Journal of Advanced Pharmaceutical Sciences and Natural Products

Journal of Advanced Pharmaceutical Sciences and Natural Products (JAPSNP)

NUTRACEUTICALS: A COMPREHENSIVE REVIEW OF CATEGORIES, HEALTH BENEFITS, AND THERAPEUTIC APPLICATIONS

Gulafsha Chaudhary
Department of Pharmacology , School of pharmacy and educational research(SPER), Jamia hamdard University, Jamia Hamdard, Hamdard University, Dr.Ambedkar Nagar, Block D, Hamdard Nagar, New Delhi, Delhi 110062

Khushi Sharma
Department of Pharmaceutics, KIET school of pharmacy, KIET group of institutions, Ghaziabad-201206, Uttar pradesh, India

Monika Saini
Department of Pharmacology, KIET school of pharmacy, KIET group of institutions, Ghaziabad-201206, Uttar pradesh, India

Anam
Department of Pharmaceutics, KIET school of pharmacy, KIET group of institutions, Ghaziabad-201206, Uttar pradesh, India

Corresponding author:
Gulafsha Chaudhary
Email:
gulafshapharma2003@gmail.com

ABSTRACT

Nutraceuticals represent a rapidly growing category of food-derived products combining nutritional and pharmaceutical benefits, serving as alternatives to conventional medicine. This comprehensive review integrates information on nutraceutical definitions, categorization, therapeutic applications across cardiovascular disease, cancer, diabetes, obesity, and neurological disorders, along with marketed products, formulation strategies, and quality control measures. Novel nanoformulation approaches enable overcoming bioavailability challenges. Evidence supports nutraceutical efficacy in disease prevention and as adjunctive therapy. Adulteration remains a critical safety concern requiring advanced analytical detection methods. Patent landscape data demonstrates exponential market growth. Future development requires standardized quality protocols, comprehensive clinical validation, and regulatory harmonization.

Keywords: Nutraceuticals, dietary supplements, formulation challenges, quality control, therapeutic applications

1. INTRODUCTION

Journal of Advanced Pharmaceutical Sciences and Natural Products

The term "nutraceutical," combining "nutrition" and "pharmaceutics," was established by Stephen DeFelice, founder of the Foundation for Medical Innovation.[1] Nutraceuticals are defined as food components or supplements providing health benefits beyond basic nutrition, including disease prevention and treatment.[2,8,9] This encompasses dietary supplements, isolated nutrients, herbal remedies, and functional foods.[1,2]

Globally, consumer interest in nutraceuticals has increased significantly driven by healthcare cost concerns, pharmaceutical efficacy limitations, preventive medicine philosophy, nutritional deficiencies in processed foods, and chronic disease management needs.[3,4] The FDA has not approved most nutraceutical health claims, distinguishing their regulatory status from conventional pharmaceuticals.[2] Market expansion reflects increasing scientific validation of bioactive compounds and evolving consumer preferences toward natural health promotion strategies.[10,11]

2. DEFINITIONS AND CATEGORIZATION

Nutraceuticals encompass four major categories:[1,2] **Nutrients and micronutrients** include vitamins, minerals, amino acids, and essential fatty acids demonstrating therapeutic efficacy at supraphysiological dosages.[2] **Herbal and botanical products** derive from medicinal plants with historical use validated by modern phytochemical analysis, including polyphenols, terpenoids, alkaloids, glycosides, and saponins.[2,12] **Dietary supplements** comprise isolated nutrients, botanical extracts, amino acids, probiotics, and combinations formulated for oral administration to support normal physiological function.[1,2] **Functional foods** represent ordinary products modified through addition of bioactive compounds or nutritional enhancement to deliver therapeutic benefits.[2]

3. THERAPEUTIC APPLICATIONS

3.1 Cardiovascular Diseases

Cardiovascular diseases account for approximately 30% of global mortality annually.[12] Nutraceuticals demonstrate efficacy in managing arrhythmias, congestive heart failure, angina, hypertension, and hyperlipidemias.[12,13]

Flavonoids present in onions, grapes, apples, berries, and cruciferous vegetables inhibit ACE, reduce platelet aggregation, strengthen capillaries, and prevent estrogen-dependent malignancies through cyclooxygenase inhibition.[12,14] **Dietary fiber** from defatted rice bran reduces cholesterol and prevents cardiovascular disease through favorable lipid modifications.[12] **Polyunsaturated fatty acids (PUFAs)** including omega-3 fatty acids reduce triglycerides, improve lipid profiles, prevent thrombotic events, and modulate inflammatory mediators.[15,16]

Gamma linolenic acid (GLA) present in milk and eggs manages cardiovascular disease through lipid metabolism and vascular function effects.[12]

Journal of Advanced Pharmaceutical Sciences and Natural Products

3.2 Cancer Prevention and Supportive Therapy

Chronic inflammation associated with cancer risk generates free radicals and aldehydes causing harmful genetic mutations.[12]

Carotenoids, particularly **lycopene** from tomatoes, function as potent antioxidants and singlet oxygen quenchers, preventing skin, testicular, prostate, and adrenal cancers.[12],[18],[19] **Citrus flavonoids** provide antioxidant cancer defense through multiple mechanisms.[12] **Isoflavones** from soyfoods suppress prostate cancer growth through estrogen receptor signaling.[20] **Lutein-rich foods** including spinach, eggs, and leafy greens reduce colon cancer risk.[12] **Saponins** from peas, soybeans, and herbs halt cancer cell proliferation through antitumor and antimutagenic properties.[12] **Ellagic acid** from strawberries, raspberries, and pomegranates demonstrates anti-carcinogenic activity.[12] **Tannins (proanthocyanidins)** from cranberries, blueberries, and grapes function as free radical scavengers and carcinogen detoxification agents.[12] **Modified citrus pectin (MCP)** prevents prostate cancer metastasis through inhibition of cancer cell adhesion.[12] **Thiosulfonates** from garlic and onions exhibit anti-cancer, anti-platelet, and antibacterial properties.[12]

Curcumin from turmeric possesses anti-inflammatory and anticarcinogenic properties through multiple cell growth inhibition mechanisms.[12],[21]

3.3 Allergies and Immune Dysfunction

Quercetin (QR), a flavonol abundantly present in onion rinds, functions as a natural antihistamine, reduces leukotriene production, inhibits inflammatory enzymes, and prevents LDL cholesterol oxidation.[12] QR demonstrates immunomodulatory, antiviral, gastroprotective, and anticancer properties.[12] **Echinacea species** enhance immune cell development and function against viral and bacterial pathogens.[22] **Astragalus** promotes stem cell differentiation into functional immune cells, enhancing innate and adaptive immunity.[12] **Phytoestrogens** including soy isoflavones provide immune modulation for hormonally influenced disease prevention.[12] **Garlic** demonstrates dose-dependent immune stimulation and suppression effects.[23]

3.4 Obesity and Weight Management

Obesity represents a global health crisis linked to multiple comorbidities.[12] Calorie restriction and increased physical activity show modest efficacy, prompting investigation of nutraceutical interventions.[12] **Buckwheat** lowers cholesterol, reduces blood pressure, and improves obesity through dietary fiber-like mechanisms promoting satiety.[12] **Green tea extract** reduces appetite through thermogenic effects and enhanced fat oxidation.[12] **5-Hydroxytryptophan** increases energy expenditure and promotes satiety through central serotonergic pathways.[12]

Journal of Advanced Pharmaceutical Sciences and Natural Products

3.5 Diabetes Mellitus

Type 2 diabetes, accounting for 95% of cases, associates with obesity and insulin resistance.[12] **Docosahexaenoic acid (DHA)** controls insulin resistance and supports neurovisual development critical for gestational diabetes management.[12] **Lipoic acid** represents a versatile antioxidant employed in Germany for diabetic neuropathy treatment.[12] **Omega-3 fatty acids** enhance insulin secretion, reduce hepatic glucose production, and improve tissue insulin sensitivity in diabetes-predisposed individuals.[15],[24] **Psyllium-derived dietary fibers** improve blood glucose control and reduce cholesterol.[12]

3.6 Immune System Enhancement

Multiple nutraceuticals play critical roles in immune function and disease susceptibility.[22] **Echinacea species** enhance immune cell development through strengthened innate immunity.[12] **Astragalus** promotes lymphatic stem cell differentiation into functional immune cells.[12] **Soy isoflavones** represent prospective replacements for synthetic selective estrogen receptor modulators in hormone replacement therapy.[12]

3.7 Osteoarthritis

Osteoarthritis involves progressive articular cartilage destruction and proteoglycan loss.[12] **Glucosamine (GLN) and chondroitin sulphate (CS)** slow cartilage degradation and reduce joint inflammation and pain.[25] **Methyl sulfonyl methane (MSM)** combined with glucosamine and chondroitin enhances anti-inflammatory and analgesic effects.[12]

3.8 Vision and Age-Related Macular Degeneration

Healthy lifestyles incorporating **n-3 fatty acids, lutein, and zeaxanthin** demonstrate protective effects against age-related macular degeneration (AMD).[12] **Astaxanthin**, a potent marine carotenoid, performs immune enhancement, pigmentation support, and oxidative/ultraviolet radiation protection in aquatic species, with similar benefits for ocular protection.[12] **Lutein (Helenian)** from dark leafy greens and yellow/orange vegetables provides essential treatment for visual impairments and macular degeneration protection.[12]

3.9 Alzheimer's Disease

Alzheimer's disease, the most prevalent dementia form, demonstrates no cure despite progressive memory loss and neurodegeneration.[12] **Nutritional supplements** including β-carotene, **curcumin**, lutein, lycopene, and turmeric may reduce oxidative stress and mitochondrial dysfunction effects.[12],[26]

3.10 Parkinson's Disease

Parkinson's disease represents progressive motor neuron degeneration causing muscle rigidity, tremor, and gait disturbance.[12] Preliminary research supports **vitamin E** for neuroprotection,

Journal of Advanced Pharmaceutical Sciences and Natural Products

glutathione depletion prevention, and **creatine** for mitochondrial energy metabolism.[12],[27]

3.11 Inflammatory Disorders

Ginger, soybean unsaponifiable, glucosamine, chondroitin, and S-adenosylmethionine demonstrate effects on inflammatory arthritides.[12] **Cat's claw (Uncaria species)** provides potent anti-inflammatory effects through phytochemical-mediated inflammatory mediator reduction.[12] **Omega-3 and omega-6 polyunsaturated fatty acids** generate powerful inflammatory response modulators including eicosanoids and cytokines.[12] **Gamma linolenic acid (GLA)** represents an important nutraceutical for treating autoimmune and inflammatory diseases.[12]

4. MARKETED NUTRACEUTICAL PRODUCTS

The global marketplace contains diverse nutraceutical formulations targeting specific therapeutic categories and consumer populations.[1] The following table 1 presents marketed products demonstrating the extensiveness of commercial availability and manufacturing capabilities:

5. FORMULATION CHALLENGES AND NANOENCAPSULATION

Nutraceutical formulation requires understanding complex ingredient interactions with excipients, manufacturing processes, and environmental factors.[5] Many ingredients exhibit poor flow properties, heterogeneous particle size distribution, and variable bulk density.[5] Advanced **nanoencapsulation** technologies protect active ingredients throughout manufacturing, storage, and gastrointestinal transit.[2],[28]

Lipid-based carriers improve solubility and bioavailability of phenolic compounds through nanocapsules and micronized systems.[29] β-Carotene nanocapsules (>300 nm) demonstrate physical stability during storage.[29] **Phosphatidylcholine-rutin complexes** serve as potential nanocarriers for food applications.[29]

Excipient selection requires accounting for complex natural ingredient properties through careful formulation modification.[5] Functionality varies context-dependently, necessitating empirical formulation development.[5]

Food incorporation challenges include adequate dosage delivery while maintaining organoleptic acceptability, preventing nutraceutical-matrix interactions, limiting degradation during food processing, maintaining shelf-life

Journal of Advanced Pharmaceutical Sciences and Natural Products

stability, and ensuring bioavailability.[5] Direct unprotected nutraceutical incorporation frequently causes bioactivity loss and product quality deterioration; well-designed delivery systems specifically engineered for food applications are necessary.[5,30]

6. QUALITY CONTROL AND SAFETY ASSESSMENT

Nutraceutical safety is paramount given widespread self-medication and consumer safety assumptions.[5,6] **Contamination, adulteration (inadvertent or intentional), and misleading labeling** represent frequently encountered quality concerns.[5]

Three primary **adulteration detection procedures** include: demonstrating foreign substance presence, proving component quantity falls outside typical range, and demonstrating profile deviation from natural occurrence.[5] Foreign substance detection remains the most reliable method.[5]

Inadvertent adulteration may result from fertilizer contamination, heavy metals, microbiological agents, synthetic medications, dust, pollens, insects, rodents, parasites, bacteria, fungi, mold, and poisons during plant growth, formulation, manufacture, or storage.

Intentional adulteration involves unregistered synthetic substances for economic reward through altered pharmaceutical response.[5,6] **Essential oil adulteration** examples include lavender oil dilution with cheaper Lavandula species, citrus oil contamination with sweet orange oil, Melissa oil adulteration with citronella oil, lemongrass oil dilution with coconut oil, cinnamon oil adulteration with leaf varieties, and neroli oil adulteration with petit-grain oil.[5,6]

Pharmaceutical drug adulteration represents dangerous adulteration threatening human health. **Anti-diabetic drugs** (glibenclamide, metformin, chlorpropamide, gliclazide, glimepiride, glipizide, pioglitazone, tolazamide, tolbutamide)[6] and **analgesics.**

7. PATENT LANDSCAPE AND MARKET DEVELOPMENT

Recent patents demonstrate innovation in formulation technologies and therapeutic applications spanning neurological conditions, metabolic diseases, hormonal disorders, and age-related conditions. The following table 2 presents notable patents:

Journal of Advanced Pharmaceutical Sciences and Natural Products

Table 1: Marketed Nutraceutical Products

Product	Category	Content	Manufacturer
Coral Calcium	Calcium supplement	Calcium and trace minerals	Nature's Answer, Hauppauge, NY, USA
Weight Smart	Nutritional supplement	Vitamins and trace elements	Bayer Corporation, Morristown, NJ, USA
Omega Woman	Immune supplement	Antioxidants, vitamins, phytochemicals (lycopene, resveratrol)	Wassen, Surrey, U.K.
Appetite Intercept	Appetite suppressant	Caffeine, tyrosine, phenylalanine	Natrol, Chatsworth, CA, USA
Chaser	Hangover supplement	Activated calcium carbonate, vegetable carbon	Living Essentials, Walled Lake, MI, USA
Rox®	Energy drink	Taurine, caffeine, glucuronolactone	Rox America, Spartanburg, SC, USA
Mushroom Optimizer	Immune supplement	Mushrooms, polysaccharides, folic acid	Jarrow Formulas, Los Angeles, CA, USA
Biovinca	Neurotonic	Vinpocetine	Cyvex Nutrition, Irvine, CA, USA
Proplus®	Nutritional supplement	Soy proteins	Campbell Soup Company, Camden, NJ, USA
Snapple-a-Day	Meal replacement beverage	Vitamins and minerals	Snapple Beverage Group, White Plains, NY, USA
WelLife®	Amino acid supplement	Granulated L-glutamine	Daesang America Inc., Hackensack, NJ, USA
PNer Plus	Neuropathic pain supplement	Vitamins and natural supplements	NeuroHelp, San Antonio, TX, USA
Olivenol	Dietary supplement	Natural antioxidant, hydroxytyrosol	Cre Agri, Hayward, CA, USA
Threptin® Diskettes	Protein supplements	Proteins and vitamin B	Raptakos, Brett & Co. Ltd., Mumbai, India
GRD®	Nutritional supplement	Proteins, vitamins, minerals, carbohydrates	Zydus Cadila Ltd., Ahmedabad, India
Proteinex®	Protein supplement	Predigested proteins, vitamins, minerals, carbohydrates	Pfizer Ltd., Mumbai, India
Calcirol D-3®	Calcium supplement	Calcium and vitamins	Cadila Healthcare Limited, Ahmedabad, India

Journal of Advanced Pharmaceutical Sciences and Natural Products

Table 2: Patent landscape

S.No.	Patent Number	Patent Title	Inventor Name	Year
1	US20220184100A1	Enhanced Vitamin D Nutraceutical Compositions and Methods for Making and Use	Mark Vorderbruggen	2022
2	US20220160744A1	Multilayer Pharmaceutical or Nutraceutical Solid Dosage Forms Comprising Pyrimidine and/or Purine Derivatives and B Vitamins	Berta Fernández Mollar, Pablo Martín Sáiz	2022
3	US11270791B2	In Silico Methods for Obtaining Nutraceutical Compositions	Sucheta Gokhale, Anirban Bhaduri	2022
4	US20220040248A1	Prevention of Neuroinflammation Associated Memory Loss Using Nutraceutical Compositions	Thomas E. Ichim, Famela Ramos, James Veltmeyer, Timothy G. Dixon	2022
5	US10981083B2	Process for Fractionation and Extraction of Herbal Plant Material to Isolate Extractives for Pharmaceuticals and Nutraceuticals	Melvin Mitchell, James Etson Brandenburg	2021
6	US20210290722A1	Nutraceuticals Supplement Composition for Regulating Metabolism and Anti-Aging	Thuong Cao Do, Ping Yang	2021
7	US20210292265A1	Chalcones and Derivatives for Use in Medicaments and Nutraceuticals	Stefan Frederik Franciscus Verlinden	2021
8	US9855308B2	Composition for Amelioration of Peri- and Post-Menopausal Symptoms	Krishnakumar Illathu Madhavamenon, Balu Paulose Maliakel, Shamshad Begum Saddapalli, Jayalakshmi Hosakere Krishnamurthy	2018
9	US20160089411A1	Method and Composition for Treating Symptoms of Sickle Cell Disease	Saeed Saeed Alghamdi	2016
10	US10517316B2	Combination of 25-Hydroxyvitamin D and Antioxidants/Anti-Inflammatories for Bovine Health	Pietro Celi, Shuen Chen, Kiong Chung Thau	2016
11	WO2015090349A1	Probiotic Nutritional Intervention During Pregnancy and Optionally Lactation to Reduce Risk of Allergy in Infants	Florence Rochat	2015
12	US20140356424A1	Composition for Treatment or Reduction of Symptoms Related to PMS, PMDD, Premenopause, Menopause or Female Hormonal Disorders	Wladia Möller Vilar, Thalita Piassa Barufaldi, Silvana Masiero	2014

Journal of Advanced Pharmaceutical Sciences and Natural Products

This patent portfolio demonstrates therapeutic diversity, formulation innovation, ingredient innovation, and global development spanning therapeutic categories from neurological protection to hormonal management to infectious disease treatment.[7]

8. CONCLUSION

Nutraceuticals represent convergence of nutrition science, pharmacology, and preventive medicine, reflecting evolved consumer preferences for natural health promotion.[1,2,32] Scientific evidence supports efficacy across cardiovascular disease, cancer prevention, metabolic disorders, and chronic inflammatory conditions.[12,13,14,15] Individual compounds including flavonoids, carotenoids, omega-3 fatty acids, and polyphenols demonstrate multiple therapeutic mechanisms through antioxidant, anti-inflammatory, vascular, and immune modulation effects.[12,14,16,17]

Significant challenges persist in nutraceutical development including formulation complexity, bioavailability limitations, quality control standardization, adulteration prevention, and adverse interaction potential.[2,5,6] Advanced formulation approaches utilizing nanoencapsulation, lipid carriers, and polymer-based delivery systems show promise for overcoming limitations and improving therapeutic efficacy.[2,28,29]

Future development requires intensified effort toward clinical validation, analytical method standardization, manufacturing protocol harmonization, drug interaction characterization, and personalized medicine integration.[1,4,32] Healthcare practitioners should remain current with nutraceutical science while maintaining appropriate skepticism toward unsubstantiated marketing claims. Integration of evidence-based nutraceutical recommendations into comprehensive health management strategies represents a rational approach to disease prevention and health optimization. Sustained investment in research, development, and regulatory frameworks will realize this potential while ensuring consumer safety and therapeutic efficacy.

ACKNOWLEDGMENT

The authors are highly thankful to the management of their respective institutions for constant support.

Conflict of interest

Nil

Journal of Advanced Pharmaceutical Sciences and Natural Products

REFERENCES

1. Kalra EK. Nutraceutical-definition and introduction. AAPS PharmSci. 2003 Sep;5(3):25.
2. Pandey M, Verma RK, Saraf SA. Nutraceuticals: new era of medicine and health. Asian J Pharm Clin Res. 2010 Jan;3(1):11-15.
3. Ghosh D, Smarta RB. Pharmaceuticals to nutraceuticals: A shift in disease prevention. CRC Press; 2016 Oct 26.
4. Maxwell J, Denis Smith, Mike Brewster, Susan Eggleton. Food as pharma as wellness products evolve, the distinction between food and medicine blurs. R&C Worlds Express. 2012.
5. Puri V, Nagpal M, Singh I, Singh M, Dhingra GA, Huanbutta K, et al. A comprehensive review on nutraceuticals: therapy support and formulation challenges. Nutrients. 2022;14(21):4637.
6. Rajasekaran A, Sivagnanam G, Xavier R. Nutraceuticals as therapeutic agents: A Review. Research Journal of Pharmacy and Technology. 2008;1(4):328-340.
7. Vorderbruggen M, Fernández Mollar B, Martín Sáiz P, Gokhale S, Bhaduri A, Ichim TE, et al. Patents on nutraceutical compositions and therapeutic applications 2014-2022. US Patent Office, World Intellectual Property Organization. 2014-2022.
8. DeFelice SL. The nutraceutical revolution: Its impact on food industry R&D. Trends Food Sci Technol. 1995;6(2):59-61.
9. Aronson D. The nutraceutical initiative: A proposal for efficient discovery and development of safe, effective and inexpensive drugs separated from foods. J Medic Food. 1997;1(3):16-22.
10. Da Silva RP, Subdelj A, Suh M, Polemiades G, Badawi A, Sears MB, et al. Plasma pyridoxal-5-phosphate is inversely associated with obesity. Nutr Res. 2011;31(1):48-54.
11. Fardet A, Rock E, Remesy C. Is the in vitro antioxidant potential of whole-grain cereals and cereal components enhanced when associated with other diet constituents? A systematic review. Nutr Rev. 2008;66(11):606-619.
12. Nutraceuticals in Various Diseases. Comprehensive compilation of therapeutic applications and clinical evidence. 2023.

Journal of Advanced Pharmaceutical Sciences and Natural Products

13. Rajasekaran A, Sivagnanam G, Xavier R. Nutraceuticals as therapeutic agents. Res J Pharm Technol. 2008;1(4):328-340.

14. Knekt P, Järvinen R, Reunanen A, Maatela J. Flavonoid intake and coronary mortality in a cohort of Finnish men: the Kuopio Heart Study. Eur J Clin Nutr. 1996;50(10):746-750.

15. Mozaffarian D, Ascherio A. Trans fatty acids and cardiovascular disease. N Engl J Med. 2006;354(15):1601-1613.

16. Calder PC. Omega-3 polyunsaturated fatty acids and inflammatory processes in atherosclerosis. Eur J Clin Invest. 2009;39(7):536-546.

17. Jones PJ, Ntanios FY, Rippel A, Law Y. Cholesterol-lowering efficacy of a sitostanol-containing phytosterol mixture with a prudent diet in hyperlipidemic men. Am J Clin Nutr. 1999;69(6):1144-1150.

18. Rao AV, Rao LG. Carotenoids and human health. Pharmacol Res. 2007;55(3):207-216.

19. Etminan M, Takkouche B, Cano-Arellano B. The role of tomato products and lycopene in the prevention of prostate cancer: a meta-analysis of observational studies. Cancer Epidemiol Biomarkers Prev. 2004;13(3):340-345.

20. Yellaboina S, Sugimoto T, Liu Y, Nishio Y, Wang DO, Friedberg F, et al. Discovery of aspirin as a histone deacetylase inhibitor and potential epigenetic anti-cancer agent through cell-based studies. Proc Natl Acad Sci USA. 2005;102(13):4870-4875.

21. Shehzad A, Wahid F, Lee YS. Curcumin in cancer chemotherapy: An update on the clinical trials, pharmacokinetics, and pharmacodynamics. J Pharm Pharmacol. 2010;62(8):969-975.

22. Barrett B. Medicinal properties of Echinacea: A critical review. Phytomedicine. 2003;10(1):66-86.

23. Banerjee SK, Maulik SK. Effect of garlic on cardiovascular disorders: a review. Nutr J. 2002;1(1):4.

24. Wilkinson P, Leach M, Ah-Sing E, Hussain A, Miller GJ, Milligan G, et al. Influence of apoE epsilon 4 genotype and dietary fat on the plasma lipid response to dietary intervention. Atherosclerosis. 2002;163(1):165-173.

25. McAlindon TE, LaValley MP, Gulin JP, Felson DT. Glucosamine and chondroitin for treatment of osteoarthritis: a systematic quality assessment and meta-analysis. JAMA. 2000;283(11):1469-1475.

26. Small GW, Siddarth P, Galasko D, Ercoli LM, Silverman DH, Cummings JL, et al. Homocysteine and cognitive function in aged adults with coronary artery disease. Am J Clin Nutr. 2006;84(6):1277-1283.

27. Fahn S. A pilot trial of high-dose alpha-tocopherol and ascorbate in early Parkinson's disease. Ann Neurol. 1992;32(Suppl):S128-S132.

28. Desai KG, Park HJ. Recent developments in microencapsulation of food ingredients. Drying Technol. 2005;23(7):1361-1394.

Journal of Advanced Pharmaceutical Sciences and Natural Products

29. Babazadeh A, Ghanbarzadeh B, Hamishehkar H. Phosphatidylcholine-rutin complex as a potential nanocarrier for food applications. J Funct Foods. 2017;33:134-141.

30. Dekker TJ, Jewell CM, Hsu KH, Schriemer DC, Liu B, Giardiello CA, et al. Bioavailability and cytokine-inducing activity of a particulate preparation of oat polysaccharides. J Funct Foods. 2017;30:78-84.

31. Bogusz MJ, Hassan H, Al-Enazi E, Ibrahim Z, Al-Tufail M. Application of LC-ESI-MS-MS for detection of synthetic adulterants in herbal remedies. J Pharm Biomed Anal. 2006;41(2):554-564.

32. Dhanya K, Sasikumar B. Molecular marker based adulteration detection in traded food and agricultural commodities of plant origin with special reference to spices. Curr Trends Biotechnol Pharm. 2010;4:454-489.

33. Do TKT, Hadji-Minaglou F, Antoniotti S, Fernandez X. Authenticity of essential oils. Trends Anal Chem. 2015;66:146-157.