine, where they encourage the growth of beneficial gut bacteria. As functional food components, prebiotics are considered intermediate between regular foods and medications, subject to certain regulatory scrutiny, especially regarding health claims. To be classified as a prebiotic, a substance must meet specific criteria, including resistance to digestion, fermentation by intestinal microflora, and selective promotion of beneficial intestinal bacteria associated with health (Gibson *et al*., 1995) [5].

While the scientific evidence for the health benefits of prebiotics is somewhat limited compared to dietary fiber, they are believed to offer several advantages. These include reducing the occurrence and duration of infectious and antibiotic-related diarrhea, alleviating inflammation, and symptoms of inflammatory bowel disease, potentially preventing colon cancer, enhancing mineral bioavailability (e.g., calcium, magnesium, and iron), lowering certain risk factors for heart disease, and aiding in weight management and obesity prevention.

Polyunsaturated fatty acids (PUFAs): Polyunsaturated fatty acids (PUFAs) are divided into two groups: omega-3 (n-3) and omega-6 (n-6) PUFAs, distinguished by the position of their first double carbon bond. Two PUFAs, linoleic acid (LA) from the n-6 family and α-linolenic acid (LNA) from the n-3 family, are essential (Balić *et al.*, 2020) [6].

Antioxidants: Antioxidants are essential for protecting cells from the damaging effects of free radicals, which are highly reactive molecules that can harm healthy cells and contribute to aging and disease. Oxygen, a reactive atom, can form these free radicals (Lobo *et al.*, 2010) [7].

Nutrient-derived antioxidants, such as vitamin C, vitamin E (tocopherols and tocotrienols), carotenoids, and other compounds like glutathione and lipoic acid.

Antioxidant enzymes like glutathione reductase, which catalyze reactions to neutralize free radicals.

Metal binding proteins like ferritin, lactoferrin, albumin, and ceruloplasmin that help control iron and copper ions, which can catalyze oxidative reactions.

Numerous antioxidant phytonutrients found in a wide range of plant-based foods.

Endogenous antioxidants like bilirubin, thiols (e.g., glutathione, lipoic acid), NADPH and various enzymes.

Dietary antioxidants include vitamin C, vitamin E, carotenoids (including beta carotene), and polyphenols like flavonoids, pro-anthocyanidins.

These antioxidants work together to combat free radicals, supporting overall cellular and systemic health and well-being.

Polyphenols: Polyphenols can be categorized based on the number of phenol rings and structural elements that link these rings together. Phenolic acids make up about one-third of the dietary polyphenolic compounds and can be further divided into two main classes: hydroxybenzoic acid derivatives (such as protocatechuic acid, gallic acid, and p-hydroxybenzoic acid) and hydroxycinnamic acid derivatives (including caffeic acid, chlorogenic acid, coumaric acid, ferulic acid, and sinapic acid). Polyphenols are natural phytochemical compounds found in various plant-based foods. Foods rich in these phenolic acids include berry fruits, kiwi, cherry, apple, pear, chicory, and coffee. There are over 8000 known polyphenolic compounds, which include phenolic acids, flavonoids, stilbenes, lignans, and polymeric lignans. These compounds are produced by plants as a defense mechanism against factors like ultraviolet radiation, oxidants, and pathogens.

Flavonoids, another class of polyphenols, have six subclasses, including anthocyanins, flavonols, flavanols, flavanones, flavones, and isoflavones. Anthocyanins like cyanidin, pelargonidin, delphinidin, and malvidin are found in various foods such as berries, red wine, red cabbage, cherry, black grapes, and strawberries. These polyphenolic compounds contribute to the diverse health benefits associated with a diet rich in plant-based foods (Pandey *et al.*, 2009) [8].

Spices: Spices are plant-based substances, used whole, broken, or ground. Spices give foods their distinctive taste, scent, and sometimes spiciness. Aromatic spices contain volatile oils responsible for their fragrance, flavor, and pungency. In addition to culinary use, spices have diverse applications in indigenous medicine, pharmaceuticals, nutraceuticals, aroma therapy, food preservation, beverages, natural coloring, perfumes, dental care products, cosmetics, and even as botanical pesticides. These versatile properties are attributed to the various chemical compounds found in spices. There is a growing demand for spices in the emerging field of nutraceuticals, contributing to increased global consumption, particularly in countries like India. Non-traditional uses, including nutraceuticals, now make up around 15 percent of spice production in India, highlighting their expanding role in the economy and various industries (D'Souza *et al.*, 2017) [9].

Minerals: Minerals play a crucial role in livestock production and reproduction. They are essential nutrients required in various physiological processes, and their adequate supplementation is vital for optimizing animal health, growth, and reproductive performance. Key applications of minerals as nutraceuticals in livestock production and reproduction.

1. **Calcium (Ca) and Phosphorus (P)**: Calcium and phosphorus are essential for bone development and maintenance, muscle function, and overall animal health. Adequate calcium and phosphorus intake is crucial for strong skeletal structure in growing animals and for preventing disorders like hypocalcaemia (milk fever) in dairy cows (Kimura *et al*., 2018) [10].
2. **Iron (Fe)**: Iron is essential for the formation of haemoglobin and red blood cells, which are critical for transporting oxygen to tissues. Iron supplementation is essential for preventing anaemia, especially in young animals (Van Wyk *et al.*, 2002) [11].
3. **Copper (Cu) and Zinc (Zn)**: Copper and zinc are important for various enzymatic reactions involved in metabolism, growth, and reproduction. Adequate copper and zinc supplementation can improve reproductive efficiency and sperm quality in males and support estrous cycle regulation in females (Ojha *et al*., 2018) [12].
4. **Selenium (Se)**: Selenium an essential of the antioxidant enzyme glutathione peroxidase. Adequate selenium levels are critical for reducing oxidative stress, improving immune function, and preventing reproductive disorders (Surai, P. F., & Fisinin, V. I., 2014) [13].
5. **Iodine (I)**: Iodine is essential for thyroid hormones, which regulate metabolism. Adequate iodine intake is crucial for preventing goiter and maintaining normal growth and reproduction (Engle-Stone, R., & Ndjebayi, A. O., 2019) [14].
6. **Magnesium (Mg)**: Magnesium plays a role in muscle function, nerve transmission, and bone health. Adequate magnesium supplementation can help prevent grass tetany in cattle and improve overall animal health (Odette O, 2005) [15].
7. **Manganese (Mn)**: Manganese is involved in bone formation, enzyme activation, and reproduction. Adequate manganese levels can improve fertility and reproductive performance in livestock. (Spears, J. W., & Kegley, E. B., 2002) [16].
8. **Chromium (Cr)**: Chromium is involved in glucose metabolism and can enhance insulin sensitivity in livestock. Chromium supplementation may increase feed efficiency & growth in cattle and swine. (Kegley, E. B., & Spears, J. W., 1998) [17].

Application of nutraceuticals

Nutraceuticals as feed additives in livestock is supported by scientific research and practical benefits for animal health, growth, and production. Increasing demand for animal products and ongoing challenges in ban of antibiotics and growth promoters that concerns over the development of antibiotic resistant microbes, increase in food borne allergies and negative impacts on the environments made researchers to look and investigating alternatives ways to improve the quality, quantity and homogeneity of farm animals and their products (Al-Shawi *et al*., 2020) [18].

Some key reasons for the -need for nutraceuticals in livestock feed-

1. **Nutrient Optimization**: Nutraceuticals can optimize the nutritional content of animal diets, ensuring that livestock receive essential bioactive compounds vitamins and minerals (Osman *et al.*, 2021) [19].
2. **Immune System Support**: Nutraceuticals, such as probiotics, prebiotics, and immune-boosting compounds, enhance the immune system of livestock, reducing the risk of infections and diseases (Panda *et al*., 2009) [20].
3. **Gut Health Improvement**: Nutraceuticals like probiotics and prebiotics promote a healthy gut microbiota, leading to better digestion, nutrient absorption, and reduced digestive disorders (Xu *et al.*, 2003) [21].
4. **Reduction of Antibiotic Use**: Nutraceuticals offer alternatives to antibiotics in livestock production, addressing concerns about antibiotic resistance (Ghosh *et al.*, 2015) [22].
5. **Stress Management**: Certain nutraceuticals, including adaptogens and anti-stress compounds, help animals cope with stressors such as transportation, handling, and environmental changes (Kumar *et al*., 2015) [23].
6. **Reproductive Performance Enhancement**: Nutraceuticals can improve reproductive efficiency in breeding animals, leading to increased conception rates and healthier offspring (Rehman *et al.*, 2019) [24].
7. **Environmental Sustainability**: Nutraceuticals that enhance feed efficiency and reduce nutrient waste contribute to more sustainable livestock production practices (Kim *et al*., 2021) [25].
8. **Consumer Expectations**: As consumer demand for safe, high-quality, and environmentally responsible animal products grows, aligns with market expectations (Van Eenennaam *et al*., 2019) [26].

Role of Nano Particles Nutraceuticals

The upcoming and promising technology of nanotechnology has the power to completely transform the worldwide livestock and agricultural industries. Nanotechnology was developed to reduce particle size to a few nanometers. The

physical and chemical properties of the molecules or element change as a result of the creation of nanoparticles using reducing agents. These nanoparticles can carry different components in a variety of environmental settings. Nowadays, nanoparticles are widely used in a variety of fields, including nutrition, therapy, targeted medication delivery, vaccine development, and numerous purifying procedures in the textile industry, among others. These nanoparticles were previously created through a chemical process, which releases pollutants into the environment. The creation of nanoparticles from plant materials, often known as "green synthesis," is becoming more and more significant recently. Due to the fact that this technique uses plant extracts, which contain proteins, carbohydrates, polyphenols, and terpenoids. Because their excretory products are highly biodegradable and work as a reducing agent to keep the minerals in a reduced form during the synthesis process, these phytochemicals have no negative environmental effects. The principal application of nanotechnology in animal nutrition is the creation of nano-minerals, particularly trace minerals with limited bioavailability. Minerals in nanoparticle form also lessen intestinal mineral antagonism, which lowers excretion and lessens environmental contamination. According to studies, feeding livestock and poultry nanoparticles enhanced their performance by strengthening their immune systems and digestive system (Michalak *et al*., 2022) [27].

Conclusion and Future Directions

Nutraceuticals are a promising tool for improving animal health, sustainability, and productivity in livestock production. Due to their host-protecting properties (antioxidant, anti-inflammatory, antibacterial, and cell survival effects), nutraceuticals offer a useful tool in feed additives to improve reproductive and productive capabilities. Most of the work is done in poultry sectors and aquaculture. There has been less literature and experiments on the livestock nutraceuticals applications in increasing the production potential of farm animals. Research must be done in livestock regarding the usage of nutraceutical applications their dosages and antinutritional factors and their regulations in livestock by keeping in mind their toxic levels. Comprehensive economic assessments of nutraceutical use in livestock should be conducted to evaluate their cost-effectiveness and return on investment for producers.

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