



Bio Vet Innovator Magazine

(Fueling The Future of Science...)

Volume 3 (Issue 9) SEPTEMBER 2026



World Rabies Day - 28th September 2026

Popular Article

Nutraceuticals: Current Status and Future Prospects

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DOI: <https://doi.org/10.5281/zenodo.23013221>

Received: September 26, 2026

Published: September 28, 2026

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Abstract:

Nutraceuticals are compounds derived from food, such as dietary fibre, probiotics, prebiotics, polyunsaturated fatty acids, vitamins, minerals, polyphenols, carotenoids, and peptides, that can influence physiological pathways in addition to their nutritional properties. For animal health, a nutraceutical's practical value depends on more than the presence of a bioactive molecule. Species, dose, route of administration, diet composition, product quality, and the animal's health status can influence the observed response. The same considerations apply to human products, where a promising laboratory result may not translate directly into a measurable clinical benefit. Accordingly, nutraceutical development requires a combination of nutritional science, pharmacological understanding, food technology and safety assessment. Increasing interest in agricultural by-products also creates an opportunity to recover useful compounds from materials that are currently discarded, provided that contaminants and anti-nutritional factors are adequately controlled. These requirements are particularly important when nutraceuticals are proposed for long-term use, because safety, efficacy and product consistency must be demonstrated over the intended period of administration.

Keywords: Functional foods, Phytochemicals, Probiotics, prebiotics, Bioactive compounds, Animal health.

Introduction:

Food has traditionally been viewed primarily as a source of calories, amino acids, fatty acids, vitamins, minerals and other nutrients required for growth, maintenance and reproduction. Research in nutrition has progressively shown that many foods also contain constituents capable of interacting with physiological processes. This observation helped establish the modern interest in functional foods and nutraceuticals, although the terminology is not used in the same way in every regulatory system (Kalra, 2003; Aronson, 2017).

The word nutraceutical was formed from “nutrition” and “pharmaceutical”, and Stephen L. DeFelice is generally credited with introducing the term in 1989. Early discussions of the field included a broad range of food-derived substances, from isolated nutrients and dietary supplements to herbal products and specially formulated foods (Andlauer and Fürst, 2002; Kalra, 2003). Because there is no universally harmonized definition, the distinction between a nutraceutical, a functional food and a dietary supplement may depend on the scientific, commercial or regulatory context in which the term is used (Aronson, 2017). The growing scientific interest in nutraceuticals is linked with changing dietary habits and the increasing burden of chronic, lifestyle-associated disorders. Research has therefore examined dietary fibre, probiotics, prebiotics, polyunsaturated fatty acids, antioxidants, polyphenols and other naturally occurring compounds for their possible contribution to normal physiological function (Das *et al.*, 2012).

Merely the presence of biological activity in a product can't prevent or treat disease; it also depends on the formulation, dose, target population and study design (Aronson, 2017). In relevance to veterinary science, it also has relevance, as, nutrition influences growth, reproduction, immunity, gastrointestinal integrity and productive performance in animals. In veterinary nutraceutical research, different species of animals, such as cattle, sheep and goat, poultry, pigs, horses, companion animals and other animal species are considered (Gupta *et al.*, 2019). This field has emphasized the interactions among diet, host tissues and the intestinal microbiome.

Classification of Nutraceuticals:

Nutraceuticals are classified according to origin, chemical composition or principal biological function.

Based On the Source:

- **Plant-derived Nutraceuticals** include polyphenols, flavonoids, carotenoids, phytosterols, essential oils and other phytochemicals. Fruits, vegetables, cereals, pulses, spices and medicinal plants can contribute different kinds of plant-derived nutraceuticals.
- **Animal-derived Materials** can supply omega-3 fatty acids, proteins, peptides and selected minerals.
- **Microorganisms** are the major sources of probiotics and other microbial products (Das *et al.*, 2012; Gupta *et al.*, 2019).

Based on Chemical Nature:

Vitamins, minerals, fatty acids, amino acids, carbohydrates, polyphenols, terpenoids and alkaloids fall under this category.

Major Sources of Nutraceuticals:

Plants provide a particularly diverse reservoir of bioactive molecules. Coloured fruits and vegetables can contribute carotenoids and polyphenols, while spices and herbs contain a wide variety of

phenolic, terpenoid and volatile compounds. Cereals and pulses can provide dietary fibre and other constituents with functional properties.

The amount and composition of a bioactive compound may vary with plant variety, growing conditions, maturity, storage and processing (Das *et al.*, 2012). Marine and other animal foods are important sources of long-chain omega-3 fatty acids, especially eicosapentaenoic acid and docosahexaenoic acid. Milk and other animal-derived foods may also contain proteins and peptides that have attracted interest for their biological properties.

In veterinary applications, the source, purity, formulation and species-specific response are important when such ingredients are incorporated into diets or supplements (Gupta *et al.*, 2019). Microbial sources have become increasingly important because the intestinal microbiota interacts closely with diet.

Role And Mechanism of Action:

- **Antioxidant Activity:** Certain polyphenols, carotenoids and vitamins can participate in the control of oxidative processes. Oxidative stress occurs when the production of reactive species exceeds the ability of biological systems to control them. Nutraceutical compounds may help maintain redox balance through different mechanisms.
- **Anti-inflammatory Activity:** Several plant-derived compounds are being studied for their effects on inflammatory signalling pathways. This is important because chronic low-grade inflammation is associated with several metabolic and degenerative conditions.
- **Modulation of Gut Microbiota:** Probiotics, prebiotics and some polyphenols can influence the intestinal microbial ecosystem. Beneficial microbial metabolites, including short-chain fatty acids, can contribute to intestinal and systemic physiological functions (Roberfroid, 2007; Sanders *et al.*, 2019).
- **Immunomodulation:** Some nutrients and bioactive compounds can influence immune-cell function and inflammatory responses. This is particularly important in animals because adequate nutrition is closely related to resistance to disease and recovery.
- **Metabolic Effects:** Omega-3 fatty acids, dietary fibre, phytosterols and several other compounds have been studied for their effects on lipid and glucose metabolism.

Importance In Veterinary Medicine and Animal Health:

Veterinary nutraceuticals are increasingly considered as supportive tools within broader nutrition and health-management programmes. The veterinary literature encompasses probiotics, prebiotics, symbiotics, enzymes, herbal products, fatty acids and other ingredients for different species and conditions (Gupta *et al.*, 2019). Gastrointestinal health is one of the most prominent areas of interest.

Maintaining a stable intestinal microbial community is relevant to digestion and intestinal function, particularly during dietary transitions, early life or other periods of physiological stress. Probiotic and

prebiotic approaches are therefore investigated for their ability to support the gastrointestinal environment (Gupta *et al.*, 2019; Sanders *et al.*, 2019). Nutritional support of immune function is another important area.

Vitamins, minerals, fatty acids and selected plant-derived compounds may contribute to normal immune processes when supplied at appropriate levels. However, a nutraceutical should not be regarded as a substitute for balanced feeding, vaccination, diagnosis or indicated veterinary treatment. Joint and musculoskeletal support has also received attention, particularly in companion animals and horses.

Omega-3 fatty acids and other ingredients have been incorporated into formulations intended to complement dietary management of joint-related problems. The suitability of an ingredient depends on the species, physiological status, formulation and evidence available for the intended use (Gupta *et al.*, 2019). In livestock and poultry, nutraceutical research includes phytogenic compounds, probiotics, prebiotics, enzymes and other feed additives.

Applications in the Food Industry:

Nutraceuticals as functional components are nowadays incorporated into dairy products, bakery products, beverages, snacks and other commercial food products. Heat, oxygen, light, moisture and interactions with other food constituents can reduce the stability of some bioactive molecules. Poor water solubility or limited gastrointestinal stability may also restrict the amount of an ingredient that becomes available after consumption.

Nutraceuticals from Agriculture and Food-Processing By-products:

Agricultural and food-processing residues are increasingly viewed as potential sources of useful molecules rather than simply as waste. Fruit peels, seeds, pomace, leaves, cereal residues and other processing fractions may contain dietary fibre, phenolic compounds, pigments, tannins and other bioactive constituents. Recovering these materials can create an additional stream of raw material while reducing the volume of discarded biomass. The concept fits within a circular-economy approach: material generated at one stage of the food chain can become an input for another process. From a nutraceutical perspective, this may lower raw-material costs and create opportunities for value addition. From an environmental perspective, recovery and reuse can reduce the pressure associated with disposal of organic residues.

For veterinary nutrition, selected by-products may eventually be developed into functional feed ingredients, but their use requires careful characterization. Nutrient composition, digestibility, anti-nutritional factors, pesticide residues, heavy metals, mycotoxins and microbial contamination must be considered before a residue is incorporated into an animal feed or nutraceutical product. Extraction technology is therefore an important part of by-product valorisation.

Benefits of Using Waste By-products as Nutraceutical Sources:

- **Reduction of food waste:** Valuable materials are recovered rather than discarded.

- **Additional source of bioactive compounds:** Polyphenols, fibres, pigments and other compounds can be recovered.
- **Economic value addition:** Agricultural residues can become raw materials for new products.
- **Environmental benefits:** Reduced waste accumulation may decrease environmental pressure.
- **Circular economy:** Nutrients and bioactive substances are kept within the production system.
- **New opportunities for agriculture:** Farmers and food-processing industries may obtain additional value from residues.

Current Challenges: Safety, Quality and Regulation

- **Bioavailability:** A compound may show biological activity in laboratory experiments but have limited absorption or rapid metabolism in the body.
- **Standardization:** Plant extracts may vary according to species, geographical origin, soil, climate, harvesting stage and processing. Therefore, two products with similar labels may not necessarily have identical concentrations of active compounds.
- **Safety:** Natural does not automatically mean safe. Botanical products may contain substances that cause adverse effects or interact with medicines. EFSA, for example, highlights concerns related to contamination, safety and variability in botanical preparations.
- **Regulatory differences:** The regulatory status of nutraceutical products differs between countries. In India, nutraceuticals are covered under the Food Safety and Standards Authority of India framework, including the Food Safety and Standards (Health Supplements, Nutraceuticals, Food for Special Dietary Use, Food for Special Medical Purpose, Functional Food and Novel Food) Regulations, 2016.

Future Prospects:

Integration of nutrition with microbiology, biotechnology, food technology and veterinary science can improve the status of this field. High-throughput methods can simplify the identification of active constituents and characterization of the alterations during processing, digestion and metabolism. Technologies such as encapsulation may improve the stability, dispersibility and controlled release of bioactive compounds.

Tailored nutritional interventions in veterinary medicine could involve adapting nutritional strategies specific to species, breed, age, physiological state and disease conditions.

Conclusion:

Nutraceuticals have undoubtedly proven themselves as a multidisciplinary area integrating food science, nutrition, health research, biotechnology and veterinary medicine. In veterinary medicine, the use of nutraceuticals should remain species-specific and evidence-based, and they shouldn't replace balanced feeding, prevention, diagnosis and proper treatment. They can be potentially used as gastrointestinal

support, immune nutrition, joint health and selected production-related objectives. Appropriate research with scientific validation and responsible product development can effectively determine the contribution of nutraceuticals to human and animal health.

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