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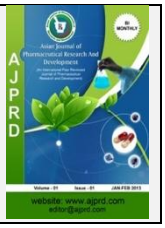

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Review Article

Neutraceuticals: A Review

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A B S T R A C T

The formation of the European Union (EU) medical device regulatory framework was largely driven by significant public health crises, including the thalidomide tragedy of the 1950s and 1960s, which revealed the dangers of insufficient oversight in both pharmaceuticals and medical devices. In response, the EU introduced a series of directives, starting with the Medical Device Directive (MDD) in 1993, aimed at harmonizing regulations across member states and ensuring patient safety. Early challenges in these regulations, such as insufficient clinical data and weak post-market surveillance, led to ongoing revisions, particularly as medical technology evolved. The thalidomide disaster highlighted the need for stringent, independent oversight, pushing the EU toward more rigorous standards for clinical evidence, post-market monitoring, and oversight of Notified Bodies independent organizations that assess device conformity.Subsequent medical device failures, such as the PIP breast implant scandal and issues with metal-on-metal hip implants, further exposed gaps in regulation. These prompted the introduction of the Medical Device Regulation (MDR) in 2017, emphasizing enhanced clinical evidence, stricter post-market surveillance, and greater transparency. Key provisions include device classification based on risk, mandatory Unique Device Identification (UDI) for traceability, and a centralized database (EUDAMED) for improved visibility. This ongoing regulatory evolution ensures the safety and efficacy of medical devices across the EU, responding to technological advances and increasing public demand for stronger protections in healthcare.

Key words: Thalidomide tragedy,public health crises,medical device failures

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INTRODUCTION:-

Industrialization has greatly advanced human civilization, but it has also led to serious environmental challenges such as air and water pollution, soil degradation, and food contamination. The overuse of synthetic chemicals, pesticides, and heavy metals has negatively impacted both the environment and human health. Consequently, lifestyle-related and chronic diseases—like diabetes, obesity, cancer, cardiovascular disorders, and other degenerative conditions—have become increasingly common.As healthcare demands continue to grow, so do medical expenses. This has prompted researchers and health professionals to seek safer, more affordable, and naturally derived alternatives for disease prevention and health maintenance. One such emerging field is nutraceuticals, which serves as a bridge between food and medicine, offering new possibilities for improving human health and longevity.[1]

Nutraceuticals contribute significantly to maintaining normal physiological functions, enhancing immunity, and lowering disease risk. Among their primary sources, plants play a crucial role due to their abundance of nutrients, antioxidants, and bioactive compounds. Progress in nutrition science, medical research, and plant biotechnology has revolutionized our understanding of food—transforming it from a mere source of sustenance into a vital tool for healing and wellness.[2,3]The word "nutraceutical" was first coined by Stephen De Felice in 1979 to describe foods or food ingredients that not only nourish the body but also offer

medical or health benefits, helping in the prevention or management of various diseases.

Nutraceuticals aid in detoxifying the body, improving digestion, and promoting healthier dietary habits. They are available in various concentrated forms such as capsules, powders, tablets, and tinctures—either as single ingredients or combined formulations. Examples include nutrient-dense foods like spirulina, garlic, and soy, or specific bioactive compounds like omega-3 fatty acids* from salmon. These are often marketed as medical foods, nutritional supplements, or dietary supplements fig 1[4,5].

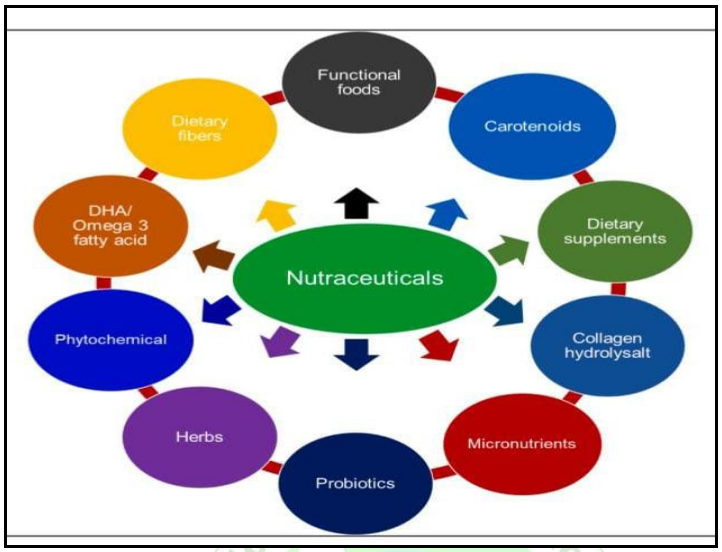

Figure 1: Neutraceuticals

WHY NEUTRACEUTICALS ?

In today's world, it's often difficult to get all the essential nutrients our body needs from regular food alone. On top of that, we live in an environment filled with pollution, chemicals, and pesticides that disrupt our body's natural balance. As a result, many new health problems have become increasingly common.

Instead of relying solely on antibiotics and synthetic medicines—which often come with side effects and are losing their effectiveness it's wiser to focus on strengthening our body's natural defense system. Nutraceuticals, being natural and easily absorbed by the body, provide the nutrients needed to boost our overall health, enhance vitality, and help our body function at its best. [6]

HISTORICAL BACKGROUND:

Importance of Nutraceuticals in Modern Healthcare In recent years, consumers have started seeking alternatives to conventional medicines — or perhaps, "less" of them. There's a growing return to the belief that natural is better, reflecting a shift toward traditional and holistic healing approaches. The global market for natural and functional products reflects this movement, valued at $281.4 billion in 2021 and projected to rise to $529.66 billion by 2028, growing at a CAGR of 9.5%. Natural sources of bioactive compounds are gaining attention because they are widely

available, cost-effective, and believed to have significant health benefits. Such sources include food, dietary supplements, medicinal plants, and even bioactive compounds recovered from food waste. The main goal behind using natural products is not merely to treat diseases but to prevent them before they occur.

There has been a clear shift from "curing" to preventing illness, with more people turning to healthier lifestyles, supplements, and nutraceuticals to delay or avoid disease onset. This transformation has opened vast opportunities — pharmaceutical industries are investing heavily in supplement development, while the food sector is innovating and marketing new functional food products. However, this rapid expansion has created a "grey area" between food and medicine, especially when products claim therapeutic benefits that are not yet scientifically proven. This evolving scenario highlights the need to clearly understand and regulate nutraceuticals — a category still not fully distinguished from conventional pharmaceuticals.

Are the Health Benefits of a Vegan Diet Truly Unique?

Few studies have rigorously compared the health outcomes of omnivores, vegetarians, and vegans as separate groups. Because of this, it's often unclear whether the reported benefits among vegans are exclusive to them or shared with vegetarians who consume limited animal products. For instance, Goff et al compared 21 vegans with 25 omnivores matched by age, gender, and BMI. The vegans had significantly lower blood pressure, fasting triglyceride, and glucose levels, along with a biochemical profile that was protective against cardiovascular and pancreatic diseases. Similarly, sedentary individuals who followed a long-term raw vegan diet showed health markers comparable to endurance athletes — lower BMI, cholesterol, glucose,

insulin, C-reactive protein, and blood pressure — compared to those on a typical Western diet.

These findings suggest that the advantages of a vegan diet might also extend to vegetarians. Vegetarian diets have been linked to improved insulin sensitivity, reduced diabetes risk, and lower chances of developing cardiovascular diseases. A study comparing 170 vegetarian Buddhist monks and 126 omnivorous men found that vegetarians had a lower BMI, blood pressure, and triglyceride levels, along with better lipid profiles and a reduced predicted risk of coronary heart disease. Another study involving long-term vegetarians (≥15 years) revealed significantly lower cholesterol, oxidative stress, and body fat compared to age- and gender-matched omnivores. Even individuals following a "prudent diet" — one that allows small amounts of red meat showed reduced risk of coronary heart disease and type 2 diabetes, as shown in a pooled analysis of 76,000 participants across five cohort studies.

Interestingly, a Taiwanese cohort of 93,209 adults reported no significant reduction in metabolic syndrome risk among vegans compared with lacto-vegetarians, pescovegetarians, and nonvegetarians, suggesting that the benefits of veganism need further study to determine if they are truly unique. The Adventist Health Study-2, which distinguished between four types of vegetarian diets (vegan, lacto-ovo vegetarian, pescovegetarian, and semi-vegetarian), offered more nuanced insights. While all vegetarian diets were healthier than omnivorous ones, vegan diets appeared to provide greater protection against type 2 diabetes and all-cause mortality. Vegans also showed the lowest BMI and reduced cancer incidence, though some exhibited minor nutrient deficiencies due to their restrictive diet.

According to Le and Sabaté, vegetarian diets in the Adventist cohort were linked to lower risks of cardiovascular diseases, certain cancers, and overall mortality — with vegan diets offering additional benefits such as reduced obesity, hypertension, type 2 diabetes, and cardiovascular deaths. Other research supports these conclusions. For example, a 74-week clinical trial in type 2 diabetic patients found that a low-fat vegan diet significantly improved blood glucose and lipid profiles compared to a conventional diabetic diet. Similarly, a study of 23 overweight men and postmenopausal women found that a low-carbohydrate vegan diet led to greater weight loss, reduced LDL cholesterol, and better heart health than a high-carbohydrate lacto-ovo vegetarian diet. Overall, when vegans are compared not only to meat-eaters but also to other vegetarians, the evidence consistently points to distinct protective health benefits associated with a vegan diet[7]

NEUTRACEUTICALS IN VARIOUS DISEASES:-

Nutraceuticals and Their Role in Health and Disease Management

Nutraceuticals play a vital role in enhancing overall health and well-being by strengthening the immune system and helping to prevent as well as manage various diseases fig 2 [8]. A wide range of disorders can be managed effectively through the use of nutraceuticals and dietary supplements, which act as supportive or preventive therapeutic options.

1. Nutraceuticals in Cardiovascular Diseases (CVDs)

Cardiovascular diseases are among the leading causes of death globally, accounting for nearly 30% of total annual mortality[9]. These conditions primarily affect the heart and blood vessels and are often linked to risk factors that respond well to nutraceutical-based interventions. [10,11]Extensive scientific evidence supports the potential of nutraceuticals in preventing and managing cardiovascular disorders such as arrhythmias, congestive heart failure, angina, hypertension, and hyperlipidemia[13]. Several bioactive compounds and dietary supplements have demonstrated significant benefits in maintaining heart health and reducing the risk of cardiovascular complications.

a. Allicin and Alliin

Increased plasma triglycerides and cholesterol levels are major contributors to ischemic heart disease and atherosclerosis. Garlic (Allium sativum), known for its antihyperlipidemic properties, helps in lowering blood cholesterol by promoting the excretion of cholesterol and its by-products through feces and by suppressing its synthesis in the body[14]. This process improves the HDL to LDL ratio, promoting a healthier lipid profile. Compounds such as allicin and alliin play a crucial role in this mechanism, provided they are protected from degradation by gastric acids. Thirteen placebo-controlled clinical trials involving 781 participants revealed that garlic supplementation significantly reduces serum cholesterol levels. Moreover, garlic also exerts mild antihypertensive effects in addition to its lipid-lowering benefits[15,16]

b. Omega-3 Fatty Acids

Omega-3 fatty acids, primarily eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are polyunsaturated fats obtained mainly from marine sources. They are well recognized for their role in cardiovascular protection. The Diet and Reinfarction Trial (DART), a randomized study involving 2,033 men recovering from myocardial infarction, reported that fish oil supplementation reduced overall mortality by 29% over two years,cardiac deaths by 30%, and sudden deaths by 45%. Clinical research further indicates that omega-3 fatty acids reduce the risk of cardiac arrhythmias and improve arterial plaque stability in patients with atherosclerosis. They enhance the electrical stability of cardiac cells, prolong the refractory period, and help regulate abnormal heart rhythms.[17,18]

c. Soy Isoflavones

Soy proteins and isoflavones are functional food components with multiple health-promoting properties, including antihyperlipidemic, antihypertensive,

antioxidant, antidiabetic, anti-inflammatory, anti-obesity, and neuroprotective effects. Clinical studies show that soy protein intake helps lower serum cholesterol levels and supports cardiovascular health[19]. The U.S. FDA recommends consuming 25 grams of soy protein daily, as it has been shown to reduce blood pressure, especially in postmenopausal women. Moreover, soy-based diets low in saturated fat are associated with a reduced risk of coronary heart disease. Research has demonstrated that soy products rich in Isoflavones, soy fiber, and phospholipids can lower the LDL/HDL ratio, thereby improving lipid balance.[20]

d. Proteins, Peptides, and Amino Acids

Hypertension, a major risk factor for CVDs, is often managed using angiotensin-converting enzyme (ACE) inhibitors. However, synthetic ACE inhibitors can cause side effects like low blood pressure, hyperkalemia, coughing, and kidney issues[21].Natural ACE inhibitors derived from milk proteins such as casein and whey provide a safer alternative. Both animal and clinical studies have demonstrated that these bioactive milk peptides exhibit antihypertensive properties, leading to a significant and safe reduction in blood pressure.[22]

e. Antioxidant Vitamins

Antioxidants are key in protecting against chronic diseases like cardiovascular disease and cancer. They prevent oxidative damage by neutralizing free radicals, which are responsible for LDL oxidation and endothelial injury. Foods rich in antioxidants—such as fruits, vegetables, fish, and natural oils—help reduce the incidence of coronary heart disease. Clinical findings reveal that vitamins C and E supplementation can help prevent coronary heart disease, though β-carotene supplements may have adverse effects and are not recommended. In the National Health and Nutrition Examination Survey I (NHANES-I) involving U.S. adults aged 25–74 years, higher intake of vitamin C was associated with a significantly lower risk of heart disease over a 10-year observation period.[23]

2. Nutraceuticals in Cancer Therapy (Chemo- and Radiotherapy)

Traditional cancer treatments like chemotherapy and radiotherapy are effective but often accompanied by severe side effects, including pain, fatigue, nausea, vomiting, diarrhea, and hair loss. Furthermore, some cancers show resistance to these treatments, reducing their therapeutic success. Incorporating nutraceuticals and plant-derived compounds as complementary therapies can alleviate these side effects and improve the overall efficacy of conventional treatments. The nutraceutical industry has evolved from promoting general health to disease prevention and management, particularly in oncology. Several plant-derived bioactive compounds have shown promise in inhibiting tumor progression, enhancing chemotherapy and radiotherapy sensitivity, and reducing treatment-related toxicity[24,25].

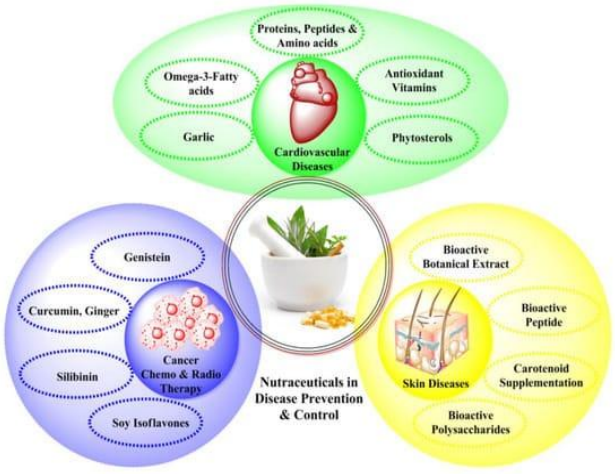

Figure 2: Neutraceuticals and dietary supplements in various diseases

For instance, Caponio et al. investigated phenolic compounds extracted from Aglianico grape pomace (GP) on colorectal cancer cell lines. The extract demonstrated strong antiproliferative and pro-apoptotic effects by increasing the expression of Bax, the Bax/Bcl-2 ratio, and caspase-3. Further analysis revealed that anthocyanins, phenolic acids, and flavonoids were the main components responsible for its antioxidant and anticancer activity[26].

CLASSIFICATION OF NEUTRACEUTICALS:-

Nutraceuticals can be broadly divided based on the types of foods available in the market into two main categories:

1. Traditional Nutraceuticals
2. Non-Traditional Nutraceuticals

1. Traditional Nutraceuticals

Traditional nutraceuticals are naturally occurring food components that have not undergone any modification or processing. These foods contain naturally present bioactive compounds that provide health benefits beyond basic nutrition. Examples include lycopene in tomatoes, omega-3 fatty acids in salmon, and saponins in soybeans, all of which play an important role in preventing chronic diseases.

Traditional nutraceuticals are further classified on the basis of their composition and biological role as follows:

I. Based on Chemical Constituents

a) Nutrients

b) Herbals

c) Phytochemicals

II. Probiotic Microorganisms

III. Nutraceutical Enzymes.

(a) Nutrients

Nutrients such as vitamins, minerals, amino acid,and fatty acids are essential for the proper functioning of the human body.

Vitamins:- found in vegetables, fruits, cereals, dairy, meat, and poultry help prevent diseases like heart disorders, stroke, cataracts, osteoporosis, diabetes, and certain cancers.

Minerals:- present in both plant and animal products, play a vital role in maintaining strong bones, teeth, and muscles, regulating nerve impulses, and supporting a healthy heartbeat. They also prevent conditions like anemia and osteoporosis.

Fatty acids:- particularly omega-3 polyunsaturated fatty acids (PUFAs) found in flaxseed and salmon, are known to reduce inflammation, support brain function, and lower cholesterol accumulation in the body.

(b) Herbals

Herbal nutraceuticals hold tremendous potential in promoting health and preventing chronic illnesses through the therapeutic actions of natural plant compounds. Willow bark (Salix nigra) contains salicin, known for its anti-inflammatory, analgesic, antipyretic, astringent, and antiarthritic properties. Parsley (Petroselinum crispum)

possesses flavonoids like apiol and psoralen, which make it diuretic, carminative, and antipyretic. Peppermint (Mentha piperita) has menthol as its active ingredient, effective against colds and flu. Lavender (Lavandula angustifolia) contains tannins that help in managing stress, depression, hypertension, cough, and asthma. Cranberries (Vaccinium erythrocarpum) are rich in proanthocyanidins, which are beneficial in preventing urinary tract infections, ulcers, and even certain cancers.[27]

(c) Phytochemicals

Phytochemicals are naturally occurring bioactive plant compounds that have various therapeutic effects. They are categorized according to their chemical structures and biological activities. Carotenoids (Isoprenoids) found in fruits, vegetables, and egg yolks have antioxidant, anticancer, and immune-boosting properties and protect the eyes from UV damage. Non-carotenoid compounds such as those in legumes, grains, and palm oil help in lowering cholesterol levels and preventing cancer. Flavonoid polyphenols, abundant in berries, fruits, and legumes, act as powerful antioxidants and phytoestrogens, helping prevent breast and prostate cancers and manage diabetes. Non-flavonoid polyphenols, found in grapes, raisins, peanuts, and turmeric, exhibit strong anti-inflammatory, antioxidant, and antithrombotic activities, reducing cholesterol levels. Phenolic acids, present in blueberries, tomatoes, and peppers, combat mutagenic compounds and protect against oxidative damage. Isothiocyanates (glucosinolates) found in broccoli and Barbarea verna seeds exhibit potent antitumor properties.

II. Probiotic Microorganisms

The concept of probiotics originated from the work of Elie Metchnikoff, who discovered the benefits of Bacillus bulgaricus in promoting gut health. The term probiotics, meaning “for life,” refers to live microorganisms that, when consumed in adequate amounts, confer health benefits to the host. Probiotics enhance digestion, improve nutrient absorption, and maintain a balanced gut microbiome. They inhibit harmful pathogens such as bacteria, viruses, and yeasts by:

1. Competing for nutrients
2. Preventing pathogen adhesion to intestinal cells
3. Producing antimicrobial substances
4. Neutralizing toxins
5. Supporting the immune system

They are especially beneficial in treating lactose intolerance through the enzyme β-galactosidase, which breaks down lactose into simpler sugars. Probiotics are commonly found in yogurt, kefir, and other fermented foods.[28]

III. Nutraceutical Enzymes

Enzymes play a fundamental role in sustaining life. People suffering from conditions such as hypoglycemia, digestive disorders, or obesity often benefit from enzyme supplementation. These enzymes, derived from microbial, plant, or animal sources, aid digestion, regulate blood sugar levels, and support metabolic health.

2. Non-Traditional Nutraceuticals

Non-traditional nutraceuticals are foods that are biotechnologically modified to enhance their nutritional or therapeutic value. These include fortified foods and recombinant products, designed to improve human wellness.

They are classified as follows:

a) Fortified Nutraceuticals

b) Recombinant Nutraceuticals

a) Fortified Nutraceuticals

These involve foods that have been enriched with additional nutrients or bioactive ingredients through fortification or selective breeding. Examples include: Calcium-fortified orange juice for bone health.Vitamin-enriched breakfast cereals and folic acid-fortified flour for nutritional supplementation. Milk fortified with vitamin D (cholecalciferol) to prevent deficiency.Prebiotic and probiotic milk* containing Bifidobacterium lactis HN019, effective against diarrhea, respiratory infections, and severe illnesses in children.Bananas fortified with the soybean ferritin gene, developed to combat iron deficiency[29,30]

b) Recombinant Nutraceuticals

These nutraceuticals are produced using biotechnological and genetic engineering techniques. Foods such as bread, cheese, yogurt, vinegar, fermented starch, and alcoholic beverages are created through fermentation or enzymatic processes. Biotechnology enables the large-scale production of probiotics and the extraction of bioactive compounds that enhance the health benefits of such foods.

Bioactive Compounds as Nutraceuticals

Bioactive compounds are naturally occurring substances present in small amounts in foods like fruits, vegetables, and whole grains. Though found in trace quantities, they provide numerous health-promoting and therapeutic effects beyond basic nutrition. Depending on their source, bioactive compounds are classified as either Herbal-based compounds, or Dietary supplements These bioactives play a key role in disease prevention, immune modulation, and overall wellbeing.[31]

MECHANISM OF ACTION:-

1. Nutraceuticals: Scientific Evidence for Their Biological Function

Nutritional supplements and functional foods are now gaining worldwide recognition for their potential health-promoting properties when regularly consumed as part of a balanced diet. Both scientists and the food industry are increasingly motivated to enhance quality of life and address chronic age-related diseases through diet-based interventions. A growing body of evidence from epidemiological studies, animal research, clinical trials, and nutritional biochemistry has shown that certain dietary supplements can play a protective role against coronary heart disease, cancer, osteoporosis, diabetes, and neurodegenerative disorders such as Parkinson’s and Alzheimer’s disease.

Researchers have been working to pinpoint the specific dietary components responsible for these health benefits.

For instance, studies have shown that individuals who frequently consume lutein-rich foods—like spinach, eggs, tomatoes, oranges, and other leafy greens—have a significantly lower risk of developing colon cancer. Similarly, flavonoids found in citrus fruits act as powerful antioxidants that may help protect against cancer. Omega-3 fatty acids, commonly found in fish oil, are also recognized for their potential role in reducing the risk of cardiovascular diseases and certain cancers. Ongoing research aims to identify which groups of people benefit most from functional foods and to better understand how these bioactive compounds can strengthen the link between diet, disease prevention, and treatment. The health-promoting effects of nutraceuticals are largely attributed to their rich content of polyphenolic flavonoids. These compounds possess strong antioxidant and free radical–scavenging properties, which enhance the body's natural antioxidant defense mechanisms and help regulate cellular redox balance.

Over the past decade, studies have revealed that beyond their antioxidant effects, flavonoids also influence various cellular signaling pathways involved in cell growth, differentiation, and survival. They can modulate the activities of key enzymes such as mitogen-activated protein kinases (MAPKs) and protein kinase C (PKC), and can affect transcription factors like STAT-1. This makes them vital in cytokine signaling, cellular stress responses, and protein regulation. Therefore, diets rich in antioxidants appear to support physiological defense systems and contribute to managing chronic diseases. However, it is equally important to note that while many supplements are beneficial, their effectiveness and safety depend on proper dosage and cautious use to avoid potential adverse effects or toxicity.

This understanding was further emphasized at the Third International Conference on Mechanisms of Action of Nutraceuticals (ICMAN 3) held in November 2004 in North Carolina, USA. The findings align with the 2005 Dietary Guidelines for Americans, which advocate for a balanced diet and active lifestyle to reduce chronic disease risk [32].

2. Nutraceuticals in Obesity and Diabetes

Diabetes mellitus is a long-term metabolic disorder that requires continuous medical care to prevent or delay complications and to manage them effectively when they arise. There are two major types of diabetes: Type 1 and Type 2.

Type 1 diabetes typically affects younger individuals and results from the autoimmune destruction of pancreatic beta cells, leading to little or no insulin production—a process closely linked to oxidative stress. Type 2 diabetes, on the other hand, is more common in adults over 40 and is characterized by insulin resistance and impaired insulin secretion. Persistent high blood glucose levels are responsible for the majority of diabetes-related complications, affecting various organs and tissues in both forms of the disease.

Recent research highlights the similarities between the two types of diabetes, particularly regarding inflammation within pancreatic islets. Modulating these inflammatory mediators shows promise as a therapeutic strategy. According to Dr. Nurit Kaiser from the Hadassah Hebrew University Medical Center (Jerusalem), both insulin deficiency and insulin resistance play crucial roles in diabetes progression. Dr. Nick Hales from the University of Cambridge further reported that experimental studies in rats and mice have shown that restricted maternal protein intake during pregnancy or lactation can lead to glucose intolerance and diabetes-like symptoms in offspring later in life. These findings suggest that nutritional imbalances early in life can have long-term metabolic effects. Therefore, nutritional interventions during childhood may be critical in reducing the risk of diabetes and obesity by maintaining healthy glucose and insulin levels[33].

3. Nutraceuticals for Cardiovascular Diseases

Increasing attention has been directed toward the health benefits of flavonoids—naturally occurring phenolic compounds found in fruits, vegetables, and grains—due to their antioxidant, anti-inflammatory, and cardioprotective effects. According to Dr.Lester Packer from theUniversity of Southern California, antioxidants play a vital role in preventing oxidative stress and maintaining the redox balance of cellular systems.

These compounds neutralize free radicals, regulate oxidative processes, and influence key cellular functions such as gene expression, cell signaling, and apoptosis. Examples of such antioxidants include vitamins C and E, thiol compounds (like glutathione and lipoic acid), carotenoids, and bioflavonoids. They also stimulate immune function and induce phase II detoxifying enzymes, which further protect against oxidative damage.

However, Dr. Werner Siems and colleagues from the Loges School for Physical Medicine and Rehabilitation, Germany, cautioned that some antioxidants—such as beta-carotene—can exhibit pro-oxidant activity under certain conditions, potentially causing harm through the formation of reactive breakdown products. Interestingly, these effects were significantly reduced when beta-carotene was combined with vitamins E and C, suggesting a synergistic protective effect of multiple antioxidants[34].

4. Nutraceuticals and Cancer

A wealth of epidemiological evidence links high consumption of fruits and vegetables with a lower risk of various cancers. This protective effect is primarily attributed to their high levels of antioxidant flavonoids, which scavenge free radicals, induce detoxification enzymes, and enhance the activity of natural antioxidant enzymes like catalase and glutathione peroxidase.

Many of these dietary compounds act on multiple cellular signaling pathways, including Activator Protein-1 (AP-1) and Nuclear Factor-kappa B (NF-κB), both of which are key regulators of inflammation, tumor growth, and cancer progression. Flavonoids help modulate these pathways by influencing the MAPK cascade, thereby preventing tumor initiation and promoting healthy cell function[35]

CURRENT RESEARCH IN NEUTRACEUTICALS:-

At present, a significant amount of research is centered around traditional herbal extracts, with scientists investigating their potential roles in promoting health and preventing chronic diseases. This growing interest partly aims to validate traditional remedies from homeopathic and Eastern medicine through scientific methods. Researchers

also strive to generate reliable safety and efficacy data for both patients and healthcare professionals. The rapidly rising demand for bioactive compounds in nutraceuticals and functional foods is largely driven by widespread health challenges such as:

1. Cardiovascular disorders
2. Breast, skin, colorectal, and brain cancers
3. Women's health issues
4. Central nervous system (CNS) disorders
5. Metabolic syndromes
6. Gastrointestinal problems
7. Immune system modulation

However, one major limitation in the field is the shortage of well-designed clinical studies providing strong scientific evidence. Despite this, the development, manufacturing, marketing, and regulation of nutraceuticals have evolved significantly over the years. Today, they have become the preferred choice for health-conscious consumers, and ongoing scientific studies and clinical trialscontinue to strengthen and expand the industry.

APPLICATIONS OF NEUTRACEUTICALS:-

Extensive scientific studies have demonstrated that nutraceuticals play a key role in managing and preventing numerous disorders such as insomnia, digestive disturbances, blood pressure irregularities, common cold, cough, depression, and delayed gastric emptying, among others that require special medical attention. In recent years, nutraceuticals have gained widespread recognition for their positive impact on major chronic and degenerative diseases including coronary heart disease, obesity, diabetes, cancer, osteoporosis, Parkinson's disease, and Alzheimer's disease.

Natural bioactive compounds present in these products act through multiple biological mechanisms such as the activation of antioxidant defenses, modulation of signal transduction pathways, regulation of cell survival-related genes, promotion of cell proliferation and differentiation, and preservation of mitochondrial function. These combined activities contribute significantly to protecting the body from various age-related and chronic disorders.Flavonoids, flavones, flavanones, and quercetin found in onions, cruciferous vegetables, blackberries, cherries, apples, and other antioxidant-rich foods can lower the risk of cardiovascular mortality. They inhibit enzymes such as cyclooxygenase and angiotensin-converting enzyme (ACE), both associated with hypertension. Furthermore, flavonoids strengthen capillaries that deliver oxygen and nutrients to body tissues. Ginger, a potent antioxidant and anti-inflammatory agent, helps prevent hypertension and heart palpitations, while allicin from garlic aids in lowering cholesterol and blood pressure. Cardiovascular health can thus be improved through lipid-lowering nutraceuticals alongside a balanced lifestyle. The synergistic use of polyherbal formulations may further enhance therapeutic outcomes.

1. **Oral Health:-**

   A new branch called odonto-nutraceuticals has emerged, focusing on phytotherapeutic agents used in dentistry. These agents act on multiple biochemical targets to promote oral health. Green tea, grapes, and cocoa seed extracts rich in polyphenols, flavonoids, and proanthocyanidins offer protection against oral infections. Aloe vera gel promotes mucosal wound healing and provides relief from oral lichen planus. Probiotics also help prevent dental caries, gingivitis, periodontitis, and halitosis[36].2.

2. **Alzheimer's Disease**

   Alzheimer's disease, or senile dementia, is marked by progressive neurodegeneration. Antioxidant-rich nutraceuticals such as beta-carotene, lycopene, curcumin, lutein, and lavender compounds can slow disease progression by combating oxidative stress in neurons. These compounds protect brain cells, thereby delaying the onset of dementia and preserving cognitive function[37].

3. **Parkinson's Disease**

   Parkinson's disease results from the degeneration of dopamine-producing neurons in the brain. It is the second most prevalent neurodegenerative disorder globally. Plant polyphenols, stilbenes, soy-based phytoestrogens, and unsaturated fatty acids have shown protective effects against neuronal loss. The herbal nutraceutical Brahmi (Bacopa monnieri) is known for its brain-enhancing and calming properties. It supports mental relaxation, reduces anxiety, enhances blood circulation to the brain, and improves memory and hormone balance[38].

4. **Eye Disorders**

   Dietary nutraceuticals are also beneficial for maintaining eye health and preventing age-related conditions such as macular degeneration. Lutein, DHA, green tea, carotenoids, flavonoids, vitamin E, and coenzyme Q10 exhibit strong antioxidant properties useful in treating presbyopia and cataracts. Compounds such as ascorbic acid, tocopherol, pyruvate, and caffeine help manage retinitis pigmentosa. Rice bran, fruits, and vegetables rich in lutein and zeaxanthin improve vision and reduce cataract risk. Essential fatty acids (omega-3, 6, and 9) and folic acid also contribute to overall eye health[39].

5. **Stress Management**

   Stress is an inevitable part of human life and has significant physiological and psychological effects. Adaptogenic bioactive compounds, known as adaptogens, help the body resist stress-related damage and maintain internal balance. They improve emotional resilience and aid in recovery from stressful conditions. Herbal adaptogens like ashwagandha and ginseng stimulate the production of heat-shock protein 70 (HSP-70), which protects cells from stress and supports mental stability and well-being[40].

FUTURE ISSUES AND PROPOSALS:-

Adopting a healthier lifestyle can play a crucial role in preventing various diseases, particularly metabolic disorders. One of the most effective ways to achieve this is by making positive changes in dietary habits. However, several important challenges remain in the field of nutraceuticals, including:

1. Developing reliable scientific standards to evaluate their role in disease prevention.

2. Creating systematic methods to assess their effectiveness through human clinical trials.

3. Establishing a smooth process to transition findings from basic scientific research into practical industrial applications.

Since nutraceuticals often consist of multiple active components rather than a single ingredient, their health benefits may result from the combined action of several compounds. Therefore, it is important to compare the preventive effects of different foods and formulations. To achieve this, more research is needed to identify and validate biomarkers linked to specific diseases. Additionally, there is a strong need to define standardized methods for measuring these biomarkers and to develop uniform indicators for accurate assessment [5].

CURRENT STATUS:-

The rapidly increasing demand for bioactive compounds used in nutraceuticals and functional foods is largely driven by growing awareness and concern about various health issues such as cardiovascular diseases, cancers of the breast, skin, colon, and brain, women's health problems, central nervous system (CNS) disorders, metabolic imbalances, digestive ailments, and immune system regulation. Despite their popularity, one major challenge in the use of nutraceuticals for disease management is the limited availability of strong clinical research and conclusive scientific evidence. Over the years, significant progress has been made in the development, manufacturing, packaging, marketing, and distribution of nutraceutical products, and this field continues to evolve rapidly. Today, consumers increasingly prefer nutraceuticals as part of their daily health routine. Ongoing scientific advancements and clinical studies are further strengthening the credibility and growth of this expanding industry[5].

CONCLUSION:-

Nutraceuticals represent a powerful convergence of nutrition and therapeutics, offering a natural, safe, and effective approach to disease prevention and health promotion. Derived from plants, microorganisms, and food sources, these bioactive compounds play a crucial role in maintaining physiological balance, strengthening immunity, and combating chronic diseases such as cardiovascular disorders, diabetes, obesity, cancer, and neurodegenerative conditions. Their antioxidant, anti-inflammatory, and immunomodulatory properties make them valuable adjuncts or alternatives to conventional medicines, often with fewer side effects. The emergence of specialized fields such as odonto-nutraceuticals and neuro-nutraceuticals highlights their expanding applications in oral and neurological health. Moreover, advancements in biotechnology and food fortification have enhanced the therapeutic potential of both traditional and non-traditional nutraceuticals. However, despite their promising benefits, more clinical research and regulatory standardization are essential to ensure their safety, efficacy, and quality. Overall, nutraceuticals offer a holistic and sustainable strategy for improving human health, reducing healthcare costs, and promoting longevity through the integration of nutrition and medicine.

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